Organization, Technology & Management in Construction

OTMC Conference 2015

02-05 September 2015, Primošten, Croatia

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Conference Proceedings

Croatian Association for Construction Management

University of Zagreb, Faculty of Civil Engineering

12TH INTERNATIONAL CONFERENCE

ORGANIZATION, TECHNOLOGY AND MANAGEMENT IN CONSTRUCTION

CONFERENCE PROCEEDINGS

Editors:
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FOREWORD

Dear colleagues and friends,

On behalf of the Organizing Committee, it is my great pleasure to welcome you to the 12th OTMC, International Conference. This time the Conference has been designed to provide the overview of the actual research in the field of organization, technology and management in construction, but also to host the meeting of IPMA Megaprojects Special Interest Group. We believe that combination of two related topics will contribute to the quality of meeting and its reaches.

Many distinguished academics and practitioners have joined the Conference. We have 4 highly interesting key note speakers and more than 120 authors of papers from 24 countries who will be presenting during plenary and parallel sessions. The parallel program of IPMA Megaproject Special Interest Group, with participation of numerous top class experts in different aspects of all the kinds of megaprojects, will be mostly available for all participants.

As a part of Conference activities it will be organised the 2-day seminar and workshop on passive house design principles. This event will be led by experts from the international Passive House Organization (iPHA) and supported by representatives from passive house institutes and other institutions from Germany, Italy, Greece and Croatia.

The Conference participants coming from more than 20 universities same as practitioners are invited to take a part at Academic forum organised with the aim of exchanging the experience on study programs, teaching methods and future trends in education of organisation, technology and management in construction.

Beside the scientific and academic content of the Conference we traditionally organise the round tables and discussion panels on actual professional topics. This time there are two round tables, the first one on the novelties in construction legislation and the second one with the highly actual topic of energy efficiency in build environment. The discussion panel will be with the topic of BIM and experiences in its application. Mentioned activities same as the session on local case studies will be available in Croatian language.

We would like to express our thanks to ministries that gave the patronage to the Conference same as to industrial sponsors for their generous support and all the partners who worked hard to make this Conference successful.

We hope that you will enjoy the Conference and that your interaction with your colleagues from many different countries will stimulate a creative exchange of ideas and will be personally rewarding. We also hope and trust that you will enjoy your visit to the very beautiful Croatian coast and the city of Primošten.

Yours sincerely,

Prof. Dr. Ivica Završki

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KEYNOTE LECTURES

Building Information Modeling Tools for Project Managers

Hans-Joachim Bargstädt

Professor for Construction Engineering and Management at the Bauhaus-Universität Weimar, Germany; former president of the Association of Civil Engineering Faculties at German universities

Abstract
Building Information Modeling is not only a tool in construction, it is a new powerful concept for planning and realization in our complex world. BIM has the potential to bring more intelligence into the construction sector.
Project managers are at the forefront of building projects together with owners and investors. They are the ones to profit most from the innovative approach by BIM-based planning and realization.

Biography
Hans-Joachim Bargstädt studied civil engineering at the Technical University Braunschweig, at the Georgia Institute of Technology, Atlanta, and at the Institute Supérieur du Béton Armé, Marseille. He received his Ph. D. from the Technical University Braunschweig in 1988.
For more than 10 years Bargstädt served in the construction industry as technical engineer, as site manager, as project manager and finally for several years as branch manager and director of a large construction company. He was responsible for public and private construction projects with a yearly turnover of up to 50 Mio €.
Since the year 2000 Bargstädt is university professor at the Bauhaus-Universität Weimar. His major fields are construction engineering, construction management, project management and disaster management.
Under his supervision a number of Ph.D. thesis have been completed in the fields of project management, production planning, Building Information Modeling, Simulation of Site Operations and the Supervision and Control of Work Performance.
One of his main research topics is the development of Building Information Modeling and its application in project management processes.
In 2012/2013 Bargstädt has been guest professor at the National Taiwan University. Since 2011 he continuously serves as guest professor at Stellenbosch University, South Africa.
He is member of the DIN working group “BIM”, the official German institution for the standardization of building information modeling tools, concepts and processes.
Together with U. Bauch he published in 2015 the “Praxis-Handbuch Bauleiter”

Project Planning Techniques: Wrong Tools for Noble Goals?

Zoltán Miklós Hajdu

Professor of Construction Management at the Szent István University's Ybl Miklós Faculty of Architecture and Civil Engineering

Abstract

The construction industry has changed dramatically over the past fifty years. Ever changing technology, materials, design and organization methods give ample evidence for that. For this reason, it is interesting that scheduling methods used in construction industry have hardly changed over the past decades. Precedence Diagramming Method (PDM) serves generation of schedulers for more than fifty years and despite the critics it is among us in the same form as was born almost sixty years ago. But time is ripe for changes. Some major generalizations of PDM technique affecting activities and precedence relationships will be discussed in the keynote presentation. Generalization of activity time-location functions allow schedulers to use any functions to model activity time-location relationships, e.g. learning curves, etc. Point-to-point type of relations can completely substitute the traditional precedence relations (SS, FF, FS and SF), and continuous type of relations gives theoretically and practically perfect solution for modeling overlapped activities. The history and the evolution of the PDM technique and the elements of the generalized model will be shown and discussed in details in the course of the presentation.

Biography

Miklos Hajdu is a Professor of Construction Management at the Szent István University's Ybl Miklós Faculty of Architecture and Civil Engineering. His current research interests focus on scheduling and other quantitative tools of construction management. A past and founding president of the Hungarian Project Management Association, and past vice-president of the Hungarian Scientific Society for Building. Professor Hajdu serves as the editor or member of the editorial board of numerous Hungarian and international journals.

Web-Based Management for Large Construction Projects

Miroslaw J. Skibniewski

Professor of Construction Engineering and Project Management at the University of Maryland at College Park, USA; Editor-in-Chief of Automation in Construction

Abstract

A broad range of offerings in web-based tools for project management, from freeware intended for small projects with limited number of activities and reporting needs to full-scale project portals supporting multiple monitoring, control and reporting functions, is capable to support a wide range of project sizes and complexities. This presentation focuses on the critical components of these systems which support large and complex projects, allowing for optimal selection of system's feature in support of critical project objectives.

Biography

Dr. Miroslaw J. Skibniewski is the A. James Clark Endowed Chair Professor of Construction Engineering and Project Management in the Department of Civil and Environmental Engineering at the University of Maryland in College Park. Prior to his current appointment he served for 20 years as a faculty member at Purdue University in West Lafayette, Indiana, where he held a position of Professor of Civil Engineering, Construction Engineering and Management. He received his M.Eng. degree from Warsaw University of Technology, and M.S. and Ph.D. degrees from Carnegie-Mellon University. Prof. Skibniewski is also a graduate of the Harvard University Graduate School of Education Management Development Program. Prior to his academic career, he worked in the industry as an engineer with the Pittsburgh Testing Laboratory, a nationwide construction engineering consulting firm in Pennsylvania subsequently renamed to Professional Service Industries, Inc. - where he was in engaged in design quality reviews, construction related claims, value engineering, forensic engineering and industrial safety investigations.

Management Of Complex Projects and Programs - Context, Concepts and Competences

Reinhard Wagner

IPMA President

Chairman of the Executive Board of GPM Founder and CEO of Projectivists

Abstract

We are faced with an increasing complexity when managing projects and programs. This is caused e.g. by the complexity of the content as well as the many influences on projects and programmes through the various context factors and stakeholders. This presentation will highlight the context of project and program management and some of the concepts we need in order to deal with the complexity in projects and programs. Finally, the presentation covers also the area of competences of individuals and organisations in order to be successful in this arena.

Biography

Reinhard Wagner studied Electrical Engineering and Business Administration in Germany and the USA. He looks back to more than 30 years of project related leadership experience in sectors such as the Air Defense, Automotive Engineering, Machinery and Not-for-profit organizations. As Certified Projects Director (IPMA Level A), he proved to be experienced in managing projects, programmes and project portfolios in a complex and dynamic context. In addition, he is IPMA Certified Programme and Portfolio Management Consultant and as such supporting senior executives in developing and improving the organizational competence in managing projects.

Since more than 15 years, he is actively involved in the development of project, programme and portfolio management standards. For example, as Chairman of the DIN Committee he led all activities for the development of the DIN Standards on (multiple) project management. From 2007 until 2012, Reinhard Wagner acted as a working group Convenor in ISO/PC236 for the development of ISO 21500 “Guidance on Project Management”. At present, he acts as Convenor of ISO/TC 258 WG04 facilitating the development of ISO 21504 “Guidance on Programme Management”. Within GPM and IPMA, he developed tools for the assessment and certification of organizations and acts as International Lead Assessor.

Reinhard Wagner is President of IPMA, Chairman of the Executive Board of GPM as well as founder and CEO of Projectivists, a PM Consultancy. He is married, has two sons in the age of 15 and 17 and lives in Friedberg / Bavaria.

PAPERS IN ENGLISH

GENERAL MANAGEMENT AND ECONOMICS

Analysis of Financial Risks Hedging Instruments for Public Works Contracts

Jana Korytárová[a]*, Jan Štaffa[a], Petra Papežíková[a], Michal Špiroch[a]

[a]Brno University of Technology, Czech Republik

Abstract

A very important point in public procurement process is represented by hedging public contracts against potential risk. There are many instruments used in the Czech Republic - insurance construction contracts, contractual penalty and retention or a bank guarantee to name several of them. But not all of them are as effective as the contractors need them to be. The main aim of this paper is to find an effective set of hedging instruments in contracts for work to sufficiently fulfil their function and protect the goals of both the investor and the contractor impending business risks.

Information on hedging instruments has been studied on the sample of 246 public works contracts of sewage facilities and equipment. The empirical part of the research focuses on the extent of hedging instruments used, and discusses their application in the context of efficiency. Research finds out that the most commonly used instruments are retention and bank guarantees. Furthermore, the reasons for significant changes in shares of these instruments in the course of monitoring have been analyzed.

The final outputs can have societal benefits and serve the contracting authorities and suppliers as a comparison of conditions of their own work contracts or as a help in creation of new work contracts.

Keywords: business risk, public works contracts, hedging against risk, sewage facilities and equipment, contract for work

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1. Introduction

Great attention is paid to efficient spending of public funds in all countries. Public sector investment projects are implemented based on legislation. In the Czech Republic it is the Act No. 137/2006, Collection of Laws, on Public Contracts, which specifies precisely the method to be used for selecting the most suitable supplier of the construction, particularly with respect to 3 E (economy, efficiency and effectiveness).

It is evident from both real practice and a number of research investigations that separate stages of the life cycle of the construction project entail a number of risk factors, which can seriously infringe, change or reduce project effectiveness. The authors of the presented paper focused on the specifics of risk management related to the implementation stage of the investment project life cycle. At this stage it is the quality of construction works, quality of deliveries as well as timely completion of the construction that are monitored most closely. Against the numerous risk factors that can occur at this stage and that can result in additional costs of the construction or in exceeding construction time schedules, instruments reducing, eliminating or transferring impacts of the above risks on a third party, can be found. The discussion has been carried out about a range of hedging instruments aiming at reducing business risk.

They should fulfil some of the functions as follows (Korytárová, 2011):

- preventive function (improvement of investor's legal position in relation to contractor)
- reimbursement function (provision of a financial compensation for damages, if any) - remedial measures
- sanctional function (penalization of the supplier for his failure to fulfil the obligations agreed on) - remedial measures.

The aim of the authors of this paper is to find out what hedging instruments are employed at the present time, at what values and if the instruments fulfil the functions required. Štaffa did basic research within his thesis (Štaffa, 2015). The research covers a set of 246 specific public work contracts for building sewage treatment plants and the appropriate sewage systems. Financial volume of the work contracts was in total 342,895,412 Euro[†]. The average value of one contract was 1,393,884 Euro. Median showed that the number of lower value contracts was greater than the average calculation, namely 904,361 Euro. On average, 7 tenders were submitted for each contract and the average time for implementation of the work was about 381 days. There were particularly insurance, contractual penalties, retention and bank guarantees that were found in the set of contracts studied among the examined instruments.

2. Methodology

The method of data collection was based on an initial premise that the Czech Act No. 55/2012, Collection of Laws amending the Act No. 137/2006, Collection of Laws, on Public Contracts, places a duty on investors to publish contracts for work on their profiles. The basic step in creating the database consisted in listing profile addresses of investors occurring in specific contracts and, subsequently, looking up the published contract for work. With respect to such a long-time data collection generating a great number of data, immediately at the start it, was proceeded to selection of public contracts covering projects related to construction of sewage treatment plants and the appropriate sewage systems (STP), primarily for the following reasons:

[†] Average rate of exchange in the years 2013 and 2014 was 26.75 Kč/€

- a great number of public contracts which are uniform with respect to the branch,
- significant municipal contracts with a higher price and importance for risks hedging,
- various investors and contractors over the entire Czech Republic.

Consequently, all the findings presented in the article are based on analyses of the data recorded, collected and sorted over a long time period. Thus a relatively unique database of contracts for work was created, which - thanks to its extensiveness - offers a comprehensive and trustworthy view of the use of hedging instruments in public contracts in the Czech Republic. At the same time, thanks to its potential, the database exceeds mere concentration on hedging instruments, thus being able to place the data also in a wider context. Final output can have societal benefits and serve contracting authorities (particularly municipalities), including suppliers, e.g. for comparison with the conditions of their own work contracts to show them if the contracts are not disadvantageous for them, or if they do not exceed the established practice. Simultaneously, it can contribute to a more effective selection of hedging instruments if a contract for work is just being created.

3. Results and discussion

Based on the analysis of 246 public contracts for construction works, a partial conclusion can be drawn. The most frequently used hedging instruments for public construction works contracts in the Czech Republic include particularly:

1) property insurance and insurance of liability for damages,
2) contractual penalty,
3) retention and
4) bank guarantee.

Insurance ranks among important hedging instruments in construction projects (FIDIC). Insurance is often the cheapest method (when available) for managing catastrophic-type physical risks and for managing higher levels of liability exposures (Edwards, 1995). It is particularly the insurance of liability for damages and construction-assembly insurance that appear in contracts for work. The insurance of liability for damages was found in 209 contracts (85% of the sample examined) and was more frequent than the property insurance, which was arranged in 160 contracts (65% of the sample examined). However, the lower than expected numbers can be due to the fact that prior to imposition of the Act No. 55/2012, Collection of Laws, (3), the requirement to arrange the insurance could be included in qualifications prerequisites within the competitive tender (selection procedure). The tenderer who passed the qualifications procedure had concluded the required insurance and consequently it was not necessary to include this in contracts. Since the source database was being created from the start of the validity of the act amendment (1st April 2012) it is certain that some contracts were already in the process of placement of orders and insurance of the first contracts given in the database was still a part of the qualifications. The authors of the present paper believe that in case of the liability insurance, the realistic number would exceed 90% limit of the frequency occurrence

In case of the construction-assembly insurance, price of the work after its completion can be considered as an effective value of the sum insured, which holds also for damage liability insurance where, however, also a smaller sum insured can be tolerated. On the contrary, an overinsurance can cause higher financial insurance costs for the contractor, usually in orders of tens of thousands, which they subsequently, include in the tender price of all tenderers. However, it is appropriate to say that in case of contracts at the value of several tens of thousand Euro, a more effective selection of the sum insured can bring only small savings in order of tenths of percent of the total price of work.

Contractual penalty is the most frequently used business risk hedging instrument. In the analysed database, contractual penalties occurring most frequently in 243 contracts for work were as following:

1) contractor's delay in the construction completion date
   the average amount being 0.14% of the price of work without VAT (median of 0.1% of the price of work without VAT)
2) exceeding deadline for elimination of defects and arrears of work
   the average amount being 0.04% of the price of work without VAT (median of 0.01% of the price of work without VAT)
3) investor's delay in payment invoices (invoices exceeding their due dates)
   the average amount being 0.05% of the sum in arrears (median of 0.05% of the sum in arrears)
4) failure in keeping the term of clearing the construction site
   the average amount being 0.04% of the price of work without VAT (median of 0.02% of the price of work without VAT)
5) failure in keeping the term of the start of defects elimination
   the average amount being 0.03% of the price of work without VAT (median of 0.01% of the price of work without VAT)

Occurrence frequency of the individual contractual penalties is shown in the diagram in Fig. 1.

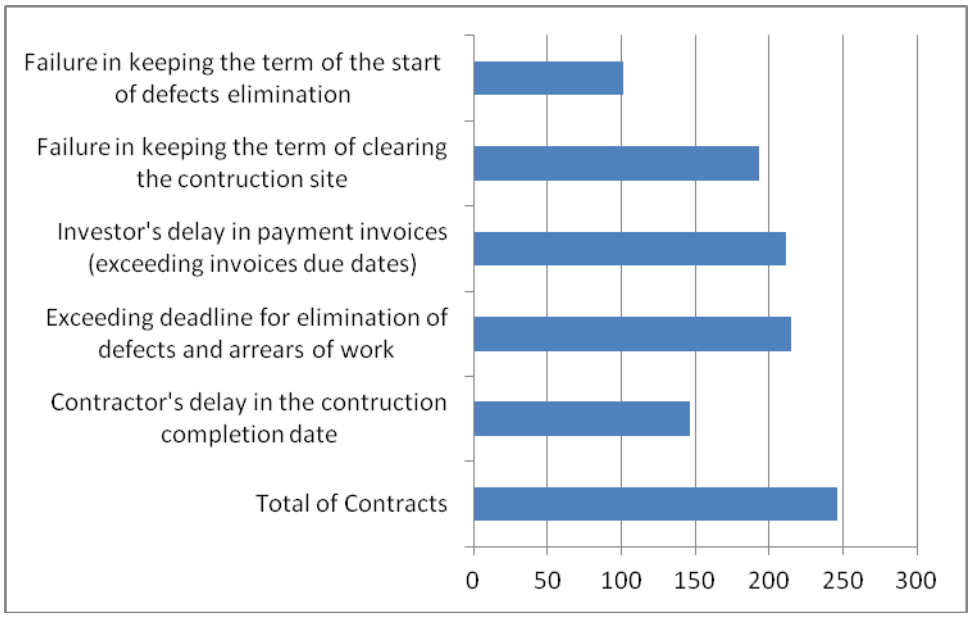

Fig. 1 Contractual penalties occurrence frequency

With regards to the occurrence frequency in contracts for work, contractual penalties are the most frequent types of hedging instruments; they are comprehensible, administratively undemanding and have an appreciated preventive effect.

Retention belongs to traditional forms of business risks hedging in contracts for work. It is a common practice in the construction industry to withhold a small proportion of payments to a contractor until the work has been completed satisfactorily (Hughes & al, 2009). Its usual size in the Czech construction practice is 10% of the price of work and usually is paid after expiration of the guarantee period. It might be interesting that for instance the amount California public entities retain from public works contract payments ranges from 10% to 5%, in most cases (Atkinson & al, 2011). Under the new law, the retention withheld cannot exceed

5% of the payment, and in any case shall the total retention proceeds withheld exceed 5% of the contract price (Jones Day, 2012).

Occurrence of retention in contracts for work was found in 107 cases out of 246 contracts monitored. An analysis of the contracts with regards to the use of this instrument provided interesting results when followed on a time axis. Till 2013, the occurrence frequency was 59 out of 100, since 2014 the frequency has decreased to 44 out of 146 contracts.

Fig. 2 Retention occurrence frequency

However, omission of the retention institute from contracts for work does not mean that investors resigned on ensuring themselves against risks, particularly against those related to defects and arrears of work found at the time of hand over and take over of the work or during the guarantee period. Actually, the analysis shows that investors have only started to prefer other hedging instruments for these risk areas. The completed analysis indicated that the use of retention in contracts for work started to decline. Apparently, the main reason for it can be attributed to an extending offer of bank guarantees and their more frequent use in contracts for work. Thanks to their nature, bank guarantees provide the investor a similar security as retention while offering the contractor (supplier) numerous advantages.

By its function in the contract of work, bank guarantee is close to the financial retention sum (retention). As the most significant advantage of a bank guarantee compared to retention, can be considered its ability to guarantee financial means to the investor in case of the failure of the contractor to keep the terms of the agreement without the necessity to retain or otherwise freeze contractor's money. Out of the contracts for work, the following ones

- Performance Guarantee
- Warranty Guarantee and
- Retention Guarantee

are worth examining in greater detail.

The essential difference between the above bank guarantees consists in the fact that the first two guarantees are characterized by the obligation to submit them to the investor while the retention guarantee was incorporated into contracts rather as a possibility of a compensation for the financial retention. Both performance and warranty guarantees were present only in 55% of contracts for work. Similarly as in case of retention, the time axis for the value of frequency of their use is of interest. The *Performance Guarantee* occurred in the contracts for work before 31 December 2013 in only 33%, the *Warranty Guarantee* even only in 30% of contracts. Since 1 January 2014 the relation has changed significantly. The *Performance Guarantee* was recorded in 70% of contracts and the *Warranty Guarantee* in 73% of contracts.

When comparing occurrence frequency of the bank guarantees and the retention in the contracts for work under examination, almost identical values, but in the opposite order, can be found. This "consistency" contributes to the assumption that the retention instrument is being substituted gradually by a combination of the above mentioned bank guarantees, i. e. the performance bank guarantee is substituted by a proper execution of the work and the bank guarantee by repairs under a letter of guarantee.

In the present contracts for work, bank guarantees already have their permanent place. Due to their functional similarity to the financial retention sum, a trend in introducing bank guarantees into contracts for work at the expense of the retention instrument was noted. Simultaneously, rough calculations of financial costs showed that a more effective setting up of the amount of the bank guarantees could bring certain financial savings. However, the amounts in question are, at maximum, in order of units of the percentage of the price of work. An average amount of the *Performance Guarantee* is about 8.45% of the price of the work, in case of the *Warranty Guarantee* 4.94 % of the price of the work. Therefore, it is appropriate to look at the bank guarantees not only with respect to financial costs but– with taking into account also further indisputable advantages connected with this type of the hedging instrument when incorporating them into the contract for work.

From the above listed facts, a recommendation has been drawn for a standard construction work contract. For every contract a mix of hedging instruments should be created comprising a) insurance of liability for damages ranging between 80 and 100% of the price of the work, property (construction) insurance in the extent of 100% of the price of the work, b) contractual penalties for contractor's delay in the construction completion date in the extent of 0.1% of the price of the work, for exceeding the deadline for elimination of defects and arrears of work with a fixed amount of penalty (€190/day in the Czech Republic), for investor's delay in payment of mature invoices in the extent of 0.1% of the sum in arrears, for failure in keeping the term of clearing the construction site with a fixed amount of penalty (€190/day in the Czech Republic) and c) performance bank guarantees in the extent of 10% of the price of the work and for repairs under a letter of guarantee in the extent of 5% of the price of the work. It is recommended not to use retention any more since bank guarantees fully substitute them or even provide a greater extent.

4. Conclusion

This paper focuses on the analysis of use of hedging instruments employed in public construction contracts and on assessment of a reasonable extent of their use in contracts for work. Analysis was carried out on an extensive sample of 246 contracts for work concluded from public orders for construction of waste-water treatment plants and the related sewage systems. Major concern has been to determine how the hedging instruments are used and how their amount is set up.

Based on the analysis of the sample examined, it is apparent that the Czech building practice uses most frequently property and damage liability insurance, contractual penalties, retention and bank guarantees. The research has revealed that the frequency of use of the separate instruments has been changing recently. The database was being created between April 2012 and August 2014, i. e. at the time when the Czech Public Contracts Act was amended. In 2012, the amendment left out from the Act the investor's requirement to request the contractor to prove his financial and economic qualifications prerequisites. Insurance is one of the instruments examined, which does not appear in contracts for work concluded prior to coming of the above act amendment into force, probably due to the fact that it is a part of qualifications prerequisites.

Finally, it should be said what hedging instruments have their place in contracts for work. A recommendation raised by this research for a standard construction work contract is a

mixture of hedging instruments comprising selected types of insurance, contractual penalties and bank guarantees.

Acnowledgement

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The Impact of Organizational Culture on the Efficiency of Higher Education Institutions

Ivana Šandrk Nukić[a*], Hrvoje Krstić[a], Dražen Holmik[b]

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Abstract

In the context of business management, the research of organizational culture has been actualized in the last decade because it promotes internal sources of competitive advantage, and that corresponds to the attitude of modern organizational theories.

At the university level, previous studies have shown that organizational culture is a reflection of the values and beliefs of all university stakeholders and that it greatly affects the decision-making processes as well as forms of individual and organizational behavior.

Culture of each organization is unique. Therefore, beside the theoretical background, also specific beliefs, attitudes, assumptions, values, norms and expectations of different stakeholders of the observed organization need to be investigated. This is essential for managing the organizational culture in a way that it teaches appropriate behavior, motivates individuals and directs them toward the desired organizational goals.

Basing on the above, this paper presents the case study of the Faculty of Civil Engineering Osijek. The study has been conducted by using the methodology of Organizational Culture Assessment Instrument, a many times validated questionnaire.

Survey results identified the dominant cultural profile of the Faculty as well as the cultural profile that respondents considered desirable in the future. This created a scientific contribution to the understanding of organizational culture in higher education institutions as well as the foundation for sustainable efficiency of the operation and management of the Faculty tested.

Keywords: organizational culture; higher education institutions; managing efficiency

1. Introduction

Increasing the efficiency plays an important role in accelerating the development of organizations (Bodla et al. 2013). There are many factors affecting the organizational effectiveness. Among those, Higher Education Report (ASHE, 2003) emphasizes that efficient realization of the organization's strategy depends on an adequate organizational culture. And an adequate organizational culture could be defined as the one that encourages employee satisfaction (Bhatti and Qureshy, 2007).

Yet, there has been little consideration of organizational culture relevant to institutions of higher education. Specific research on organizational culture in higher education institutions probably begun with Tierney's highly-cited article *Organizational culture in higher*

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education: Defining the essentials. According to Tierney, organizational culture results from the internal dynamics within an organization that derive „from the values, processes, and goals held by those most intimately involved in the organization's workings" (Tierny, 1988:3).

As such, organizational culture in higher education is not monolithic (ASHE, 2005). Faculties and universities vary in location, size, and mission, each of which can have a potentially profound influence on the internal dynamics of the organization.

On the other hand, it has been suggested that leaders in higher education must understand the value systems of their institutions in order to adjust their leadership behavior and accomplish the strategic goals (Tsai, 2011). Additionally, there is evidence to suggest that different faculties and universities may manifest notable differences in organizational culture and decision-making (Tierney, 2008).

This cognition points in fact to the knowledge gap that has been one of the motives for the study presented by this paper – as organizational culture varies between different higher education institutions, specific studies should be carried our in order to identify the culture of different higher education institution and enable their efficient functioning. The reality is that empirical support for this statement is scant. Therefore, the aim of this paper is to provide scientific contribution through analysis of the organizational culture of a specific higher education institution, being the Faculty of Civil Engineering Osijek.

All organizational components of the J.J Strossmayer University of Osijek aspire towards the same strategic goals: to raise the quality of the teaching process, to achieve proactive involvement in the European scientific research area, to develop cooperation with industry and civil society in order to become a driver of economic and regional development (Strategy of Josip Juraj Strossmayer University of Osijek 2011 – 2020). Results of the analysis of the organizational culture of the Faculty of Civil Engineering Osijek are expected to be beneficial for generation of employee satisfaction and production of a positive impact on the Faculty's efficiency in achieving strategic goals.

2. Literature review

Organizational culture is the subject of multidisciplinary research since the early 20th century. In terms of business performance, the concept became dominant in the 1980s (Bellot, 2011) but the more intensive research of organizational culture at the university level began only in the new millennium (Kaufman, 2013).

Since the concept of organizational culture combines several disciplines, primarily organization, psychology, sociology and anthropology, even its very definition is complex and many authors have tried to explain it through the lens of descriptive typologies.

One of the most influential scholars on the field of organizational development and culture, professor Edgar Schein, defined the organizational culture as the deeper level of basic assumptions and beliefs that are shared by members of an organization (Schein, 2004). He developed a model of the organizational culture that identifies three distinct cognitive levels in organizational cultures:

- artefacts and behaviours;
- espoused values;

- assumptions;

Only artefacts and behaviours are a fully visible manifestation of the culture, but in its core, the organizational culture is determined by the other two hardly detectable elements. That is the source, or the main reason for which the culture is difficult to be managed and changed.

Another comprehensive set of studies has been carried out by professor Gert Hofstede, who teaches that the culture is a system of collectively held values (Hofstede et al., 2010). There have been other important studies, too. Deshpande and Webster (1989) described the organizational culture as the pattern of shared values and beliefs that help individuals understand organizational functioning and thus provide them with norms for behaviours in the organization. Charles Handy (1993) linked the organizational culture to the organizational structure. As a result, he identified four types of culture being the power, the role, the task and the person. Quinn and Rohrbaugh developed (1981) the Competing Values Framework, consisted of two dimensions: the first dimension measures organizational focus from internal to external and the second dimension differentiates a focus on flexibility, discretion and dynamism from focus on stability, order and control. These two dimensions form four quadrants, as presented in the Illustration 1., each representing a distinct set of values.

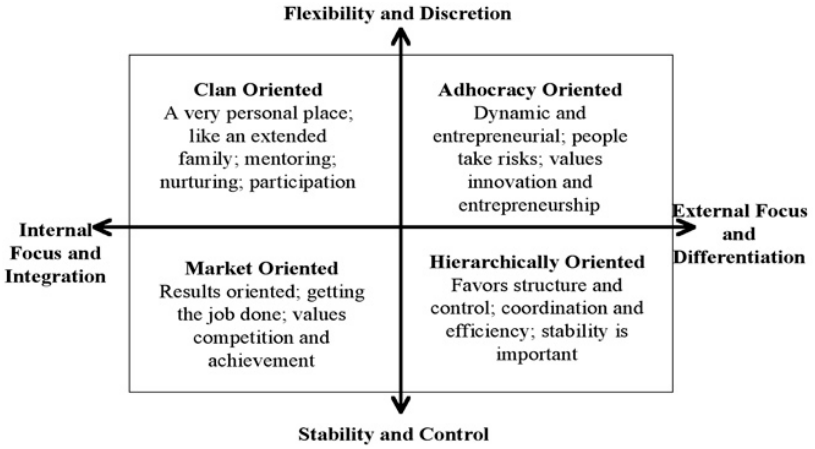

Illustration 1. Competing Values Framework (adapted from Cameron, Quinn, 2005)

Besides the above mentioned, there are other scholars who have tried to define and categorize the concept of the organizational culture. However, it can be resumed that although many authors have been dealing with the organizational culture, after years of conceptualization and assessment, the consensus emerged on the organizational culture being one of the key determinants of sustainable competitive advantage, performance and long-term effectiveness of organizations.

At the university level, culture can be defined as the values and beliefs of university stakeholders (i.e., administrators, faculty, students, board members and support staff) (Bartell, 2003). The culture is like the personality of an organization – even only by observing interactions among its staff and/or students, or noticing the building maintenance, one can perceive different cultural characteristics.

Unlike most business organizations, faculties often possess goals that are difficult to measure (Strategy of Josip Juraj Strossmayer University of Osijek 2011 – 2020; Bartell, 2003). Further, diverse internal and external stakeholders share responsibility and decision making power (Bartell, 2003; Mintzberg, Van der Hayden, 1999). Internal stakeholders range from domestic and foreign undergraduates to graduate, professional, and continuing education

students. External stakeholders include those in the surrounding community, the political jurisdiction, granting and accrediting agencies, unions and the press (Bartell, 2003). Faculty leaders face therefore a challenging role of coordinating both internal and external components.

The university environment is a rapidly changing. Some major external components facing today's universities include mass education, state funding reduction, distance learning and capital equipment cost These components influence the effectiveness of academic programs, delivery systems and internal relationships, often requiring adaptation and institutional change (Bartell, 2003).

Furthermore, among internal stakeholders, conflicts often exist. Primarily, professors consider autonomy and academic freedom of high importance, while administrators place more value on procedural processes (Fralinger, 2007). As a result, change and innovation are often repressed or slowed. In order to remedy this, both administrators and faculty need to find a balance between their conflicting roles through increased cross-communication in order to establish an effective organizational culture. Effective organizational culture implies that shared meaning is held by all members, and that individuals within the faculty must clearly know their role and feel an inherent sense of obligation to that role (ASHE, 2003).

Not just effective organizational culture but also effective cultural change in higher education institutions depends on information and communications technology. According to Dhillon (2001), information is the lifeblood of higher education institutions. It is a resource and needs managing as such, requiring a high level of commitment from senior managers and staff at all levels of the organization. In his study, Dhillon found that failing in generation and dissemination of information at a faculty, leads to feeling of powerlessness and the existence of a „blame" culture within the organization.

Ensuring effective channels for communication is a major challenge for achieving cultural change in the organization. As a result of the findings, Dhillon (2001) revealed specific recommendations: the quality of the information itself, identifying responsibility for information and establishing ownership, and communicating knowledge and information through appropriate means, including verbal, print, and electronic media. He concluded that after such cultural change, both students and staff staff began to recognize and understand their roles and responsibilities.

Notwithstanding, in the study conducted the same year, certain communication obstacles were detected (Hellawell and Hancock, 2001). It was confirmed that it is difficult for faculty academic staff to communicate and work together when they are either scattered across a large building or in different buildings altogether. Therefore, the authors suggested that faculty and staff of similar departments should be housed together in order to form a more cohesive group. Also faculty boards and higher hierarchical university members (Dean, Associate Deans, Heads of Department) should meet in a regular fashion in order to operate collegially (Hellawell and Hancock, 2001). In general, the situation is that the fewer hierarchical layers in an organization, the less chance for conflicts and misinterpretation of the organization's basic underlying assumptions, beliefs, and values (Valentino, 2004).

According to the 2003 Higher Education Report, an effective university culture teaches and exhibits appropriate behavior, motivates individuals, and governs information processing. Strong values can give rise to beliefs about preferred modes of conduct and desirable objectives (ASHE, 2003). Since values and beliefs greatly influence decision-making

processes and shape individual and organizational behaviors at universities (Tierney, 1988; Bartell, 2003), faculty leaders are increasingly becoming more aware of the concept of culture and its significant role in faculty change and development.

The literature suggests that to be effective, leaders must possess a vast knowledge and a complete understanding of assumptions and values among all relevant stakeholders. Because of that, the relationship among three dimensions of organizational culture (congruence, strength, and type) and organizational effectiveness has been investigated (Cameron and Freeman, 1991). The researchers found that the type of culture was a greater determinant of organizational effectiveness than were either congruence or strength. Because of that, authors of this paper have studied the organizational culture at the Faculty of Civil Engineering Osijek and the results of the study shall be presented hereafter.

3. Research methodology

3.1. Measures

From what has been previously presented, the organizational culture is of great importance even for non-profit organizations like higher education institutions. Therefore, its measurement and control are appealing, yet challenging issues. As a lot of definitions have emerged out of organizational culture's complexity, a variety of classifications and measures have been proposed, too (Giritli et al., 2013).

In order to identify cultural types in this study, often used measurement tool named Organizational Culture Assessment Instrument (OCAI) has been chosen for its validity (Kaufman, 2013). OCAI is a questionnaire developed to produce an overall organizational culture profile (Cameron, Quinn, 2005). This instrument is based on previously mentioned Competing Values Framework, which originally emerged from the empirical research question of what makes organizations effective (Quinn and Rohrbaugh, 1983). With regard to using the Competing Values Framework for profiling the organizational culture, four sets of values presented in Figure 1 are being considered as specific types of the organizational culture, determining the organization's way of doing business and its effectiveness.

OCAI questionnaire complements the Framework by assessing the fundamental cultural aspects of the organization through six key dimensions (Cameron, 2008):

1. dominant characteristics,
2. organizational leadership,
3. management of employees,
4. organizational glue,
5. strategic emphases,
6. criteria for success.

Each dimension offers four alternative statements (A, B, C and D), representing the above differentiated cultural types. When completing the questionnaire, respondents are asked to rate their organizations' culture by dividing 100 points among the four alternatives, in each of the six dimensions. A higher number of points should be given to the alternative that is most similar to their organization. Based on those rates, averages for OCAI alternatives A, B, C and D are calculated. In that way, dominant and subordinate organizational culture types of the organization is being detected, indicating also the area where current and preferred organizational cultures differ and where change is needed.

It is important to emphasize that none of the types is dominant over the others (Cameron, 2008; www.ocai-online.com).Some culture types are only more appropriate for a certain context:

1. In the clan culture, the organization's performance is determined by loyalty, tradition and collaboration. It means, working together with the emphasis on concern for people. Because of that, in the clan organizations, employees usually feel less negative about work pressure and a low salary compared to a market culture. Everybody feels respected: all employees are taken seriously and managers are considered mentors. In such an organization high commitment and solidarity produce effectiveness.
2. Adhocracy culture is the characteristic of organizations that concentrate on external positioning with a high degree of flexibility and individuality. In order to achieve success and effectiveness, leaders of adhocracy type organizations foster experimentation and innovation, taking risks and being at the edge of new knowledge. Meeting these challenges forms a dynamic, entrepreneurial and creative workplace.
3. In a market culture, leaders are genuine hard drivers so the company exists as a competitive workplace with no mercy. Ever increasing market share and returns are the ultimate goal, thus in such results-oriented organizations only winning counts.
4. Finally, a hierarchy culture is a highly formalized and structured organization whose success depends on predictability and efficiency. Employees function on grounds of well-defined procedures and leaders act like coordinators.

Additionally, it is important to say that respondents are asked to rate each dimension twice: first regarding the current state of the culture in their organization and then in respect to the preferred organizational culture, as they feel it should be in the future. In that way, OCAI identifies both the current organizational culture and the preferred, future organizational culture. As such, this measurement tool not only reflects the underlying attributes (management style, strategic plans, climate, reward system, leadership, and basic values) of the organization but also serves to diagnose and initiate change in the organizational culture as the organization progresses through its life cycles and copes with external environmental pressures (Fralinger, 2007).

3.2. Sampling and data collection

The survey using the OCAI questionnaire at the Faculty of Civil Engineering Osijek was conducted during March and April 2015. In order to take into consideration opinion of all relevant stakeholders, the questionnaire has been given to all employees (board members, professors and assistants, administrative and technical personnel) as well as some randomly chosen students at the Faculty. The questionnaire was sent to the employees by e-mail and it was printed out for students. In order to ensure the anonymity of responses, a box was set in the student administration office, and respondents were asked to leave the completed questionnaires in the box.

There are 91 employees at the Faculty of civil engineering Osijek. Out of those, 36 employees filled in the questionnaire, but only 26 filled it in correctly. Consequently, the size of the sample to be taken into account is 28,57% of the total number of employees. Additionally, 55 students filled in the questionnaire, but only 44 correctly, which makes a contribution of 6% of total number of students at university study programme. Since it is more difficult for students to influence the Faculty's culture than for the employees, the overall sample is considered acceptable and reliable. Nevertheless, reliability of the study shall be additionally tested by using Cronbach's Alpha coefficients, as presented later in the text.

In order to reflect the nature of the sample, the first part of the analysis concerns descriptive statistics. Results showing the characteristics of the respondents are provided in Table 1.

Table 1. Characteristics of the sample

Respondents	Frequency	Percentage (%)
Employees (N= 26)		
Male	9	34,62
Female	17	65,38
Professors & assistants	13	50,00
Lecturers	1	3,85
Administrative & technical personnel	12	46,15
Department for technical mechanics	2	7,69
Department for materials and constructions	5	19,23
Department for organization, technology and management	1	3,85
Department for geotechnics, roads and geodesy	2	7,69
Department for water engineering and environmental protection	3	11,54
Architecture and urban planning	2	7,69
Other	11	42,31
Students (N = 44)		
Female	30	68,19
Male	14	31,81

As seen in Table 1, the sample consists of all the main stakeholders influencing the organizational culture of the Faculty of Civil Engineering Osijek.

4. Results and discussion

4.1. Main results

The core part of this empirical research derives from the OCAI, and follows its measurement methodology as described earlier. The average scores for all the participants, i.e. the overall sample, indicating current cultural types and cultural types that are preferred for the future, are shown in Table 2.

Table 2. Mean scores of the organizational culture dimensions for the sample

	Dominant characteristics	Organizational leadership	Management of employees	Organizational glue	Strategic emphases	Criteria of success	TOTAL cultural profile of the sample
NOW							
Clan	17,21	16,03	20,21	19,21	23,86	29,07	20,93
Adhocracy	19,36	26,64	14,79	20,14	20,73	19,71	20,23
Market	35,29	26,26	25,64	22,17	24,60	12,64	24,43
Hierarchy	28,14	31,07	39,36	38,47	30,81	38,57	34,41
FUTURE							
Clan	42,46	37,03	42,00	40,69	40,36	47,43	41,66
Adhocracy	20,79	26,46	22,86	32,76	23,71	13,14	23,29
Market	19,56	3,66	9,29	7,93	11,89	9,36	10,28
Hierarchy	17,20	32,86	25,86	18,63	24,04	30,07	24,78

The findings indicate that the current dominant organizational culture of the sample is hierarchy. Such finding is in compliance with the study results provided by Smart, Kuh, and Tierney (1997) stating that public faculties tended to manifest either hierarchy or adhocracy cultures. The next dominant cultures, that are present at the Faculty of Civil Engineering Osijek, are market and clan, followed by adhocracy cultural type.

However, the analysis identified clan as being by far the most preferred dominant cultural type. This finding contributes to the understanding of organizational culture, but also signals the preferred direction of organizational change. Putting more emphasis on the clan culture would be desirable also because of the findings stated in the Higher Education Report (ASHE,2003), that the most successful faculty cultures appear to be those that support both group cooperation and individual achievement.

The next most dominant preferred type is hierarchy. Clan and hierarchy cultures are followed by adhocracy and market cultural types. Such aversion towards the market and even adhocracy culture is in fact welcome in the context of the higher education institution. Namely, those university cultures that encourage competition rather than internal cooperation tend to exhibit dysfunctional behavior (ASHE, 2003). This type of behavior often leads to conflict between the university culture and the actions of the hierarchies, resulting in alienation, disorganization, and confusion (Schein, 2004; ASHE, 2003).

These average results of the overall sample can be analyzed in more details by the sample subcategories, as presented in Tables 3 and 4, and interpreted in the next sections of the paper.

Table 3. Mean scores of the current organizational culture by the sample subcategories

	Culture types			
	Clan	Adhocracy	Market	Hierarchy
Respondents as relevant stakeholders				
Students	21.39	21.96	25.80	30.85
Professors and assistants	15.26	17.37	29.30	38.08
Lecturers	11.67	17.50	26.67	44.17
Administrative and technical personnel	26.18	17.22	13.96	42.64
F-value	*5.378*	*0.002*	*8.645*	*0.621*
Pr(>F)	*0.00553* **	*0.998*	*0.000277* ***	*0.539*
Employees upon organizational structure				
Department for technical mechanics	35.83	17.50	13.33	33.33
Department for materials and constructions	21.00	21.83	28.00	29.17
Department for organization, technology and management	0.83	10.00	15.83	73.33
Department for geotechnics, roads and geodesy	12.08	13.33	16.25	58.33
Department for water engineering and environmental protection	5.00	18.89	42.50	33.61
Architecture and urban planning	11.25	13.75	40.42	34.58
Other	25.91	16.82	13.79	43.49
F-value	*5.347*	*0.841*	*6.696*	*4.53*
Pr(>F)	*5.03e-05* ***	*0.54*	*2.71e-06* ***	*0.000301* ***
Respondents upon gender				
Male	20.94	22.08	25.36	31.62
Female	20.92	17.90	23.27	37.90
F-value	*0*	*7.061*	*0.804*	*6.973*
Pr(>F)	*0.99*	*0.00818* **	*0.37*	*0.00859* **
T-value	0.99	*0.0082*	*0.37*	*0.0086*

Results for the relevant stakeholders presented in Table 3 show that there are no significant differences between dominant cultural types identified for employees and students at the Faculty of Civil Engineering Osijek. All tested categories perceive the hierarchy as being the dominant cultural type. This is somewhat expected for the institution that is part of the public system. However, it is interesting that the next most prominent culture type is market both for students and teaching staff, whilst administrative and technical personnel find the clan type to

be the second dominant type. This finding points to the fact that there is a parallel existence of two different subcultures at the observed institution. Such data is in compliance with study conducted by Mattson and Brent (2008), suggesting the presence of two distinct cultures, those of faculty and administrators respectively, on most campuses.

Furthermore, the analysis of cultural types as perceived within different organizational departments suggest that there are more than two different cultures present at the Faculty of Civil Engineering Osijek: Department for technical mechanics feels that the clan culture is currently dominant, Department for architecture and urban planning thinks they work following the market culture values, and, in the same time, all the other departments see hierarchy as the dominant cultural type at the Faculty. Differences between departments are usually present in bigger institutions than the Faculty, but in this case they can be interpreted as a result of specific research interests and professional differences among employees. Still, these differences put pressure on the leadership of the Faculty and the high probability of coexistence of discontent and the satisfaction caused by the same decisions.

No significant differences were detected by the analysis based upon the gender of respondents.

Table 4. Mean scores of the preferred organizational culture by the sample subcategories

	Culture types			
	Clan	Adhocracy	Market	Hierarchy
Respondents as relevant stakeholders				
Students	42.87	24.94	11.24	20.95
Professors and assistants	38.46	26.73	10.00	24.81
Lecturers	36.67	28.33	8.33	26.67
Administrative and technical personnel	41.11	13.06	7.22	38.61
F-value	*0.353*	*14.87*	*0.578*	*7.354*
Pr(>F)	*0.703*	*1.26e-06 ****	*0.562*	*0.000892 ****
Employees upon organizational structure				
Department for technical mechanics	35.83	30.83	11.67	21.67
Department for materials and constructions	43.00	24.00	12.33	20.67
Department for organization, technology and management	50.00	18.33	3.33	28.33
Department for geotechnics, roads and geodesy	38.75	20.00	2.08	39.17
Department for water engineering and	36.67	31.11	8.89	23.33

environmental protection				
Architecture and urban planning	37.92	29.58	12.08	20.42
Other	39.09	12.73	7.42	40.76
F-value	*0.507*	*5.875*	*0.965*	*4.951*
Pr(>F)	*0.802*	*1.59e-05 ****	*0.451*	*0.00012 ****
Respondents upon gender				
Male	41.11	25.19	12.41	21.30
Female	38.82	17.99	6.67	36.52
F-value	*0.414*	*6.462*	*4.784*	*16.88*
Pr(>F)	*0.521*	*0.012 **	*0.0302 **	*6.45e-05 ****
T-value	*0.52*	*0.012*	*0.03*	*6.4e-05*

Table 4 shows that all relevant stakeholders of the Faculty of Civil Engineering Osijek prefer the clan cultural type for the institution's future. This finding suggests an organizational change that could generate multiple benefits for the Faculty. Primarily, domination of the clan culture would be in compliance with previously reported most desired, functional behavior in the university context (ASHE, 2003). Additionally, cherishing the clan values would diminish the pressure placed on the leadership of the Faculty due to the cultural differences among the relevant stakeholders. Finally, there is a study suggesting (Crow, 2007) that state-funded universities must overcome what he perceived as the restraint of government oversight and attempt to balance the exigencies of state funding against attempts to attain greater institutional recognition. He thinks that the clan culture would be the best platform to achieve that.

Reported characteristics of identified current and preferred organizational culture at the Faculty of Civil Engineering Osijek can be demonstrated also by diagrams as in Illustrations 2 and 3. The solid line presents the current organizational culture and the dashed line shows the preferred organizational culture.

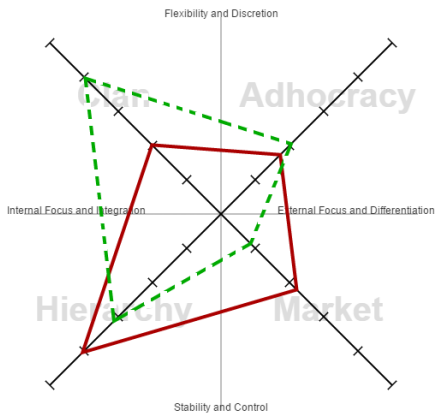

Illustration 2 Organizational profiles as perceived by the employees of the Faculty of Civil Engineering Osijek

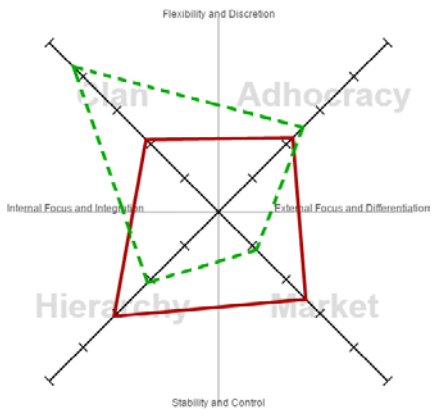

Illustration 3 Organizational profiles as perceived by the students of the Faculty of Civil Engineering Osijek

There is scientific evidence that organizational performance has significant correlations with the cultural dimensions: involvement, collaboration, transmission of information, learning, care about clients (i.e. students), strategic direction, reward and incentive system, system of control, communication, coordination and integration. The effective organizations should provide employee satisfaction and organizational commitment (Bodla et al. 2013). In consequence, concentrating on creating a culture identified as preferred in the organization would facilitate getting desired organizational performance.

Possible advice on how to guide the organizational development of the Faculty of Civil Engineering Osijek from the current hierarchy culture towards the preferred clan culture could be found in Schein's eight steps of creating psychological safety for organizational members: create a compelling positive vision, provide opportunities for formal training, allow employees and students to manage and be in control of their own personal learning process, support informal training of relevant “family” groups and teams, practice fields, coaches, and feedback, be a positive role model, create interdepartmental groups and cross-departmental liaisons, provide support groups, and align the organizations reward and discipline systems with the new way of thinking and working (Schein, 2004; Valentino, 2004).

4.2. Additional tests

Analysis of variance (ANOVA) test was performed to examine the differences among mean scores on current and preferred organizational culture types. These results are also presented in the Table 3 for the current organizational culture and in the Table 4 for the preferred organizational culture.

In respect of the current organizational culture, a post hoc Scheffé test ($p < 0,05$) revealed that there are significant differences between mean scores from different organizational departments in all cultural types but adhocracy. Additionally, in market culture there are significant differences even among the relevant stakeholders.

Concerning the ANOVA test results for the preferred organizational culture, a post hoc Scheffé test ($p < 0,05$) revealed significant differences in mean scores of hierarchy and adhocracy cultural types both for relevant stakeholders and different organizational departments. In hierarchy cultural type even the mean scores of different gender respondents significantly vary.

Such variations within the mean scores can be interpreted as a positive impact on diversity and quality of the Faculty's activities aimed toward external stakeholders (Kaufman, 2013).

Beside the analysis of variance, also the reliability coefficients (Cronbach's alpha) were calculated for each of the different culture types being assessed by the OCAI, as it can be seen from the Table 5.

Table 5. Cronbach's alpha coefficients

Culture type	Now	Preferred
Clan	0,84	0,79
Adhocracy	0,46	0,61
Market	0,75	0,66
Hierarchy	0,77	0,79

Taking into account that coefficients above 0,5 arguably indicate reliability of tests performed, it can be said that coefficients presented in table 5 suggest the fairness of all cultural types. Only the result of the current adhocracy type is at the border line, which is of no concern since that type was not identified as dominant for any of the tested subcategories. Anyhow, that coefficient is close enough to the value of 0,5 to be considered acceptable, too.

5. Conclusion

In organizations, people come together and try to connect the interdependent parts of the mechanism to achieve organizational goals and improve the efficiency for organizational development. Understanding the organizational culture is one of the key prerequisites to improve the effectiveness and manage the performance of the organization in direction of achieving its strategic goals.

Primarily, this study aimed to identify which are dominant current and preferred cultural types at the Faculty of Civil Engineering Osijek. By using the OCAI questionnaire for cultural assessment, the study identified that there is a consensus among all relevant stakeholders on hierarchy being the dominant current cultural type at the Faculty. This suggests that the Faculty functiones as a stabile, highly structured and centrally controlled organization. Such culture is to a large degree adequate for an organization being a part of the public system.

However, a niche for organizational development arises from the assumptions and beliefs valued by the main stakeholders – students, teachers and administrative personnel. The results of this study point that dominantly preferred organizational culture by all stakeholders is clan. This means they prefer the most collaborative and the least competitive of the four main corporate culture types. In the clan culture mentoring, employer commitment and employee engagement are thought to promote empowerment and loyalty that will drive performance and business success.

As supporting the development and implementation of the preferred culture brings about organizational effectiveness, it can be concluded that emphasizing the clan cultural type at the Faculty of the Civil Engineering Osijek would foster achieving stated strategic goals and improve the Faculty's effectivenes.

As such, the results of this study have original implications both for the scientific researchers and the Faculty's management. Contribution has been given concerning

understanding the culture of a specific higher education institution, thus providing a base for more complex organizational development models as well as for efficient leading of the institution.

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Strategic Analysis of Croatian Construction Industry

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Abstract

The construction industry has always been closely connected with social and economic activities in each country. The importance of Croatian construction sector for the entire economy is expressed in all significant sector indicators. The purpose of this paper is to give a brief view of Croatian construction, especially in recent years when global crises affected the entire national economy. The main goal of this paper is to analyze strategic perspectives of construction industry in Croatia. To achieve this goal, authors made strategic analysis of construction industry and paper presents results of this analysis – PEST analysis and Porter's five competitive forces model. At the end, authors give directions of future strategic development of construction industry in Croatia.

Keywords: strategic analysis, construction industry, PEST analysis, Porter's five forces model

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1. Introduction

The construction industry is in a period when only new ideas, as well as different proactive and concerted action can encourage a long-awaited recovery from the business crisis. The volume of construction works in Croatia has been continuously decreasing since the mid-2008. The whole period characterized by weakening in the real estate demands, a significant slowdown in investment activities and the absence of large state infrastructure projects, which resulted in large losses in enterprises and the whole industry. It is important because the construction industry has a significant effect on the behavior of the total GDP and investments, as well as the declining in the number of employees (Sectoral Analysis, 2014).

According to the impact of global and European construction market to the construction industry in Croatia, it is necessary to observe global trends in order to fully identify all opportunities and threats of the environment. To be able to see the strengths and weaknesses it is necessary to study the local industrial and administrative opportunities of construction because local social and cultural conditions have influence to all crucial factors of success and abilities. Using managerial knowledge and tools it is possible to create business strategies that will, by careful "maneuvering", achieve optimal direction of development.

The developmental strategy should include choosing the ways of business managing, the construction sectors on which to shift the focus and to invest in, and predetermining the desired speed and rate of the growth in order to achieve the set goals. Adopting a strategy for future development is particularly important at this very moment, when we can see recovery options out of the crisis and a strong need for choosing new directions for the industrial development. Also, by joining Croatia into EU, it has become necessary to carry out the restructuring of the existing relationship with the market, and (if necessary) to select the new business models.

Great student and co-author of this paper Marina Džunić presented the internal analysis of the construction industry, showing all its strengths and weaknesses. The analysis was based on the Strategic Development Framework 2006 - 2013 by the Central Office for Development Strategy and Coordination of EU Funds, and also on the Sectoral analysis for the years 2013 and 2014 of the Institute of Economics in Zagreb. In this study it has been used less known tools in the construction industry, such as PEST analysis and Porter's model of five competitive forces.

2. A status indicator of the Croatian construction industry

The share of construction industry GDP in total GDP of Croatia has been recorded a continuous fall since the crisis of 2008, as it’s shown in the following table:

Table 1. The share of construction in total GDP of Croatia

Year	in %
2008	7,3
2009	6,8
2010	5,7
2011	5,2
2012	4,6
2013	4,4
2014	4,1

Source : Statistical Yearbook 2014 and Sectoral Analysis

Furthermore, a large number of workers has been employed in the construction (in June 2014, according to the data Sector Analysis of Institute of Economics, there have been employed 89,716 people, what makes 6.6% of the total number of employees in Croatia). However, they were mostly people with lower level of education, such as low-skilled workers, as it's shown in the following table:

Table 2. The educational structure of employees in the construction industry on 31 March 2013

The education level	Number of employees	%
VSS	4.999	7,66
VŠS	3.601	5,53
SSS	28.046	43,07
NSS	3.128	4,80
VKV	1.509	2,32
KV	13.438	20,64
PKV	3.358	5,16
NKV	7.043	10,82
Total	65.113	100,00

Source: Statistical Yearbook Republic of Croatia for 2014

Due to these factors, the construction sector significantly has big impact in general economic situation in the country. As it is known the construction industry is generator out of the crisis, but in order to achieve the necessary investments. It's not only about investments in construction, but in any industry, because the building industry is involved in almost every investment of 30-50 %. However, it is important to set strategic objectives and design well-planned development strategy to ensure maximum realized investment gains and achieved so much expected development, not only in construction sector but in general economy. According to large number of activities that are associated with the construction, with many interdependent factors, the strategy forming requires a high degree of planning, researching and interdisciplinary working, but first of all defining the objectives to be achieved.

3. The current situation strategic analysis of Croatian construction industry

Successful corporations use strategies which can also be applied for the purpose of changing business strategies in the construction industry. All examples of corporation successful business indicate the need of using the rules, tools and mechanisms for analyzing problems arising within the stagnating companies or entire industries. Objective and adequate analysis and assessment of the current situation have to be the basis for initiating changes. Also carefully placed mission, vision, goals and following specially tailored business strategy. Furthermore, it will be displayed two analytical methods, less well known and used in construction, such as PEST analysis and Porter's model of five competitive forces with their results.

2.1. PEST analysis

PEST analysis represents a tool for business environment analyzing. PEST acronym means political, economic, social and technological environment, we are looking at in order to make assessments of the environment of enterprises. PEST method is also one of the fundamental analysis of the strategic planning process. It is used for analyzing the conditions in existing

markets or emerging markets. The external influences on the company's business, or in this case, the construction industry are analyzed by PEST method.

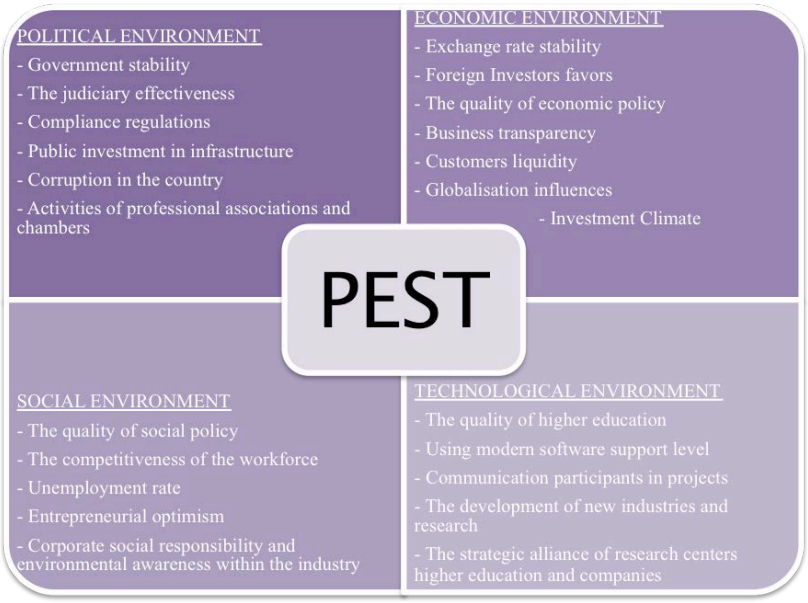

Figure 1. PEST analysis environment

For the purpose of this paper is made PEST analysis of Croatian construction industry, by evaluation of individual environmental factors.

The political environment usually significantly affects the business opportunities in a particular area. Also monitoring and understanding of political relations is of the great importance for predicting operating results and strategic development. The construction industry particularly depends on the political situation, mostly because of legislative process and its conditions as well as the state investments to launch large-scale projects and infrastructure investment. Another problem linked to the construction sector in the political environment is the lack of regulation of certain business segments, such as the non-existence of a unified mode of the cost. Also there are no technical regulations for the recycling of certain types of material. So it results unsuccessful management of construction waste. Otherwise, some important binding regulations (eg Special Practices on Construction adopted in 1977) represent a potential threat to the success of construction projects, because they are outdated and not harmonized with the modern principles of business and today's regulations.

The economic environment represents the conditions for business enterprises in all aspects of financial and economic environment. The best results will be achieved in terms of a stable economy, in a high entrepreneurial skills and a favorable investment climate. In such conditions it will be easier to start and maintain a business and also to attract customers. The big effects of the global crisis that began in 2008 are still very present in Croatian economic environment.

Social environment describes all social trends and population factors directly involved in the operations of a business entity or population that business affects to. Entrenched social norms and social structure of the population can be important information for the operations initiation and maintenance. The level of education of local people is one of the crucial factors

in the study of the social environment. Because of the potential work-power planning and marketing of products this indicator is important.

Technological environment includes all the technological equipment, modern systems and infrastructure necessary for an efficient operation. In the construction sector there is a very high dependence on technology business. It is necessary to keep track of technological advances for the company to be competitive and harmonized with modern business practices. Yet significant technological improvement related to software support is very present in the construction sector in recent years. To adjust the company to changes there should be resources and time to be invested in individual company. In that way the company has need for new tools and provided added value in production.

2.1.1. Implementation process analysis

Political, economic, social and technological environment of the construction industry was estimated by using a variety of factors that show the relevant impact on the construction industry. For each environmental group the best factors that characterize the individual construction industry environment are selected. Also is designed PEST analysis tables with registered marks (Table no. 3).
According to statistical data, studies and empirical evidence the authors have evaluated each of the individual categories. Every specific factor that affect on the construction industry was graded according to the strength of the impact assessments and to the importance of the impact of the construction industry. Power of the impact indicates the nature of the impact and its positive or negative impact on the construction industry. Impact strength rating is scored from 1 to 5. If a factor negatively affecting the building industry, the sign will be negative marks. On the other hand, if the impact is positive, the sign will be positive . The importance of the impact describes the extent to which a particular factor affecting the construction industry. It is estimated grades 1 through 10.

Table 3. PEST analysis

ENVIRONMENTAL PART	IMPACT POWER (+ positive impact, - negative impact)	IMPACT IMORTANCE (assessment 1 - 10)	OVERALL
Political environment			
Government stability	-3	4	-12
The judiciary effectiveness	-4	7	-28
Compliance regulations	-4	9	-36
Public investment in infrastructure	-3	8	-24
Corruption in the country	-2	5	-10
Activities of professional associations and chambers	3	6	18
subtotal (max: 300, min: -300)			*-92*
Economic environment			
Exchange rate stability	-2	9	-18
Foreign Investors favors	-5	9	-45
The quality of economic policy	-5	8	-40
Business transparency	-4	9	-36
Customers liquidity	-5	10	-50
Globalisation influences	2	6	12
Investment Climate	-4	8	-32

subtotal (max: 350, min: -350)			-209
Social environment			
The quality of social policy	-3	3	-9
The competitiveness of the workforce	-1	7	-7
Unemployment rate	-5	7	-35
Entrepreneurial optimism	-4	8	-32
Environmental awareness on environmental and energy-efficient projects	-2	8	-16
Corporate social responsibility and environmental awareness within the industry	-4	8	-32
subtotal (max: 300, min: -300)			-131
Technological environment			
The share of " high-tech " companies	-4	7	-28
The quality of higher education	2	9	18
Using modern software support level	-2	9	-18
Communication participants in projects	-4	10	-40
The development of new industries and research	-4	9	-36
The strategic alliance of research centers , higher education and companies	-4	6	-24
subtotal (max: 300, min: -300)			-128
OVERALL (max: 1250, min: -1250)			-560

Source: author's research

From the perspective of political, economic, social and technological impact to construction industry results show the current unfavorable impact of the environment. There is still big influence of the economic crisis and industry inertia for new ways of doing business. Overall construction industry in Croatia is -560 points on the scale of minimum -1250 (denoting extremely negative screenplay) and of maximum 1250 (denoting extremely positive screenplay).

The greatest negative impact still has customer's liquidity, eg. the problem of untimely payment of overdue financial obligations. The largest positive impact on the construction industry has the quality of higher education and industry trade associations and chambers. These effects are still underutilized. If the industry could develop and monitor the needs of the market it is necessary to develop adequate conditions in raising the competitiveness of the workforce. First, through better basic education but also through lifelong learning what is the only way for ensure successful implementation of the latest technologies in everyday practice. Also it is important to raise the entrepreneurial optimism level, using modern software tools and strategic linking of research centers, enterprises and other development institutions.

2.2. Porter's model of five competitive forces

Porter's analysis of industry shows its long-term profitability. It answers to the questions about the prosperity and benefits of participating in activities as well as the fact that company

should be taken to ensure its position. It analyzes five major impact (competitive forces) that act on the industry (Tipurić, 1996):

1. entry barriers - information about existence and influence of the companies able for entering the market if the industry profitability is high enough (risk of potential competitors - newcomers)
2. the threat of substitutes - customers moving to substitute products
3. buyers bargaining power
4. suppliers bargaining power
5. rivalry - the number and strength of the existing competition

Porter's model of five competitive forces is shown in illustration no 2.

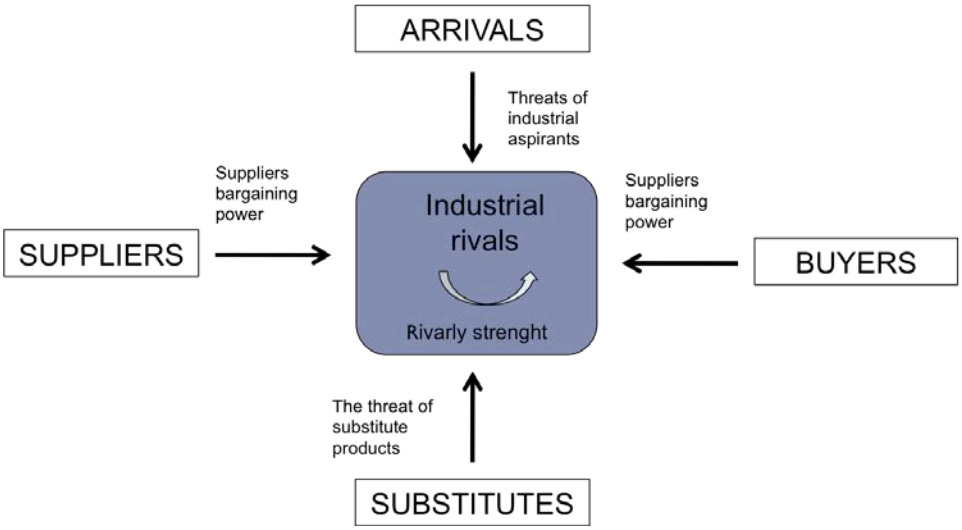

Figure 2. Porter's model of five competitive forces

The result of this analysis represents a total assessment of of these five forces strength. It determines the basic profit potential in industry and defines differences in long-term industrial profits. The industry competitiveness determines the strongest competitive force. If industry has a stable competitive structure, convenient location to suppliers, customers and substitute industries as well as a small risk of other companies entering the market, in that case the industry profitability will be higher (Tipurić, 1996) .

2.2.1. Implementation process analysis

In each group of competitive forces there are several key factors, designed tables and power factor. From the organization perspective it’s evaluated the factors impact on the business. Sign + or - is indicates the factor presence, while 0 means factor absence. If the factor is present, the sign + marks competitive industry advantages and opportunities. The sign – marks a factor that poses a threat and industry vulnerability. It also counts total factors impact in a competitive force and the interrelationship between them. It is important to note the possibility that the factors reversed or that their relationship intensifies the pressure forces on operations.

The total all five competitive forces impact is interpreted together. It means the pressure force is characterized as low if all the answers to the questions are positive for the organization's activities (+) and high if they are negative (-). Finally, according to analysis basis may suggest resolving to avoid vulnerability and exploiting competitive advantages (Pfeifer, 2002) .

The following table Porter's five competitive forces is specific for the construction industry.
Table 4. Evaluation of rivalry (competition within the industry)

	low +	0	high -
The construction industry has a great international companies competition			-
Within the industry developed a healthy competitive relationship			-
The competition provides continuous competition in the field of research and development			-
There is a possibility of achieving partnerships, consortia or clusters	+		
Competitors offer a better quality product (the expertise)			-
The increase awareness of energy efficiency caused demand for ' high - tech ' solutions, in which the current Croatian construction industry is lagging behind			-
The product is complex and not standardized and is demanding for realization			-

The conclusion from the table indicates that the competition effects in the construction industry are very high almost in all ways of negative character. It results a high level of pressure on the construction industry from foreign competition. There is a big competition with unhealthy competitive relationships that are not conducive to positive market play, product development or improvement. Otherwise, the construction product has very specific characteristics as well as uniqueness of each project with difficult approach to realization.

One particularly negative impact on the construction industry in Croatia is lagging behind in research and development of new products and materials, particularly in the area of energy efficiency. The market increasingly demands a sustainable approach to projects, and the construction industry is characterized by inertia of new knowledge turns to 'high tech' solution, which usually require an interdisciplinary approach. It is important to note that Croatian construction industry is very closed and not open minded for new knowledge or international experience exchange. The positive impact of rivalry shows examples of association and the creation of a consortium to participate in tenders for major domestic and foreign projects.

Table 5. Entry barriers (foreign companies)

	low +	0	high -
Foreign companies have greater ‘’know-how’’ and the resources for research and development			-
European directives on market opening allow the entry of foreign firms into the Croatian market, but also enables the export of Croatian construction products and services		0	
Nostrification employee’s diplomas in foreign countries	+		
For industry it is important to provide licenses and patents	+		

Ignorance of the complex Croatian construction regulations	+		
Is it difficult for newcomer to find skilled workers		0	
Do the domestic clients prefer foreign brands			-

Overall of entering barriers on the market shows a moderate positive opportunities assessment for the construction industry. The need for validation and authorization documents and ensure licenses are aggravating circumstances for foreign companies. But with the Croatian accession to the European Union, legislative barriers to the entry of foreign firms into the Croatian market are significantly reduced. Moreover, foreign companies have much greater capital supply, references and much greater "know-how" level in accessing tenders and projects implementation. Therefore investors commonly believe that foreign brands are better and more capable.

On the other hand, Croatian companies have much greater knowledge about complex building regulations in the Republic of Croatia. In that sense domestic companies have bigger advantage to foreign companies during domestic market competitions.

Table 6. Substitutes

	low +	0	high -
Switching to other products is not possible due to the specific construction products	+		

Peculiarity of the construction industry is in irreplaceable product with product of any another industry. For that reason the competitive forces pressure rating is low.

Table 7. Bargaining power of suppliers

	low +	0	high -
Timeliness of delivery is important for the success of the project and thereby increases dependence on supplier			-
Business transparency			-
Suppliers offer available goods, materials and services		0	
The quality of the delivered raw material has a high impact on the quality of the end product			-
It is possible to easily find new and cheaper suppliers		0	
Orders industry significantly affect the income of suppliers which reduced their negotiating strength	+		
The costs of acquisition are not a significant part of the total cost			-

Suppliers are very important for the success of projects in the construction industry. Therefore, their impact on the construction industry is very high. Seven factors of five have a negative impact on the construction industry, because the purchase cost (both material and all other resources) a significant portion of the total construction costs. The realization quality of a particular project really depends on the quality of raw materials delivered and the timeliness of delivery. All of that has important influence the success of the project.

Furthermore, concerns suppliers, contractors and investors in practice usually are not sufficiently transparent defined contracts, what is the source of many disputes. The only

positive factor for the construction industry is a significant amount of orders, what makes space to secure a better position in negotiations with suppliers.

Tablica 8. Customers/investitors bargaining power

	low +	0	high -
Is there a large number of customers / investors with regard to the offer			-
The product is an important customer to meet their basic needs	+		
Customers are aware of the work and understand the business process			-
Customers are highly sensitive to price			-
The customer and contractor relationship is simply and clearly defined			-

Current bargaining buyer or investor power represents a very high pressure on the construction industry. Because of the lingering crisis and supply and demand disorder, the buyer bargaining power has strengthened and become high. In a stable market conditions it is reducing. The only positive factor that keeps the construction industry at bargaining position is the fact that the construction product is extremely important to customers for their basic needs, and creating the business conditions.

Table 9. The overall impact of industry profitability to Porter's five forces

	Low pressure	Moderate pressure	High pressure
Rivalry			x
Barriers to entry		x	
Substitutes	x		
Suppliers bargaining power			x
Bargaining power of buyers / investors			x

According to the analysis results, the construction industry is facing with high pressures, because the total Croatian economy is still in crisis. Construction investment projects still represent a major risk due to many internal and external factors that affect the business conditions for domestic and foreign companies. The current situation can be improved by increasing the competitiveness in the international market, emphasizing the recognizable image of Croatian construction industry as a solid and experienced commercial activity, and also investing in researching and developing. In that way industry would enter in step with global energy needs and market trends, networking and experience exchange.

3. Conclusion

In last recent years Croatian construction industry state is on very low level of business activity. National construction sector barely survives. The saturation of the housing market and the inability to initiate new investment requires finding a new and different ways of doing business and new business strategies. It is therefore necessary to be focused for new products, high quality, knowledge and standards. In this way it is possible to improve the image of excellence and break into new, larger markets.

During the separate analysis implementation, there was a need for balancing the legislative framework and for improving the economic environment for business development. Due to

market demand, there is a great possibility of development through projects related to energy and sustainable development as well as growing through investment in new technology .

An important developing segment is so called 'soft ' skills. In this sense it is possible to build an international contact network, knowledge and innovation needed for the information dissemination. Also, launch of the international ‘hubs’, clusters and projects cooperation, what is good platform for achieving the co-financing from international funds. It is possible to build a rich construction industry by stimulating entrepreneurial ideas as well as making knowledge society. In that kind of atmosphere we should be focused on natural values, energy management, and of course, on most ethical and efficient economy.

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Identification of the Factors Influencing Results of the Company

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Abstract

At the moment of its foundation, each company had already defined objectives of the enterprise, which should be reached during the operation on the market. Identification of the factors influencing results of the company is very important mainly for the company management. Main objectives of the company are usually profitability, competitive ability and long-term operation on the market to ensure constant attainment of own goals. Main objective of this paper is to determine and consequently validate the degree of influence of financial analysis partial indexes on the change of the main indicator during valuated period, which expresses the goal of the company – return on equity (ROE). To reach the objective of this research, logarithmic method and the method based on pyramid decomposition were used.

During the use of the method of pyramid decomposition of return on equity index, mutual relations between particular indexes during valuated period were monitored. From using logarithmic method, the degree of influence of partial indicators on the change of main indicators during valuated period, from which it is possible to derive conclusions for next managerial decisions, were observed.

Keywords:f inancial analysis; Du Pont pyramid of return on equity; logarithmic method

1 Introduction

In terms of long-term management of the company it is necessary to consider several aspects. Definitely profitability ranges among the most important factors of success of company management. Furthermore other factors which indicate effective management can be considered. These factors include good company liquidity, low debt and market value of the company.

It is possible to say that profitability of the enterprise is the key to all other aspects of successful management. Good liquidity, optimal debt and market value can be achieved by using profitability. In order to ensure profitability, it is necessary to strictly observe the proceedsing from the sales operating activities (spheres of business) and costs that are necessary for the actual operation of the production process.

In terms of the profitability indicators, it is possible to take into account several types of

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profits that are expressed by net income or profit, to which the tax burden or profit is added, including the tax burden plus interest accrued from foreign sources.

This article discusses the influence of variables that effect top indicator of profitability. Its aim is to highlight the impact of various financial ratios on the top indicator, which is expressed by return on equity, e.g. profitability.

2 Present state references

In adopting fundamental and long-term decisions of financial and non-financial character, businessmen should always carry out some sort of investigation into its existing operations and how their activity is reflected in the financial performance and health of the company – financial analysis. Financial analysis is a set of activities which aim is to identify and comprehensively assess financial situation of enterprises (Schoellová, 2008).

Financial analysis interprets company's past and present financial health and predicts its future condition (Moynihan, Jain, McLeod & Fonseca, 2006).

Financial analysis involves comparing the firm's performance to that of other firms in the same industry field and evaluating trends in the firm's financial position over time. One rich source of information for financial statement analysis is the audited financial statements. Financial statements are usually part of the annual report that listed companies submit to regulatory agencies such as Securities and Exchange Commission and Stock Exchange entities (Tugas & Ramon, 2012).

Financial ratio analysis is a process of determining and interpreting relationships between the items of financial statements, to provide a meaningful understanding of the performance and financial position of an enterprise. Ratio analysis is an accounting tool for presenting accounting variables in a simple, concise, intelligible and understandable form. Ratio analysis is a study of relationships among various financial factors of a business (Babalola & Abiola, 2013).

The basic criterion for the assessment of profit rate is the Return on Equity ROE, also known as the Return on Invested Capital. Generally, the ROE indicator can be characterized as a ratio of profit and equity sources, on invested capital. Profit, in the profitability indicators, can differ depending on whether it uses Earnings before Interest and Taxes EBIT, Earnings before Interest EBT, Earnings after Taxes EAT or Earnings after Taxes increased by Interest Expenses. The most widely used form of earnings in the ROE indicator, has become Earnings after Taxes, which best describes the transaction outcome and it is not affected by the sources from which the activities of the firm are financed.

The ROE indicator reflects the overall profitability of company´s own sources and their evaluation in terms of profit. The level of ROE indicator depends on the Total Return on Equity and the Interest Rate on Debt. The indisputable advantage of this indicator is the possible identification of substantial relations between analytic indicators and the ability to express these relations using simple mathematical operations. Then, the whole system of the Return on Equity decomposition can be created, as the top indicator, to the partial analytic indicators. This type of decomposition is known as pyramidal decomposition of ROE – e.g. Du Pont Pyramidal Decomposition (Vejsadová Dryjová, 2013).

3 Methodology and methods

Financial analysis provides an important source of information about the company´s management. With the help of financial analysis, financial health of the company can be evaluated - also, financial analysis provides an image of the company development during the

evaluated period. Essential sources for the creation of financial analysis are financial statements - balance sheet and profit and loss statement (Ondrušková, 2014).

Methods of financial analysis are sorted out into three main types, which are: elementary methods (horizontal and vertical analysis), methods of ratios and methods of using the indicators system.

Profitability is the net result of a number of policies and decisions. The ratios examined thus far provide useful clues to the effectiveness of firm's operations, but profitability ratios go on to show the combined effects of liquidity, asset management and debt on operating results (Brigham & Ehrhardt, 2011). This paper deals with pyramidal decomposition of the profitability ratio ROE which belongs to the group of methods using indicators' system. Return on equity is one of the key indicators for measuring performance of the company. ROE is obtained by dividing net profit and equity. This indicator is also used in pyramidal decomposition (DuPont analysis). Relationship of individual analytical indicators which influence ROE, and at the same time are used in the pyramid decomposition of the ROE, can be expressed by the following equation:

$$ROE = Tax\ burder \cdot ROA \cdot Compound\ leverage\ equity \tag{1}$$

Tax burden defines how large share of the profits before tax, will remain to the company after paying taxes, and can be expressed as a quotient of EAT and EBT (Kislingerová & Hnilica, 2008).

ROA, also called productive force, is a key measure of profitability. A value of ratio is given by the ratio of profit to total assets invested in the business. Return on assets is used for pyramidal analysis of ROE (Kislingerová, 2004).

Ratio of compound leverage factor consists of the interest burden indicators and indicators of leverage. Interest burden is defined as the ratio of EBT and EBIT. The leverage is indicated as the possibility of increasing the profitability of its own resources with the help of foreign capital and its ratio can be determined by dividing the total asset by value of equity (Nývltová & Marinič, 2010).

The method of pyramid decomposition is based on the chain decomposition of a synthetic indicator, which is implemented in the form of the equation - on the left there is a synthetic indicator and the right side of this indicator is divided into a number of fractions, e.g. analytical indicators. When the chain decomposition on the left side of the equation is equal to the results on the right, then everyone should have this economic indicator informative value.

General formulation of the pyramid decomposition:

$$\frac{A}{B} = \frac{A}{C} \cdot \frac{C}{D} \cdot \frac{D}{E} \cdot \ldots \cdot \frac{K}{B} \tag{2}$$

Relationship of indicators in the pyramid decomposition of ROE:

$$ROE = \frac{EAT}{EBT} \cdot \frac{EBIT}{S} \cdot \frac{S}{A} \cdot \frac{EBT}{EBIT} \cdot \frac{A}{E} \tag{3}$$

Where:	*EAT*	Earnings after taxes
	EBT	Earnings before taxes
	EBIT	Earnings before interest and taxes
	S	Sales
	A	Total assets
	E	Equity

Unlike the chain decomposition, pyramidal decomposition has vertical structure. Pyramid decomposition has its name derived from the shape of arrangement of individual indicators into a pyramid form. The top of an imaginary pyramid consists of a synthetic indicator - this is usually an indicator of return on equity or return on investment. This synthetic indicator branches into a number of analytical indicators at several levels. With the help of decomposition of synthetic indicators into analytical indicators, relations between used sub-indicators are described, making it possible to describe the relation between them.

This analysis has a practical use for the evaluation development of the company over time, for comparing to intercompany management companies or for analysing your own business, when we determine the degree of the impact of individual indicators on profitability. Logarithmic method for multiplicative links and also distribution number of the cumulative links between analytical indicators (Synek, Kopkáně & Kubálková, 2009) primarily serves for assessing the impact of the various components of the synthetic indicator.

Factors that affect the value of ROE can be detected using pyramid decomposition of this indicator, where ROE indicator acts as a synthetic indicator, which is decomposed into analytical indicators. Pyramidal decomposition is also known as the DuPont analysis. During decomposition of the indicator on the first level, we get an indicator of the tax burden, an indicator of ROA profitability and compound leverage factor (Kislingerová & Hnilica, 2008).

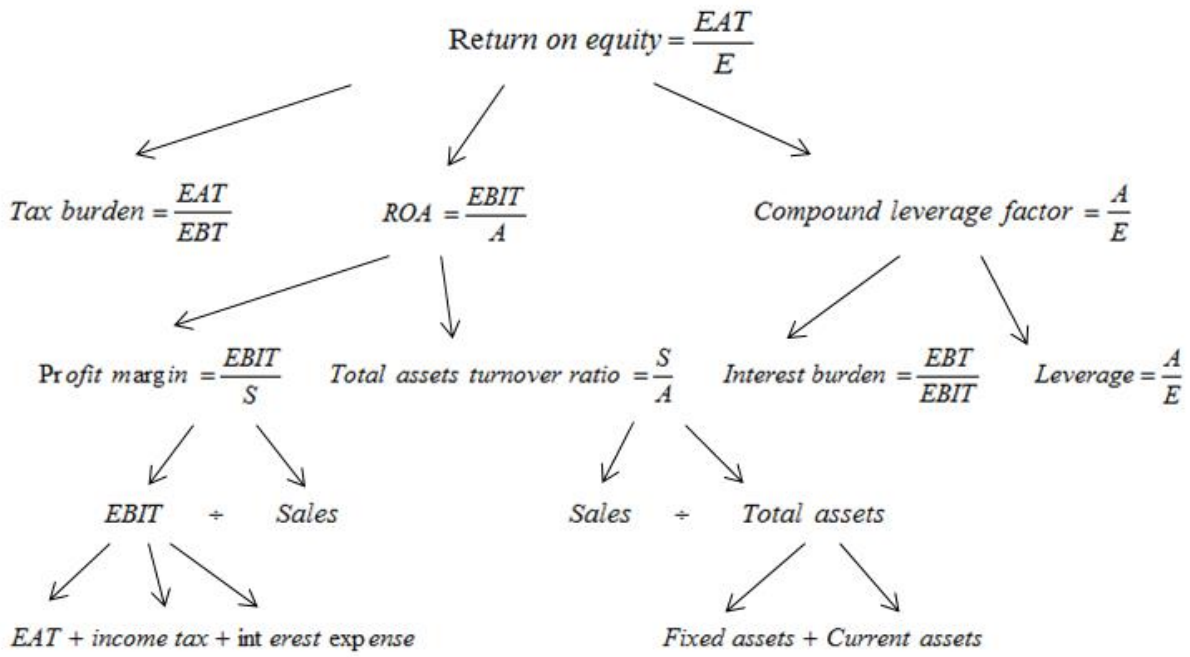

Fig. 1 Pyramid decomposition of ROE

Mathematical methods used for determining the significance of factors are based on comparing the values of indicators which describe an investigation of the state. The values can be compared from several points of view, based on temporal, spatial or material differences. Difference or proportion (index) can be most commonly used to describe them. Value of synthetic indicator arises from the basic effect of partial analytical indicators, and with the help of mathematical methods, it can be determined by quantifying the effect of these partial indicators. Among these methods is included logarithmic method which has the widest application in practice. Logarithmic method is based on the total detected change and the subsequent identification of the influence of analytical indicators. This method gives clear results, but it cannot be used if the synthetic indicator of change is zero. Logarithmic method is used for pyramidal analysis (Synek, Kopkáně & Kubálková, 2009).

$$\Delta X = \frac{\ln I_a}{\ln I_x} \cdot \Delta X + \frac{\ln I_b}{\ln I_x} \cdot \Delta X \tag{4}$$

Where: X synthetic indicator

I_a index of changes of analytical indicator obtained ratio of indicator value a_1 to indicator value a_0 within changes of period

I_b index of changes of analytical indicator obtained ratio of indicator value b_1 to indicator value b_0 within changes of period

I_x index of changes of analytical indicator obtained ratio of indicator value X_1 to indicator value X_0 within changes of period

4 Case study

Construction company STRABAG which ranks among the largest construction companies operating on the market, was selected for the case study. Method of pyramid decomposition of ROE was used for the financial analysis. Logarithmic method was used for identification of the extent of the effects of changes in analytical indicators on the synthetic indicator. Selected data from the financial statements for the years 2012 and 2013, which is shown in Table 1, was used in the research..

Tab. 1 Selected data from financial statements

Values in CZK	**2013**	**2012**
EAT	391,846	210,579
EBT	486,448	253,437
Interest expense	15,210	25,333
Total assets	9,684,919	10,262,289
Equity	3,252,470	3,611,307
Sales	12,536,939	12,769,293

Data from Tab.1 was further modified to ratios based on the formula provided by Fig. 1, with which it works in the following Table 2.

Tab. 2 Financial ratios

ROE	**2013**	**2012**
	12.05%	**5.83%**
Tax burden	80.55%	83.09%
EAT/EBT	80.55%	83.09%
Compound leverage factor	288.74%	258.35%
EBT/EBIT	96.97%	90.91%
A/E	297.77%	284.17%
ROA	5.18%	2.72%
EBIT/S	4.00%	2.18%
S/A	129.45%	124.43%

Results reported in Tab. 2 were extended by the logarithmic method, thanks to which, it is possible to answer the question regarding the extent to which specific analytical indicators, in other words the factors, influencing the change of synthetic ROE. Results of logarithmic methods in connection with particular values of analytic parameters are contained in Table 3.

Tab. 3 Logarithmic method use

ROE	**difference**	**index**	**ROE**	**Compound leverage factor**	**ROA**
	6.22%	**206.61%**	**6.22%**		
Tax burden	-2.54%	96.95%	-0.27%		
EAT/EBT	-2.54%	96.95%			
Compound leverage factor	30.40%	111.77%	0.95%	**30.40%**	
EBT/EBIT	6.06%	106.66%		17.62%	
A/E	13.60%	104.79%		12.77%	
ROA	2.46%	190.68%	5.53%		**2.46%**
EBIT/S	1.82%	183.29%			2.31%
S/A	5.02%	104.03%			0.15%

5 Results

By decomposition indicators of ROE and with the help of logarithmic methods, it can be identified which analytical indicator has the highest influence on the change of the synthetic indicator. For better illustration, obtained values have been processed into a pyramid decomposition where rests are on the top of a synthetic indicator and analytical indicators are below. From the values given to each parameter of Figure 2, it shows to what extent a change of analytical indicators influenced synthetic indicator.

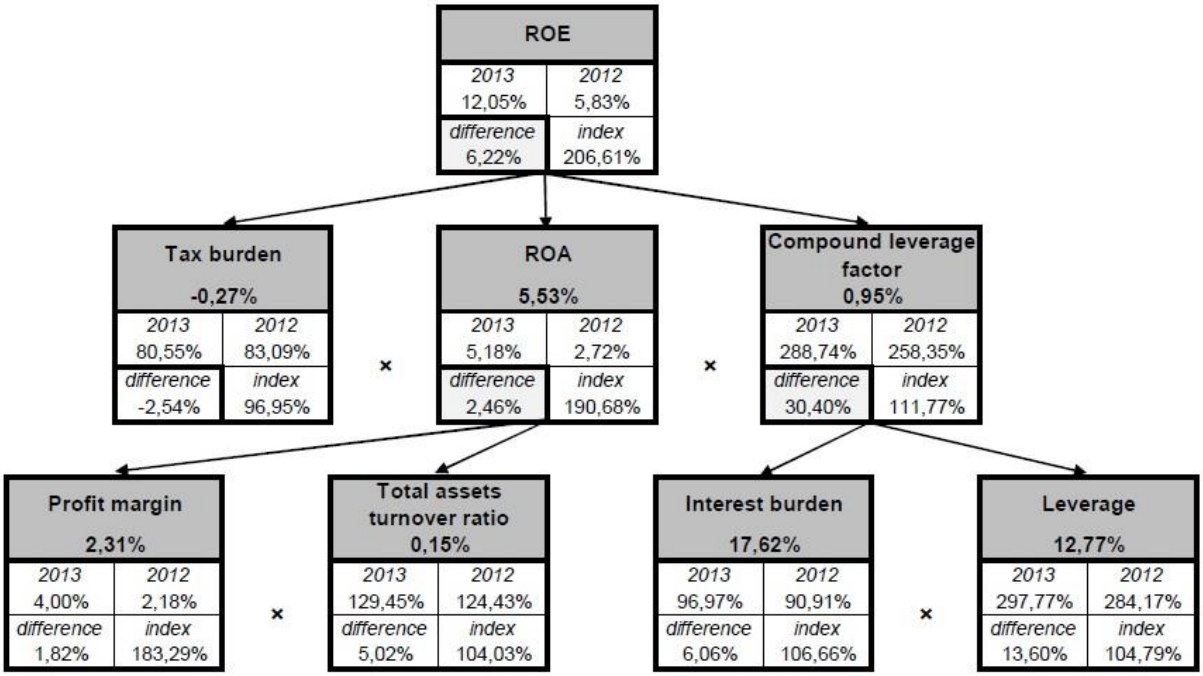

Fig. 2 Pyramidal decomposition of ROE using logarithmic method

For the change of ROE, the most significant effect had ROA, which is mainly influenced by the change indicators of profit margins. From the above pyramid decomposition of ROE, it can be deduced to which extent specific analytical indicators were influenced by the change in equity profitability.

6 Conclusion

Identification of factors affecting business performance is extremely important especially for the management of the company. By using methods of pyramid decomposition of the indicator of return on equity, interdependencies among the different indicators during the reporting period can be observed. With the use of logarithmic methods, it is possible to see various indicators from a new perspective - it is possible to monitor the degree of influence of sub-indicators on the main indicators of change during the reported period, from which one can draw conclusions for other management decisions.

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Purchasing Management in a Construction Company: An Introductory Insight

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Abstract

This paper provides an introductory insight into the purchasing management of a construction company, aiming to identify important aspects related to the creation of a corporate purchasing model. Analysis and discussion are conducted within the context of the performed literature review, which also includes selected studies focused on corporate purchasing in the Czech construction industry. The output of this paper is an introductory draft of a corporate purchasing model and 5 key questions for future research, which should contribute to the creation of internal guidelines supporting effective management of corporate purchasing.

Keywords: buying situation; construction company; material; model; purchasing management

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1. Introduction

This paper examines the topic of purchasing management in the construction industry. Its objective is to identify and discuss important aspects of purchasing management in construction companies and incorporate them into a corporate purchasing model designed so as to serve as a starting point for the creation of internal corporate purchasing guidelines. The paper does not aim to present comprehensive research results: it is only meant to serve as an introduction into this topic and as a basis for future detailed research.

The paper is based on the analysis and synthesis of knowledge gained during the literature review including mentored final theses and seminar papers describing purchasing practice in the construction industry.

The paper itself is structured as follows: after a brief presentation of the research background, various aspects of purchasing management are identified and discussed, followed by an outline of the main features of the proposed corporate purchasing model for construction companies.

2. Research Background

Purchasing management is gaining in importance, especially in market segments with sufficient competition among suppliers that results in price pressure on the part of the customers. In the case of manufacturing enterprises, the purchase of goods and services accounts for around 40–60% of their costs (Lukoszová, 2004). It can therefore be expected that savings resulting from lower purchase prices of commodities have a positive effect on the profits of these companies or on their chances of winning a contract, as they can offer lower bid prices in tenders.

The purchasing behaviour of companies is influenced by a number of factors, such as the character of the buying situation (straight rebuy, new task, and modified rebuy; Abu-ElSamen, 2010), the size of the institution or the nature of the purchased goods or services. Under certain circumstances, it is also possible to consider the use of electronic reverse auctions, if these goods or services can be clearly specified (Kaufmann and Carter, 2004); in this context, the use of electronic reverse auctions seems to be appropriate primarily in the case of standardised products.

The construction industry is a very specific market in that any construction project usually includes a number of internal as well as external stakeholders (Travaglini et al., 2014) with different interests, expectations, specialisations and expertise. Moreover, in contrast to other industries, construction activity results in a custom-built structure that is stationary (immovable), while production resources (material, human labour and machinery) are moved to the construction site. It can therefore be assumed that the purchasing behaviour of construction companies will also differ from that of other companies due to the particular circumstances affecting them.

For these reasons, it seems to be reasonable to approach purchasing management of a construction company with the objective of designing appropriate purchasing models that would contribute to effective purchasing of quality products from reliable suppliers at reasonable prices and under favourable supply conditions.

3. Discussion on some specific aspects of purchasing in a construction company

The primary item purchased by construction companies is construction material, accounting for about 60–70% of the total construction costs. Besides material, construction companies also purchase production machinery and equipment, vehicles, subcontractors' goods and services, non-productive material, computer and office equipment, work clothing and equipment and small tools.

The selected analysed studies focusing on purchasing management of Czech construction companies (Paulišová, 2015; Sláma, 2015) confirmed that companies use thresholds when

making decisions on purchases. These thresholds can be applied at two levels: 1) purchases up to a certain threshold can be approved by lower management, while purchases that exceed the threshold have to be approved by senior management; 2) purchases below certain thresholds are processed under less strict requirements than the ones that exceed these thresholds.

For smaller companies this means that in the case of minor purchases any of the qualified suppliers (i.e. suppliers whose quality, reliability of supply and reasonableness of prices have been verified) can be directly asked to deliver the requested items, while for purchases exceeding the threshold it is usually necessary to carry out at least a simple tender, inviting the prescribed minimum number of suppliers.

In some cases, it may be difficult to ensure that the prescribed number of pre-qualified suppliers participates in the tender, especially in situations where a company has to deliver outside its traditional geographical area and current suppliers cannot be involved due to high costs of transportation; in this case, a supplier of building material, for example, has to be found within the immediate area of the construction site. Buying decisions may then be different with regard to the availability of suitable suppliers (Bildsten, 2015).

Another specific situation occurs when a customer (who is usually known in advance due to the custom-made nature of construction contracts) requires the purchase of a particular material from a particular producer. This situation often arises in the case of installation of roofing or floor structures where the clients usually have a clear idea about the material they want to incorporate into the structure.

Purchase of machinery and equipment is more complex, because machinery is consumed gradually during its lifetime, so it is necessary to consider not only the purchasing price of the machinery, but also its technical parameters, capacity, expected lifetime and the amount of expected operating and maintenance costs (life-cycle costs factor). An optimised selection of construction machinery may be based e.g. on the so-called machine's working hour cost, which includes not only the cost of ownership, but also the cost of transportation, assembly and disassembly, etc. (Dražić et al., 2012).

In the case of selection of subcontractors, the decision can be based on quality, time flexibility, reliability and interoperability as well as price. When considering hiring new subcontractors, it is reasonable to check their quality, especially on the basis of submitted references.

Acquisition of non-production material is a typical example of straight rebuy. These are for example repeat purchases of office paper, where purchasing price can be the only evaluation criterion, if the purchased product is specified in sufficient detail. The straight rebuy category can, however, also include energy supplies or services (telephone services, etc.).

On the contrary, in the case of purchase of computer or office equipment it is desirable to take into account technical parameters in addition to the price. A suitable price/performance ratio then ensures that customers get the best value for their money.

Purchases of protective equipment and small tools are not key items in terms of their cost. However, in the case of larger volumes (for larger companies), a systematised purchase may help achieve better purchase prices. Similarly, the principles of efficient purchasing management could be applied to high-frequency small purchases to contribute to better business results of the company.

However, a more widespread use of electronic reverse auctions, which bring numerous benefits such as decrease in bid price (Hur et al, 2007), savings in time (Smeltzer and Carr, 2003), enhanced transparency and elimination of spatial and geographical barriers (Walley and Fortin 2002), seems to be unlikely where construction companies are the buyers. One of the reasons is the fact that electronic reverse auctions harm long-term buyer-supplier relationships and, in addition, many companies do not want to participate in auctions even in the role of bidders (Hanák and Dosedělová, 2014).

It seems that auctions will remain, at least in the foreseeable future, primarily in the realm of contracting authorities (who benefit greatly from the increased transparency of the tender) and a few large construction companies with sufficient volumes of purchases performed via auctions to achieve price reductions that comfortably exceed the cost of auction system acquisition and other related costs.

4. Introductory draft of purchasing model for construction companies

Figure 1 represents the introductory draft of a purchasing model for construction companies, showing selected basic aspects of purchasing management associated with construction production.

An important step within purchasing management is to decide what products and services will be subject to fully regulated purchasing (FRP, purchase procedure strictly set by a directive) and to partially regulated purchasing (PRP). PRP could be used for small items acquired randomly in small quantities and at low prices (such as certain office supplies or minor purchases of material or tools at the construction sites). PRP is permissible only if the thresholds, responsible persons and eligible suppliers are clearly defined.

In the case of FRP, the individual processes and buying situations are defined and specified in detail. Unlike PRP, FRP also requires specifying the level of qualifications, the list of pre-qualified suppliers, the structure of the evaluation criteria and other tender requirements (minimum number of suppliers invited/actively participating in the tender, number of tender rounds, etc.). If circumstances allow, the company can also evaluate whether it would be appropriate to use electronic reverse auctions.

Given that middle-sized and large companies purchase a broad portfolio of products (construction material, machinery, transport equipment, HW & SW, non-productive material, energy, utilities, etc.), it will be necessary to sort the purchased items into individual categories and to set a reasonable purchasing process for each category (see an illustration in Figure 2).

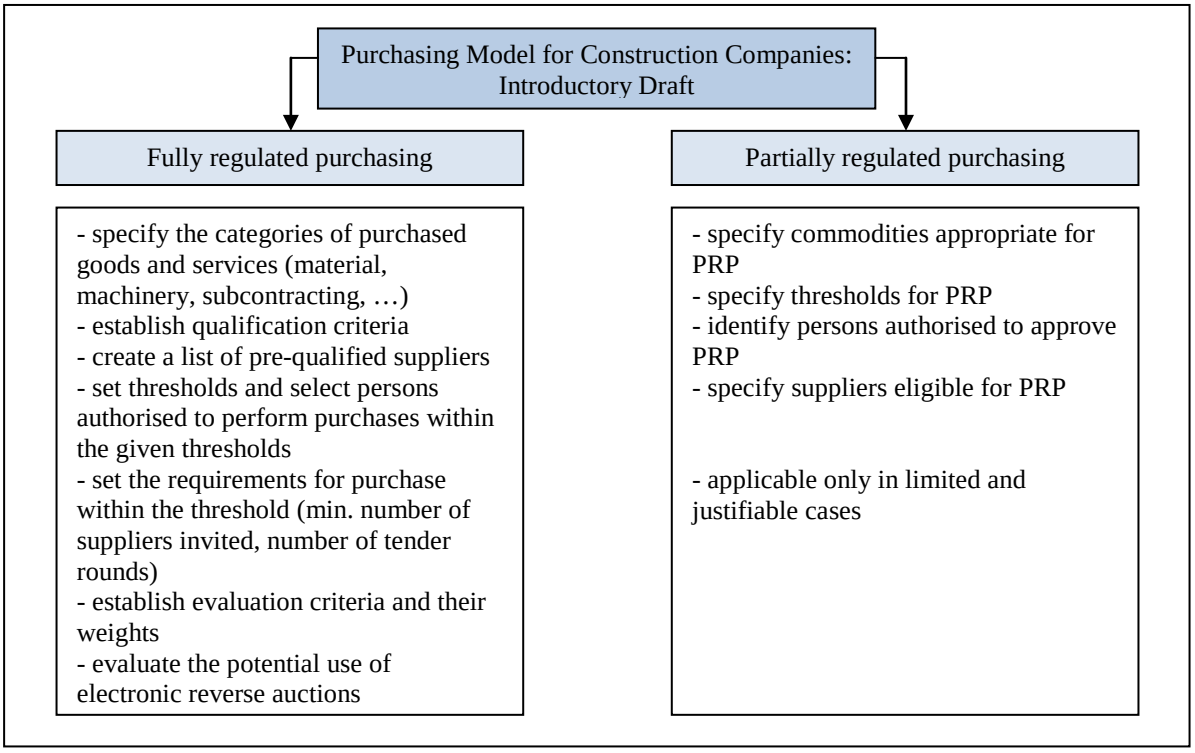

Fig. 1. Introductory draft of purchasing model for construction companies

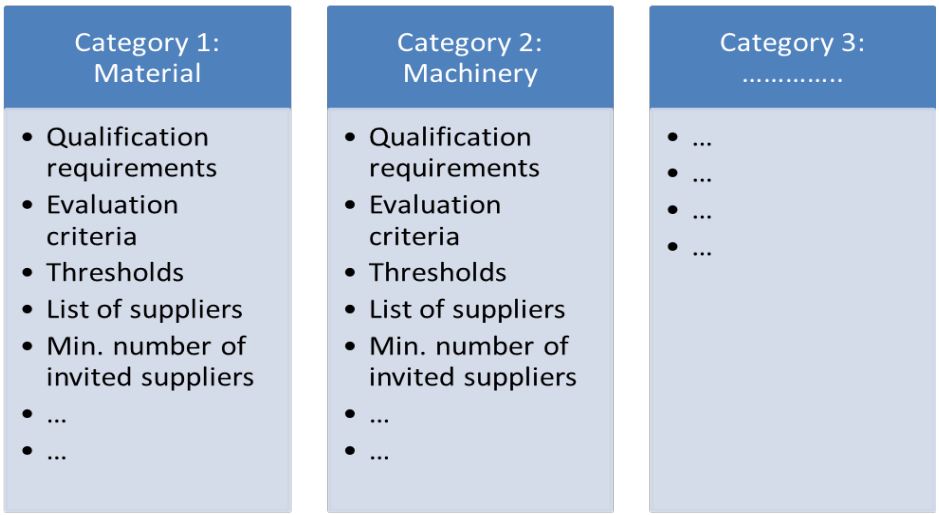

Fig. 2. Sample categorization of items purchased within the FRP

As the nature of the items purchased in each category is intrinsically different, the purchasing process within the individual categories may also differ. For example, material may be evaluated according to its price and quality, while in the case of machines operating expenses and other parameters such as production capacity and complexity of assembly and disassembly could be taken into account as well, considering their long lifetimes. In the case of IS/IT purchases, future expandability of the product, update options or connectivity with existing equipment may also play a role when selecting the supplier. These differences will apply, in addition to the evaluation criteria, also to other aspects of purchasing.

5. Future research on purchasing management in a construction company

The next stage of research will focus on the appropriate categorisation of products purchased by construction companies with regard to company size and nature of its core business, i.e. its specialisation within the construction industry (traffic structures, buildings, etc.). It can be presumed that there will be differences between small and large companies, as small companies constitute a distinct organisational form and have a specific approach to individual purchasing tasks (Ellegaard, 2006). Among large companies, on the other hand, the question arises how to manage corporate purchasing synergy in a decentralised company (Rozemeijer, 2000).

Moreover, individual parameters (qualification requirements, evaluation criteria, .etc.) will be set for each category, with the main focus on FRP. The creation of a purchasing model is also a prerequisite for the potential introduction of purchasing performance measurement system, which contributes to creating transparency in desired purchasing competence (Pohl and Förstl, 2011).

Attention will also be paid to the importance of managing buyer-supplier relationships to achieve mutual benefits (Chen et al., 2004), as trust, reliability, flexibility and cooperation are of significant importance in the construction industry (e.g. between the main contractor and the subcontractor).

Summary of 5 fundamental questions arising in the context of purchasing management of construction companies:

- How to set thresholds with regard to the size of the company, its turnover and quantity of orders?
- What evaluation criteria to choose and how to assign weights?

- How to evaluate criteria that are difficult to quantify (such as quality or interoperability)?
- What qualification criteria to require in the context of availability of suitable suppliers and with the premise of ensuring a competitive environment in the tender?
- How to evaluate the potential use of electronic reverse auctions?

6. Conclusion

Efficient purchasing management is one of the factors that significantly contribute to good business results of a company. In the case of micro-businesses, there are no significant reasons that would justify the effort needed to introduce internal guidelines. In the case of middle-sized and large companies, however, internal guidelines are recommendable, as regulated purchases under clearly specified conditions contribute to lower supply prices and promote competition between suppliers. Due to the wide portfolio of products purchased, the purchasing management of a construction company is a complicated area that deserves detailed analysis.

The objective of this paper was to clarify selected aspects of corporate purchasing in the construction industry and outline the basic features of the proposed purchasing model. The related analysis identified key questions that will be subject to examination at a later stage of the research. Answers to these questions will contribute to the development and more detailed description of the model with the aim of providing companies with guidelines for effective purchasing management.

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Reflections on Piketty: The Influence of Global Economic Trends on Construction

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Abstract

The main aim of this article is to assess the influence of global economic trends on construction. More specifically, this article applies the main findings of a seminal book by Thomas Piketty (*Capital in the Twenty-First Century*) on the analyses of the future trends in construction business. According to Piketty, there are two main trends in global economy: growing social inequality, first, and, second, weakening of the state as a result of tax evasion of the wealthiest people. Consequently, it is possible to predict that, in the future, the states will not be able to finance megaprojects in construction. Second, production of luxury will be the main source of a lucrative business. For - if the richest one percentage of population takes almost entire benefits of the world's economic growth – than fulfillment of needs and desires of the wealthiest will be the main source of income in the future and construction business should adapt itself to this new economic environment.

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1. Introduction

There are very few books (if any) in the history of economics that attracted so much attraction in such a short period of time as Thomas Piketty's book *Capital in the Twenty-First Century*. To illustrate, this book even provoked discussion in the Croatian Parliament between the Prime Minister and members of oppositional parties. Furthermore, not just scientific community but also newspapers quote Piketty and it started to be almost a fashion to have opinion about the Piketty's book. Accordingly, this paper will first present the main findings of this book. The third section questions some of Piketty's findings and, than, this article will outline – if Piketty's main conclusions are correct – the possible impact of global economic trends on construction business.

2. Capital in the Twenty-First Century: the main hypotheses

Social inequality is the main issue in Piketty's book. The author finds that social inequalities started to decrease after the First World War and continued to decrease by the end of the 1970th. Since then, inequalities have been increasing and today they are approximately at the same level as before the Great Depression. Furthermore, if present trends continue, we may expect that – in the near future – level of inequalities become higher than before the First World War (WWI). It is important to notice that trends are the same in all the countries Piketty investigated (European countries, the USA, China and India are in the focus) although the magnitude of inequality is not the same. According to Piketty (2014: 228),

> the differences are obvious: the top thousandth in the United States increased their share from 2 to nearly 10 percent over the past several decades — an unprecedented rise. But there has been a remarkable increase of top incomes everywhere. In France and Japan, the top thousandth's share rose from barely 1.5 percent of national income in the early 1980s to nearly 2.5 percent in the early 2010s—close to double. In Sweden, the same share rose from less than 1 percent to more than 2 percent in the same period.

It is important to mention that Piketty was not the first who noticed the rise of inequality around the world. For example, Reinicke (1998: 4) argued, 17 years ago, that 358 wealthiest people in the world earn more than 3 billion of the poorest people (today just 85 wealthiest earn more than half of population of the world, see Novi list, 6/5/2015). According to Thurow (1996: 42), "no country not experiencing a revolution or a military defeat with a subsequent occupation has probably ever had as rapid or as widespread an increase in inequality as has occurred in the United States in the past two decades." However, that what differentiates Piketty is the fact that he made his conclusion on the basis of the most comprehensive, by now, statistical analysis of inequality around the world.
What caused such unpreceded rise of inequality? According to Piketty, many factors contributed but the most important one are the tax evasion and changes in taxation policy. "Large amounts of unreported financial assets are held in tax havens (nearly 10 percent of global GDP). Certain nongovernmental organizations have proposed even larger estimates (up to 2 or 3 times larger) (p. 328)." However, even more important are changes in taxation policies. To illustrate, "Roosevelt increased the top marginal rate of the federal income tax to more than 80 percent on extremely high incomes… By contrast, at the time of this writing, Washington is still wondering whether the Obama administration will be able in its second term to raise the top rate left by Bush (of around 35 percent) (p. 331)." So, tax rate for the richest people in the USA dropped from 80 percent to just 35 percent. The same trend occurred in other countries around the World.

> Between 1920 and 1980, the share of national income that the wealthy countries chose to devote to social spending increased considerably. In just half a century, the share of taxes in national income increased by a factor of at least 3 or 4 (and in the Nordic countries more than 5). Between 1980 and 2010, however, the tax share stabilized everywhere. This stabilization took place at different levels in each country … around 40 percent in Britain,

and between 45 and 55 percent on the European continent (45 percent in Germany, 50 percent in France, and nearly 55 percent in Sweden) (p. 333).

However, that what is the most striking is that today *the richest people pay lower taxes than the poorest ones*.

For example, a detailed study of French taxes in 2010, which looked at all forms of taxation, found that the overall rate of taxation (47 percent of national income on average) broke down as follows. The bottom 50 percent of the income distribution pay a rate of 40–45 percent; the next 40 percent pay 45–50 percent; but the top 5 percent and even more the top 1 percent pay lower rates, with the top 0.1 percent paying only 35 percent (p. 347).

There are some others factors that also contribute to growing inequalities. For example, rich people can better invest their money because they have enough money to hire the best economic advisers. Furthermore, they can make capital investments that produce higher rates of return than small investments. In short, poor people – even when they have some extra money – are in much worst position to make clever investment of their money than rich ones.

What are the consequences of growing social inequalities? Actually, it is very difficult to find any sphere of economy, politics or society that is not affected by growing inequality. One of the most important consequences is diminishing significance of work and increasing value of property. After the Second World War (WWII), work was much important for standard of living of certain individual than it is today. According to Piketty (p. 173), "during the decades that followed World War II, inherited wealth lost much of its importance, and for the first time in history, perhaps, work and study became the surest routes to the top." During this period of time, it was much important – to say it simply – whether somebody had a decent job than that what he/she inherited. Furthermore, marriage was not the main venue for changing of social status. Since 1980th things started to change and once again marriage and inheritance become – as they were prior to WWI – the main source of wealth.

Younger people, in particular those born in the 1970s and 1980s, have already experienced (to a certain extent) the important role that inheritance will once again play in their lives and the lives of their relatives and friends. For this group, for example, whether or not a child receives gifts from parents can have a major impact in deciding who will own property and who will not, at what age, and how extensive that property will be—in any case, to a much greater extent than in the previous generation. Inheritance is playing a larger part in their lives, careers, and individual and family choices than it did with the baby boomers (Piketty, 2014: 269).

During the period from 1918 to the end of 1980th, education was a tool for improving social status. Since states – especially in Europe and in former Soviet bloc – enabled university education for free, young people from poor families had opportunity to achieve high education, to find lucrative jobs and to improve their social position (in comparison with their families). Is today situation the same? It is important to say that situation is still much better than it used to be in 19th century, when university education was affordable almost exclusively for young people from wealthy parents. Today, much broader parts of society have opportunity to educate and to obtain even the highest degree. However, very fact that somebody finishes a university is not a guarantee that he/she will get a job and especially not a prestigious job. In many countries, especially at the South of Europe, educated young people are unemployed. It starts to be much important which university one finishes than whether

he/she finished university at all. If one wants to become a member of elite, it is almost a precondition for him/her to finish some elite universities (Harvard, Stanford, Princeton…).

Parents' income has become an almost perfect predictor of university access… This inequality of access also seems to exist at the top of the economic hierarchy, not only because of the high cost of attending the most prestigious private universities (high even in relation to the income of upper-middle-class parents) but also because admissions decisions clearly depend in significant ways on the parents' financial capacity to make donations to the universities. For example, one study has shown that gifts by graduates to their former universities are strangely concentrated in the period when the children are of college age. By comparing various sources of data, moreover, it is possible to estimate that the average income of the parents of Harvard students is currently about $450,000, which corresponds to the average income of the top 2 percent of the US income hierarchy. Such a finding does not seem entirely compatible with the idea of selection based solely on merit. The contrast between the official meritocratic discourse and the reality seems particularly extreme in this case. The total absence of transparency regarding selection procedures should also be noted (Piketty, 2014: 339-40).

So, children of rich parents do not have much better starting points just because of inherited wealth (inherited wealth represents roughly two-thirds of private capital in France in 2010) but also because they have much better opportunities to graduate at elite universities and, accordingly, to get elite jobs. In short, money tend to reproduce itself, rich people have much better chances to increase their wealth then poor people and, consequently, we may expect that, in the future, social differences will be even higher than they are today.

However, are this rising social inequalities good or bad for economy? For, completely equal distribution of income and wealth would not, for sure, motivate people for work and investment. So, would a low level of inequality undermine the incentive to work? There are two contradictory theoretical answers to this question.[2] One group of economists argues that inequality has a positive influence on economic growth. For example, Stiglitz (1969) and Bourguignon (1981) argue that the marginal propensity to save by the rich is higher than that of the poor. Furthermore, GDP per capita growth is positively related to savings. Therefore, a country with less equality should have higher rates of GDP per capita growth. According to these authors, redistribution has a negative influence on economic growth because equality reduces savings. Moreover, an income tax decreases the incentive to invest and accumulate wealth.

The other school of thought argues that equality fosters economic growth.[3] There are two primary reasons for this. First, equality enables an optimal use of human resources. The best example is education. If all the people, including the poorest, have access to education, human capital would be used optimally. In contrast, in a country with strong inequality, only the potential of the richest people will be fully developed because only they will have full access to education. Second, equality fosters enterprise. A prerequisite for enterprise is capital. More equal distribution of wealth enables more people to show their entrepreneurial abilities, which may have a positive influence on economic growth.

When theoretical arguments are in diametric opposition one has to rely on empirical data to determine which theory explains reality better. And, concerning influence of equality on economic growth, the empirical record is unequivocal. According to Aghion et al (1999,

[2] A very instructive overview about the relationship between inequality and economic growth can be found in Aghion, Caroli, and Garcia-Penalosa (1999).

[3] See for example Galor and Zeira (1993) and Benabou (1996).

1617), "several studies have examined the impact of inequality upon economic growth. The picture they draw is impressively unambiguous, since they all suggest that greater inequality reduces the rate of growth."[4] Piketty's investigation confirms Aghio et al (1999) findings. Rise of inequality has not spurred economic growth. Exactly opposite, it hindered it. From 1945-80 social inequalities were the lowest and economic growth was the fastest. In contrast, from 1980, social inequalities are on the rise but economic growth slowdowns.
Rise of inequalities and slow economic growth are coupled with an equally important process – weakening of the state. The state promoted economic development after WWII and the state was the owner of an important part of modes of production by the end of 1980th. However, since then, the states have privatized almost all assets.

In 1950, the government of France owned 25–30 percent of the nation's wealth, and perhaps even a little more… The Renault Company became a joint-stock corporation in 1990, as did the public telecommunications administration, which was transformed into France Telecom and opened to private investment in 1997–1998. In a context of slower growth, high unemployment, and large government deficits, the progressive sale of publicly held shares after 1990 brought additional funds into public coffers, although it did not prevent a steady increase in the public debt. Net public wealth fell to very low levels. Meanwhile, private wealth slowly returned to levels not seen since the shocks of the twentieth century (Piketty, 2014: 100-1).

As a result of these privatizations, almost entire wealth of nations is in the private hands. Value of state properties approximately matches the value of public depts. In other words, the states do not possess almost anything. Furthermore, tax evasion and lowering of taxes for the wealthiest gradually diminish the states abilities to finance public education and universal healthcare. Moreover – if this trend continues – even basic function of the state (policy, army, judicial system) might be jeopardized.

To conclude presentation of Piketty's book, the main processes that characterize modern economies are: rising of social inequalities, slowing of economic growth and weakening of the state.

3. A brief criticism of Pikett's book

It is out of the scope of this type of the article to make a comprehensive analysis and criticism of Piketty's book. However, this article will mention two main weaknesses of Piketty's book (according to the author of this article). First, Piketty has not identified the main cause of relative social equality during the 1917-89 period. Second, his proposal for solving the problem of rising social inequality is not feasible.
According to Piketty (2014) two world wars caused decrease of social inequality ("it was the wars of the twentieth century that… transformed the structure of inequality (p.330)"). However, Piketty does not provide any explanation about causality between world wars and decline of inequality. Throughout human history people have been involved in myriad of wars. However, these wars have not – as far as we know – decreased inequality. In contrast, wars enabled smaller groups of people to enrich themselves enormously. In contrast, wars made thousands of people homeless, crippled, injured and orphaned. Even in modern time, wars do not decrease inequalities. According to Stiglitz (2008), the Iraqi War (2003-) has

[4] The main empirical studies about the influence of equality on economic growth are conducted by Alesina and Rodrick (1994), Perotti (1992, 1993, 1996) and by Person and Tabellini (1994).

been the second most expensive war in American history. Yet, social inequality in the USA dramatically increased during this war.

So, what is more plausible explanation for diminishing of inequality during the 1917-1980 period? The answer seems so obvious that it is amazing that Pikkety has not noticed it. It is evident that October Revolution, rise of communist movement and Marxism caused decline of inequality around the world. Similarly, the collapse of communism in Eastern Europe and the Soviet Union caused opposite process – rise of inequality.

Why the October Revolution had such a positive influence on reduction of equality? First, Marxist ideas – which, in essence, demand reduction or even elimination of inequality - started to be very popular around the world after WWI. As a result, workers movements started to be influential and powerful. Second, triumph of the October Revolution and revolution attempts in Germany and Hungary – after WWI – caused fear among members of rich elites. Therefore, these elites were willing to accept progressive tax system in which they paid up to 80 percent of their income. In return, social-democratic parties did not nationalize their properties. This compromise was the essence of "welfare state" – a model that produced a fast economic growth and a low level of inequality in the West during the 1918-1980 period. When Marxist ideas become unpopular, both in the East Europe but also in the West, welfare started to be gradually dismantled. As a matter of fact – after the collapse of communism in the Soviet Union – rich elite have not had reason to fear revolution anymore and have not had any reason to endure a high level of taxation of their incomes. Furthermore, economists started to preach neoliberalism as the only type of economic system that enable economic growth and progress. In short, triumph of neoliberalism over Marxism and disappearance of communism from Eastern Europe caused extreme rise of inequality in almost all the countries in the world. Of course, the collapse of communism in Easter Europe and the Soviet Union also caused many positive processes – democratization, better human right protection and national liberalization. However, this collapse did not have – to say the least – a positive impact on reduction of social inequality.

Piketty's failed attempt to identify the main cause of increase of inequality causes also his unrealistic proposal for solving the problem of rising inequality. Piketty proposes progressive taxation of income on the world scale ("the ideal tool would be a progressive global tax on capital (p. 360)"). There are so many problems with this idea that it actually sad that Piketty finishes his excellent book with such an unrealistic proposal. Questions that immediately come to mind are the following: Which institution would institute this tax? Who would collect this tax? Who would distribute money collected with this tax? But even more important is the following: if national states – having all state instruments on their disposal – cannot increase percentage rich people pay for taxes, how one can expect that institutions without any real power – like the United Nations – can establish such a tax? Does Piketty really mean that it is possible to have necessary consensus of 200 states (which would be a precondition for this type of taxation)? Or to say another way: if rich people are powerful enough to impose higher percentages of tax on low and middle class than on the wealthiest class inside their own countries how one may expect that they would not prevent establishment of progressive global tax? Here we come to the essential problem of Piketty's book: he wanted to overcome Marxism by providing an alternative program that would reduce social inequality. However, even though Marx idea of world revolution turned to be unrealistic, it was far more realistic than Piketty's idea that it is possible – without world revolution - to establish a progressive global tax on capital.

4. Global economic trends

In spite its weaknesses in identifying causes of inequality and in proposing viable solution to it, Piketty's book is excellent in detecting trends in modern economies. So what are the main trends now and in foreseeable future? First, it should be mentioned that it is very difficult to predict future. Only few weeks before he seized power in Russia, Lenin predicted that his generation would not see revolution. Nobody predicted fall of Berlin Wall and very few economists predicted economic crisis in 2009. However, scientists should count on data and –

on the basis of them – identify existing trends. And the most important ones are rise of inequality in almost all states in the world and weakening of the state (with some exceptions, like China).

So, which level of inequalities we may predict in the future? According to Piketty (2014: 190), "the future could hold in store a new world of inequality more extreme than any that preceded it." Is it something that can prevent this trend? There are some possible tools that may prevent this trend. The most important one is democracy as such. Very fact that only minority bears fruits of technological development show that – in democracies – disadvantaged *majority* may vote for the parties that want to protects interests of poor. During the 19th century conservatives were against universal suffrage claiming that representatives of poor people – who are majority – would nationalize property of the wealthiest. Social-democrats believed the same. The difference was that conservatives argued that such nationalization would be harmful for economy and social-democrats claimed that this would be beneficial for society as a whole. Indeed – after WWII – not only East European countries but also many West European countries nationalized the most important branches of economy. According to Piketty, (2015: 100), "in the industrial and financial sectors most directly affected by the postwar nationalizations, the state's share of national wealth exceeded 50 percent from 1950 to 1980."

So, if nationalization was possible in 1945, why it is not possible in 2015? The previous section answered this question. Simply saying, when communism and Marxism disappeared, capitalism became "the only game in town". It was not just capitalism that prevailed but also an idea that capitalism does not have alternative. Consequently, social inequalities are now accepted as an inevitable consequence of economic progress. Even the poorest people do not vote for that what is left of leftist parties. In a word, inequality is perceived as something natural and something that cannot be changed. To quote Piketty once again:

> Whether such extreme inequality is or is not sustainable depends not only on the effectiveness of the repressive apparatus but also, and perhaps primarily, on the effectiveness of the apparatus of justification. If inequalities are seen as justified, say because they seem to be a consequence of a choice by the rich to work harder or more efficiently than the poor, or because preventing the rich from earning more would inevitably harm the worst-off members of society, then it is perfectly possible for the concentration of income to set new historical records… The key issue is the justification of inequalities rather than their magnitude as such (p.189).

It is important to mention that throughout human history people accepted social inequality as given and justified. In ancient Egypt, 100.000 worked hard for 20 years in order to make a grave for one single person – pharaoh. It is enough to compare the luxury of the palaces in which nobility used to live with the living conditions of the poor people – a great majority of the population – to see that inequality was accepted as natural. In a way, we just return to "normal" situation that lasted for centuries. Period from 1917-1980 was an exception to the rule that people do accept a high level of inequality as being justified. By now, there is no sign that people are willing to stand up against rising inequality today or in the near future. Therefore, the only realistic prediction is that inequality will rise in the future. Accordingly, since increase of inequality causes decrease of economic growth (see section 1), we may predict that economic growth will slow down. In addition, tax evasion and lowering of taxes for the wealthiest will produce further weakening of the state that will be reduced to its basic functions (military, policing and judicial system). In a word, neoliberal capitalism and neoliberal ideas will completely triumph in the future.

5. The Influence of Global Economic Trends on Construction

Economic trends, identified by Piketty, will have ifluence on all branches of economy, including construction. The most important factor that will influence construction is weakening of the state. Throughout history the state has had very important role in construction, especially in financing large-scale infrastructure projects. The state financed irrigation of Nile. It financed construction of the China Wall and Roman roads. Many railways and roads, including highways were built by the state. The state had decisive role in all the branches of economy, including building infractructure and housing, in the Communist block. However, the Great Depression (1929-32) challenged the idea - even in the West - that the market alone, without state intervention, could solve economic problems. Large-scale infrastructure projects, financed by the state, were one of the most important elements of the New Deal. The American state financed construction of dams, bridges, hospitals, schools, airports. The state also financed the electrification of rural America, the building of canals, tunnels, highways, streets, sewage systems, and housing areas, as well as universities. State financed infrastructure programmes consumed roughly half of the concrete and a third of the steel of the entire nation (McJimsey, 2000: 221). The state interventionism also produced a rapid economic growth, prior to WWII, in Germany and the Soviet Union.

Are Western countries capable of making similar investments in infrastructure today? No, they are not. According to Piketty (2014: 331), "the crisis of 2008 was the first crisis of the globalized patrimonial capitalism of the twenty-first century. It is unlikely to be the last. Many observers deplore the absence of any real 'return of the state' to managing the economy." Why the state did not intervene the same way as it intervened in 1933? The reason is simple: the state in the West is not capable to intervene any more. France and Germany are role models for the new position of the state. According to Piketty (2014: 133), "in France and Germany, where net public wealth represented as much as a quarter or even a third of total national wealth in the period 1950–1970, whereas today it represents just a few percent (public assets are just enough to balance public debt)." Situation in Southern States of the European Union is much worse. Lowering of taxes for the wealthiest and tax evasion produced impotent states in the West, incapable of financing infrastructural projects. Construction companies in the West will have to adapt to this new business environment in which they can count just on private investments.

However, there are some exceptions to the rule that the state become increasingly weaker. The most important one is China. In this country, non-private sector accounts for more than 2/3 of China's industrial output (Antić, 2010: 70). The state finances the most important infrastructural projects. For example, the China's state was the main investor of The Three Gorges Dam project worth 22.5 billion dollars.[5] The state did not help just by financing the project. It also helped building houses for 1.3 million people who were displaced because of this project. Would it be possible to make such a project in the West (when one take into account not just problem with financing but also legal issues connected with property rights)? It is hard to imagine it. Therefore, it is no wonder that China – country with a strong role of state, especially in the field of financing infrastructural mega-projects – is economically the most successful country in the world during the last 40 years, having annual rates of growth around 10 percent.

In short, weakening of the state will have a strong impact of construction, especially in the field of financing infrastructural projects, with few exceptions, among which China is the

[5] "International Water Power and Dam Construction". *Waterpowermagazine.com*.1/10/2007 (Accessed 9/5/2015)

most important one. Therefore, we may expect a further movement of construction business from the West to China.

Rising social inequality will also have an impact on business in construction. Production of luxury will be the main source of lucrative businesses. For - if the richest one percentage of population takes almost entire benefits of the world's economic growth – than fulfillment of needs and desires of the wealthiest will be the main source of income in the future. Consequently, construction business should adapt itself to this new economic environment. Since fruits of technological advancement will go almost exclusively to the richest people, their purchasing power will be disproportionally higher in the future than it is today. On which product may the wealthiest spend their money? If they have five times more money in year 2030, it is obvious that they cannot eat ten times more food in this year. However, they may build new villas on elite resorts; they may build two times bigger yachts and buy new most expensive cars. Therefore, construction business should focus on building of luxury products, from luxury villas to luxury headquarters of the most prestigious firms. Briefly, one may expect that, in the future, we will have thousands of brand new Mercedes, BMWs, Rolls-Royces, Porsches and Lamborghinis that will drive on highways fool of holes.

Finally, changes will also occur inside construction companies as such. Social inequality will rise not just on the level of states but also inside the firms. According to Pikkety (2014: 2015,

the vast majority (60 to 70 percent, depending on what definitions one chooses) of the top 0.1 percent of the income hierarchy in 2000–2010 consists of top managers. By comparison, athletes, actors, and artists of all kinds make up less than 5 percent of this group. In this sense, the new US inequality has much more to do with the advent of "supermanagers" than with that of "superstars.

It is important to stress that rise of incomes of the top managers does not match their performances. To illustrate, managers that brought their banks to bankruptcy received extra bonuses in spite of the fact that their banks had to be saved by public money. How this is possible? Piketty, once again, gives a plausible explanation: "Because it is objectively difficult to measure individual contributions to a firm's output, top managers found it relatively easy to persuade boards and stockholders that they were worth the money, especially since the members of compensation committees were often chosen in a rather incestuous manner (p. 356)." The same processes will occur in construction companies where we may expect further rise of income for top manager and reduction of salary for average workers.

To conclude this section, global economic trends will have the following impacts on business in construction: first, the state will not be able to finance infrastructural mega-projects, production of luxury estates will be the main source of lucrative business and social inequalities will rise not just on the level of entire society but also inside the firms, including construction companies.

6. Conclusion

Piketty's book - *Capital in the Twenty-First Century* – investigates historical trend in the field of social inequality. The author finds that this trend has been U-shaped. Inequality was extremely high up to the end of the First World War. Since then, it started to decline. This trend lasted up to 1980th. However, during the last 30 years, social inequality has been on the rise once again. Piketty claims that two world wars caused the decline of social inequality. However, this article argues that success of the October Revolution and influence of Marxism caused decline of inequality rather than wars. Since governing elites

were afraid that revolution may also happen in the West, they accepted very progressive tax systems that declined inequality and caused very fast economic growth in the West. Similarly, the collapse of communism in Eastern Europe and Soviet Union – coupled with disappearance of Marxism - caused not just explosive rise of inequality but also slowing of economic growth. Piketty's proposal for solving this problem – global progressive tax on wealth – is simply not possible to administer. Therefore, social inequality will continue to rise. One of the consequences will be weakening of the state. Tax evasion and abandoning of progressive taxation have produced growing public dept. Simply saying, if the richest people pay lower taxes than poor, the state cannot collect enough money for functioning of welfare state. The above mentioned trends will influence construction industry. The weak state will not be able to finance big infrastructural programmes and that will cause decline of demand for construction business. Therefore, construction business will have to focus on production of luxury because only the wealthiest class will have more and more financial resources. China shows that weakening of the state in not inevitable. However, there is very little chance that China's economic system becomes a role model for the West. Therefore, China will continue to be an engine of the world's economy and the West will continue to stagnate. As a result, construction business will gradually move to China and those countries that will continue to have a strong role of the state in the economy.

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A Theoretical Assessment of Causes of Job Insecurity in the Construction Industry

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Abstract

The construction industry has been dealing with drastic changes over the past years, changes that result in a number of negative consequences one of them being job insecurity. These changes concern issues such as increased economic dependency between countries, rapidly changing consumer markets and escalated demands for flexibility within as well as between organisations. However, it is an organisations' responsibility to manage the changes accordingly to avoid issues such as job insecurity. Hence this paper theoretically discuses job insecurity in the construction industry. The study was conducted with reference to existing theoretical literature, published and unpublished research. The study is mainly a literature review/survey on job insecurity in the construction industry. Literature revealed that employment downsizing, financial crisis, lack of experience and training, technological changes, racism, gender and lack of education were the major causes of job insecurity in the construction industry. The current study is a theoretical assessment of job insecurity in the construction industry and the study contributes to the body of knowledge on the subject of job insecurity in the construction industry.

Keywords: insecurity; job insecurity, construction industry, South Africa

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1. Introduction

The construction industry has been dealing with drastic changes over the past years, changes that result in a number of negative consequences one of them being job insecurity. These changes concern issues such as increased economic dependency between countries, rapidly changing consumer markets and escalated demands for flexibility within as well as between organisations (Sverke, Hellgren and Naswall, 2006). However, it is an organisations' responsibility to manage the changes accordingly to avoid issues such as job insecurity. Job insecurity in the construction industry can be defined as being uncertain about your employment status due to a number of reasons in a construction company. Jobs in the construction industry and related sectors have fallen relative to other industries, resulting in high unemployment and idle capacity (Construction Industry Employment Trends, 2011). Job insecurity can be defined as the fear of losing your current potential job, due to a number of reasons within the company or organisation in which you are employed. Landsbergis, Grzywacz and LaMontagne (2012) further states that job insecurity can be defined as a psychosocial stressor at the job level, caused by employment conditions and work organisation, and reflecting a worker's perceptions of fear of loss or job instability. This study adopts the definition by De Witte, De Cuyper, Vander Elst, Vanbelle and Niesen, (2012) which states that job insecurity implies discrepancy between what workers wish for (security about the future of their present employment) and what they "get" (the perception that the present job is insecure). Therefore, this study is a theoretical evaluation of the causes of job insecurity in the construction industry.

2. Methodology

The research was conducted with reference to existing theoretical literature, published and unpublished literatures. The study is mainly a literature survey/review and looks at the literatures relating job insecurity in the construction industry. This is because the concept of job insecurity in the construction industry has attracted much attention in recent years and that public and private sectors, researchers and research bodies, be it corporate or government who wish to find measures of mitigating job insecurities should start with an understating of their causes. The current methodology falls within the qualitative research methodology.

3. Causes of Job insecurity in the construction Industry

3.1 Employment Downsizing

The most commonly used tactics in reorganisations is the practice of downsizing (Sverke, Hellgren and Näswall, 2006). Richtner and Ahlstrom (2006) further states that companies implementing a downsizing strategy aiming at increasing cost efficiency and operational effectiveness may face the fact that their innovative ability is hampered. Due to the tight schedule and budget in most local construction companies it is expected of one to worry about their employment status once the word "downsizing" starts flying around. Employment downsizing has become a fact of working life as companies struggle to cut costs and adapt to changing market demands (Leung, 2009). More downsizing is not always the solution to controlling job insecurity (Jeon and Shapiro, 2007). The construction industry also facilitate downsizing as a coping strategy, Construction Employment Industry Trends (2011) sate that the construction industry facilitates downsizing when demand falls, but also allows rapid expansion during recovery.

3.2 Financial Crisis

Martinez, De Cuyper and De Witte (2010) states that job insecurity can be the economic situation in the country, a downsizing, and outsourcing in the company or changes in the organisational structure. Financial crisis in a company or an organisation is the worst threat of having to cut down costs due to loss of financial assets, which includes cutting down

employees. When the country's economic situation at certain moment changes the industry can get in a more "unsteady" position and then it becomes more likely that the workers face the possibility of losing their jobs or valued features (Martinez et al. 2010). With help from other companies or organisations most financial crisis are dealt with. However, it becomes devastating when the crisis is globally. These global changes have called for alterations in organisations and organisational practices in order for companies to be able to survive in this new context with increased competitiveness (Ritcher, 2011). The global financial economic crisis triggered sharp output contractions in almost all the industrialized economies in 2008 for the first time in the post Second World War era. This has a negative effect on the increasing number of job insecurity worldwide. The increased job insecurity due to recession has resulted in sustained and devastating impacts on individuals, families, households and their communities.

3.3 Technological Changes

Accelerating use and demand of technology is making life more effective, time consuming, money saving and creating efficiency in construction companies. Within industries, occupations, and education groups, computerisation is associated with reduced labour input of routine manual and routine cognitive tasks and increased labour input of non- routine cognitive tasks (David, Levy and Murnane, 2003). Technology will never replace man, moreover its use makes the need for man less demanding which can lead to employee cut offs. Increases in the productivity resulting from the investment in new technology induced firms to respond to periods of weak demand by firing workers as soon as they did not need them (Nikolaou, Theodossio and Vasileiou, 2005). Technological advances make it easier to take on specific job tasks, which simply means less workers are needed for the relevant task or responsibility. Recent economic and technological changes have reduced labour market frictions and thus made it easier for firms and workers to search for, and contract with alternative trading partners (Matouscheck, Ramezzanal and Nicoud, 2003).

Technological advancement and environmental or political legal changes and policies enable the companies to move in the direction routed by changing environment of the new era (Thomson, 2009). Thomson (2009) further adds that with rapid advances in information technology and acute resources constraints across the globe, the business world has become more complex and fluid in recent times. It becomes challenging for people who are less technological advanced to take on some responsibilities. During the last decade a growing number of commentators in the public media have argued that recent economic and technological developments, such as increased international competition, labour market deregulation and the rise of internet, have increased job insecurity in developed countries and have thereby made some groups in society worse off (Matouschek, Ramezzana and Nicoud, 2003).

3.4 Racism

Much legislation has been passed, and many corporations now have explicit emphasis placed on the value of diversity (Batool and Batool, 2012). Despite decades of democracy in South Africa there still is unfairness with regard to skin colour on our construction site which particularly leaves one with unanswered questions about their position and growth at work. As diversity is a potential breeding ground for racism, organizations should strive to educate themselves on what racism entails and how to prevent it (Batool and Batool, 2012). The construction industry is perceived as a relatively low- status industry with hard working conditions, strictly defined working hours and a persisting "laddish" culture in a white, male-dominated environment (Caplan, Aujla, Prosse and Jackson, 2009).

3.5 Gender

With all the difficulties experienced by women in construction it makes it challenging to stay positive and motivated at work, considering all the limited opportunities of growth or even keeping their jobs for longer periods. Women are under- represented in all construction

occupations and professions (Sang and Powell, 2012). It is further alleged that women have access to fewer good- quality jobs within the formal economy than men and usually get more precarious work, such as domestic service and other care work. However, for the most part, men in developed economies have fared worse than women, as they are concentrated in those sectors most seriously affected by job insecurity particularly construction and the manufacture of durable goods. Men also experience job insecurity in relation to their gender, Sverke et al. (2006) adds that traditional values may prompt men to experience higher levels of job insecurity than women, since this role traditionally requires the man to be the breadwinner of the family. Men would then tend to be more vulnerable to the threat of job loss as it would not only threaten their source of income, but also their identity to a higher degree than it would for women (Sverke et al. 2006).

Perceived as male dominated industry

Women who work in male dominated occupations face challenges that differ from those who work in more gender- balanced and female- dominated occupations, these challenges affect their retention and career success (Martin and Barnard, 2013). There are individuals who still believe that some occupations are gender orientated. Martin and Barnard (2013) add that the challenges women face in attempting to penetrate successfully and persevere in historically male- dominated work environments emanate from traditional gender hierarchies and norms that prevail in the family and society. It is believed that organisations need to legitimise women's characteristics, natural behaviours and values, and give them a platform in order to level the playing field for both genders (Martin and Barnard, 2013). Every employee should be given a fair chance at work despite their gender. South African research on gender issues at work from a woman's perspective have studied specific pre- defined phenomena like: the life- role construction of career orientated women (Martin and Barnard, 2013). Another challenge to women who pursue success in male- dominated occupations relates to characteristics male- type behaviour expectations distinct to these occupations (Martin and Barnard, 2013).

3.6 Lack of Experience and Training

Less or minimum contribution to a workers' role in a construction project as a team member will constitute to low production, one needs to be aware of the new standards and effective ways of performing their tasks. Batool and Batool (2012) state that successful and effective job trainings largely impact the productivity of employees during their present jobs. Factors as the level of professional development, age, etc might influence the perception the workers have about the events of job insecurity (Martinez et al. 2010). It is a challenge to get a new job with no experience or some sort of training hence higher concern of job insecurity, Sverke et al. (2006) states that it is nevertheless reasonable that an individual who feels that she could easily obtain a new job does not react as negatively to job insecurity perceptions as someone who feels she is unable to acquire new employment. The major purpose of training is to upgrade the employee's abilities to cope with specific situations and performance of various specific situations and performance of various specific tasks with a certain level of simplicity (Olofsson and Rashid, 2009).

Organisations are facing problems of staff turnover, due to lack of motivation and low employee's satisfaction level, these two factors could be addressed through extending opportunities of learning, developing and importing on- hand training and workforce experience (Batool and Batool, 2012). Training keeps an employee in line with the new systems or new ways of performing their tasks, at the same time gaining experience. Employee training also gives one confidence in their work and keeps them motivated. The modes and methods of training have begun to differ from the past and new techniques are being approached in the present, training is becoming more hands- on in order to make it more practical for the employees (Batool and Batool, 2012).

3.7 Lack of education

The highly educated employees can understand the situation and assess it positively as they possess persistence, rationality and thinking power (Sageer, Rafat and Agarwal, 2012). Furthermore, an uneducated employee will start panicking due to less knowledge of what the organisation is experiencing. Hence, the basic assumption is that subjective expected job insecurity influence risk perception, people with a less secure employment situation will perceive risks as comparably higher than people with a more secure employment situation, regardless of gender and ethnicity (Olofsson and Rashid, 2009). Lower status jobs are often also associated with lower levels of education, resulting in fewer coping strategies (Sverke et al. 2006). Having the right skills is also important, Sverke et al. (2006), further adds that organisational strivings for functional and numerical flexibility have resulted in demands for new type of skills as well as in changes in employment contracts.

Learning ability and education shall be given importance upon selection of employees (Batool et al. 2012). Qualifications guarantees employees a better chance of being selected for a job position. New technology- learning methods are arising due to modern-day revolutionisation in the economic, labour and technological world of workforce (Batool et al. 2012). Batool et al. (2012) further adds that apart from the basic theories, skills such as critical thinking, information assessment, drawing up work- plans and coordination of resources have risen on the demand graph for future trainees. Education also increases and facilitates workers, and thus lead towards success and continues betterment in business (Batool et al. 2012).

4. Lesson learnt

The consequences related to job insecurity cover a broad spectrum including illness and poor well- being as well as negative job attitudes and undesirable behaviour. The growth and success of an organisation is reliant on the type of workers involved in the organisation and their ability to perform at their level best, with no uncertainties about their job. These consequences may directly affect the productivity and the development of the organisation, not only because workers might reduce their performance but also because valuable workers may take a drastic decision and look for other jobs with better prospects. The study further revealed that the construction industry has been dealing with a number of changes in the past years which concern issues such as increased economic dependency between countries, rapidly changing consumer markets and escalated demands for flexibility within as well as between organisations which lead to job insecurities in the industry. Furthermore, literature showed that employment downsizing, financial crisis, lack of experience and training, technological changes, racism, gender and lack of education were the major causes of job insecurity in the construction industry.

5. Conclusion

The current study examined literature relating to job insecurity in the construction industry. Literature showed that jobs in the construction industry and related sectors have fallen relative to other industries leading to job insecurities in the industry. Job insecurity brings about great concern in the construction industry which affects the workers negatively. The study further revealed that employment downsizing, financial crisis, lack of experience and training, technological changes, racism, gender and lack of education were the major causes of job insecurity in the construction industry.

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Critical Success Factors for the Survival of Small, Medium and Micro Enterprise Construction Companies in the South Africa Construction Industry

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Abstract

The objective of this study is to investigate the critical success factors necessary for the survival of SMME construction firms in the Gauteng Province of South Africa. A literature survey was carried out. The data for this paper was collected from both primary and secondary sources. The primary data was acquired through the administration of structured questionnaires. The questionnaire was distributed to construction SME firms in the Gauteng Province construction industry. The questionnaire was designed based on information emanating from an extant review of literature. Out of the 140 distributed questionnaires, 120 were received back which represented 86% response rate. Findings derived from the study indicated that producing quality work, good cash flow management, good contractual understanding, having a business plan, effective communication channel in the firm, maintaining good relationships with clients, proper record keeping, sensible operating costs, recruiting qualified staff and availability of effective marketing strategies were perceived as the main critical success factors required by SMMEs in the Gauteng Province for their survival in the construction industry. The findings emanating from this paper will form a basis for future research on construction SMMES in South Africa.

Keywords: construction SMMEs, development of SMMEs, South Africa SMMEs

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1. Introduction

Within the developed and developing countries of the world, it is now generally accepted by policy-makers at local, regional and national level, that Small Medium and Micro sized Enterprises (SMMEs) are becoming increasingly important in terms of employment, wealth creation and the development of innovation (Nieman, Hough and Nieuwenhuizen, 2003; Sha, 2006). There is evidence that the contribution made by SMMEs is more pronounced in developing countries like South Africa, than in developed countries (SBP 2013). In such developing countries, SMMEs eradicate poverty in a sense that their contribution is not only of income generation but also to income distribution. Large firms normally tend to produce an elite number of high wage income earners whereas SMEs produce a significantly large number of relatively low-income earners (Temtime and Pansiri, 2004). Furthermore it is frequently emphasized that SMMEs performance, are interrelated with the economic performance of a country. SMMEs especially those that operate in the construction sector are an important contributor to the economy and are considered a driver for reducing unemployment in South Africa as defined by the National Credit regulation Act; given that the formal sector continues to shed jobs when business transaction are not favourable (Aigbavboa & Thwala 2014).

Presently as large construction enterprises continue to restructure and downsize due to constant changes in the economic demands in South Africa, Small, Medium and Micro Enterprises (SMMEs) in the construction industry have come to play an increasingly imperative role in both in the industry and South Africa's economy and development. SMMEs in the construction industry as a whole have a significant relationship to the economy, in that a change in economic output of an economy can result in a proportionate change in demand and, as a result, a change in the output of the construction industry (Raymond and Ganesan, 1997; Scott 2011).However there has been great concern regarding the survival of SMMEs in the construction industry, as many of the SMMEs operating in the construction environment barely survive over a five year period. While not all construction SMMEs will thrive and be successful, a few good contractors will emerge to become more sustainable and globally competitive (Rwelamila & Dlungwana 2004). Hence this study sought out to investigate the critical success factors for the survival of construction SMMEs in the Gauteng Province of South Africa. The paper commences with an overview on literature in relation to critical success factors for the survival of SMMEs, followed by explanations of the research methodology adopted for the purpose of this study; presentation of the findings and discussions and lastly conclusions are drawn and recommendations are made.

2. Critical success factors for the survival of construction SMMEs

From a South African perspective, it is difficult to ignore the importance of the construction Small, Medium and Micro Enterprises in the construction industry as well as the overall development of the country considering the immense impact SMMEs have on the economy. Small, Medium & Micro Enterprises play a crucial role in almost all economies but particularly in developing countries with major employment and income distribution challenges, such as South Africa (Cant 2013). SMMEs are known to occupy a significant and strategic role in uplifting the economy. As Aremu & Adeyemi (2011) states, the performance and growth of small and medium enterprises (SMEs) is a major driver and indices for the level of industrialization, modernization, urbanization, gainful and meaningful employment for all those who are able and willing to work, income per capital, equitable distribution of income, and the welfare and quality of life enjoyed by the citizenry. Bankseta (2013) explains that other researchers have estimated that the total economic output of SMMEs in South Africa to be 50% of GDP and also estimated that they provide employment to about 60% of the labour force. While in USA, one of the world‘s most economically influential countries, SMEs create 50% of private employment (Davies 2011; Moloi 2013), and in countries like China, Austria, and Canada, SMEs’ employment creation is above 50%. In New Zealand, SMEs represent 86 percent of its 259,000 businesses and these firms account for approximately 27

percent of the total employment, in Morocco, 93% of firms are SMEs and account for 38% of production, 33% investment, 30% export and 46% employment, in Bangladesh, enterprises of less than 100 employees account for 99% of all firms and 58% employment and also, in Ecuador, 99% of all private companies have less than 50 employees and account for 55% of employment (Robert and Leo Paul 2003; Ufot, Reuben & Michael 2014). The SMMEs in the construction industry also contribute significantly in terms of scale and share in the development of any country. The construction industry SMMES also contributes to the national socio-economic development by providing significant employment opportunities at non-skilled and skilled levels beyond that, it provides the infrastructure and services that required for other sectors of the country to grow such as; schools for education and training, factories and shops for commercial etc. (Bondinuba 2012).Governments are thus great benefactors of a strong construction industry, due to the fact that governments provides a bulk of the infrastructure within a country requires the services of the construction industry for it to be implemented. While many construction projects in the industry may come in a bigger scale and awarded to large enterprises; small and medium-sized construction enterprises undertake the large number of projects dispersed throughout a country and they form the bulk, by number, of companies in each industry, and offer operational flexibility to the larger firms in their role as sub-contractors (Ofori and Toor 2012). However the although in dominance in the construction industry, many of the SMMEs involved in the construction industry struggle to survive for a period of over five years. Mbonyane (2006) found that in South Africa on average 50 % of small businesses that are started eventually fail, and there are those businesses that are not growing beyond the survivalist; this failure rate can be partially attributed to the lack of support for small, medium and micro-enterprises. Additionally Burke (2006) states that the survival phase is a minefield for new ventures, of which many companies do not make it past that phase. In relation to this, a vast amount of literature has been published on what is perceived as critical success factors that SMME contractors need to be aware of in order to see their enterprises survive, prosper and grow into larger enterprises in the industry.

To fulfil their pole position in the economy, SMMEs need to be familiar with critical factors that are the cornerstone of success in business; these are factors that could determine whether a construction SMME develops into greater growth or fails to stay in existence. In looking to the research literature, there is no unanimity between researchers on the factors that contribute to the success of SMMEs. However, some factors are discussed more often in the previous research; Kusar et al (2004) states that SMMEs can successfully enter and remain in the global market if they can fulfil customer needs for features and quality of products. Whilst Wijewardena and Zoysa (2005; al-Mahrouq 2010) identified six main factors that had positive and significant impact on the success of their sample firms, these factors were as follows; customer orientation, product quality, efficient management, supportive environment, capital accessibility and marketing strategy. With Olwale and Garwe (2010) stating that managerial competencies are very important to the survival and growth of new SMEs. Jaafar and Abdul-Aziz (2005, Phaladi and Thwala 2008) surveyed 172 SME's contractors in Malaysia and concluded from what they call Resource-Based-View that contractor success lies in project and financial management capability, marketing and supply chain relationship; moreover, they state that educational background and owner-manager characteristics are not necessarily success factors because competent skill can be employed to run the firm. Bakar, Razak, Yusof, & Karim (2012) found that in Malaysia, the ten most important factors contributing to growth of construction companies are: good company management; good cash flow management; sufficient knowledge and experience; good team members; technical expertise; good site management; commitment to customer satisfaction; availability of capital; availability of skilled workers; and good relations with clients.

3. Research methodology

A quantitative research design was used for the purpose of this study. The preferred research instrument used in this research for collecting data was a questionnaire that was delivered to small, medium and micro sized contracting firms around the Gauteng Province of

South Africa targeted participants of this study were construction SMME owner-managers, usually positioned as project managers, construction managers, and quantity surveyors in the construction SMME sector of Gauteng, all registered with the professional associations in South Africa. The main reason being that these professionals are involved in these SMMEs operations on a daily basis and based on their experiences they are in better positions to analyze the factors they see as relevant to succeed and survive in the industry. The number of targeted firms was 120 firms. Out of the 120 questionnaires distributed to construction SMME within the grade 1-5, the researcher retrieved a total of 82 back, which represents a 67% response rate.

3.1 MIS (Mean Item Score)

The questionnaire comprised of questions that had to be ranked from a 5-point Likert scale like that of the critical success factors , which ranged as follows; 1 = strongly disagree, 2 = disagree, 3 = Neither agree or disagree, 4 = Agree, 5= Strongly Agree. The five-point scale was transformed to mean item score (MIS) for each of the critical success factors for survival of SMMEs as assessed by the respondents. The indices were then used to determine the rank of each item. The ranking made it possible to cross compare the relative importance of the items as perceived by the respondents. This method was used to analyze the data collected from the questionnaires survey. The mean item score (MIS) was calculated for each item as follows;

$$\text{MIS} = \frac{1n1 + 2n2 + 3n3 + 4n4 + 5n5}{\sum N} \quad \text{.....Equation 1.0}$$

Where; n1 = Number of respondents for strongly disagree; n2 = Number of respondents for disagree; n3 = Number of respondents for neutral; n4 = Number of respondents for agree; n5 = Number of respondents for strongly agree; N = Total number of respondents. After mathematical calculations, the criteria are then ranked in descending order of their mean item score. The data collected from the respondents were coded, edited and recorded into the Microsoft Excel software program. It was then imported into Statistical Package for Social Sciences (SPSS) a software program to convert it into a suitable format for analysis. The data was then interpreted in form of tables and graphs.

4. Findings and discussion

The study included 67% male respondents and 33% female respondents , with a majority of the respondents (26.8%) being within the age group of 41 – 50 years old, closely followed by respondents in age groups of 36- 40years and that of over 50 years with 25.6% and 20.7 % respectively. The ethnicity in the study contains a majority of black Africans (54.3%) followed by (23.5%) whites. The majority of respondents' highest educational qualification were baccalaureate degree (39 %) followed by post matric diploma (32.9%), and the minority were (1.2%) doctorates degree. With accordance to the CIDB grading standards, respondents were asked to highlight their grade, 43.9% majority were grade 4 contractors followed by 29.3 % which were grade 3 contractors.

Table 1.0 reveals the respondents' ranking on factors they considered to be relevant in sustaining their construction SMMEs and keeping them in operation.

Based on the ranking (R) using the calculated standard deviation (SD) and mean scores ($\bar{x}$) for the listed critical success factors for construction SMMEs in the Gauteng province of South Africa, results showed that the most influential factors include the following: Producing quality work (SD=0.37; $\bar{x}$=4.91; R=1); Good cash flow management(SD=0.44; $\bar{x}$=4.86; R=2); Good contractual understanding(SD=0.46; $\bar{x}$=4.80; R=3); Having a business plan (SD=0.60; $\bar{x}$=4.80; R=3); Effective communication channel in the firm (SD=0.62; $\bar{x}$=4.66; R=4); Maintaining good relationships with clients (SD=0.66; $\bar{x}$=4.65; R=5); Proper record keeping (SD=0.58; $\bar{x}$=4.61; R=6); Sensible operating costs(SD=0.59; $\bar{x}$=4.60; R=7); Recruiting qualified staff(SD=0.80; $\bar{x}$=4.53; R=8); Effective marketing strategies (SD=0.79; $\bar{x}$=4.50;

R=9).These findings were in agreement with Donkor (2011) who stated that No matter how small the business is, or how large it has grown, the success will depend a lot of the contractor's skills in bringing the right people on board, and how both relate to each other. Furthermore the findings are also in line with Nieman (2006; Petrus 2009) who pointed out that accurate record keeping is vital as a task under the organizing function and concurrently in this regard Wright (1995; April 2005) shares the notion that when keeping a proper record system is effective, it enables the business managers to keep a diary for business appointments, issue detailed invoices to customers and file copies of such in alphabetical order, in addition he points out that record keeping is not only important for financial, sales or administrative records, but also enables the business managers to assess the progress of the company periodically.

Table 1. Critical success factors

Critical success factors	σX	$\bar{x}$	R
Producing quality work	0,37	4,91	1
Good cash flow management	0,44	4,86	2
Good contractual understanding	0,46	4,80	3
Having a business plan	0,60	4,80	3
Effective communication channel in the firm	0,62	4,66	4
Maintaining good relationships with clients	0,66	4,65	5
Proper record keeping	0,58	4,61	6
Sensible operating costs	0,59	4,60	7
Recruiting qualified staff	0,80	4,53	8
Effective marketing strategies	0,79	4,50	9
Supportive government policies	0,74	4,44	10
Having effective Human resource management	0,76	4,41	11
Networking	0,71	4,33	12
Having personnel with risk management expertise in firm	0,80	4,30	13
Key clients that respond to services offered	0,92	4,29	14
Adapting to change in technology	0,81	4,00	15
Use of ICT	0,82	3,83	16
Having a niche market	1,31	3,53	17
Using social media as a Marketing Tool	1,09	3,46	18

(σX = Standard deviation; $\bar{x}$ = Mean; R = Rank)

Although not completely similar to these findings, In Malaysia Bakar, Razak, Yusof, & Karim (2012:8762) found that the ten most important factors contributing to growth of construction companies are: good company management; good cash flow management; sufficient knowledge and experience; good team members; technical expertise; good site management; commitment to customer satisfaction; availability of capital; availability of skilled workers; and good relations with clients. However the findings herein are in disagreement with Elfring & Hulsink (2007) who emphasized on the importance of social networks on SMEs, especially on start-ups.

5. Conclusions

The paper set out to explore the critical success factors necessary for the survival of construction SMMEs in the Gauteng province of South Africa. A broad review of international and South African literature was carried out to identify the factors that were

recognized as critical to success prior to this study. Literature on the critical success factors necessary for the survival of construction SMMEs revealed the following to be the main factors: efficient management; supportive environment; capital accessibility and marketing strategy; managerial competencies; good record keeping; performance management; customer orientation; the product quality factor; knowledge and experience; market specialization and also diversified expertise. Findings from the questionnaire survey revealed that the perceived critical success factors for the survival of construction SMMEs in the Gauteng Province of South Africa are as follows: producing quality work; good cash flow management; good contractual understanding; having a business plan ; effective communication channel in the firm; maintaining good relationships with clients ; proper record keeping ; sensible operating costs; recruiting qualified staff and availability of effective marketing strategies .Thus it can be recommended that construction SMMEs should adopt this adopt these factors to remain effective within the industry. Producing quality work is considered the most important factor and closely followed by good cash flow management. Hence it can be concluded that reputation and good financial management is key to the survival of construction SMMEs in the Gauteng Province.

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The Impact of the Use of EU Funds in the Construction Sector Croatia 2014 - 2020

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Abstract

The subject of this paper is to analyze the possibilities for financing construction projects from EU funds and the possible impact on the Croatian construction sector in the period from 2014th to 2020th year.The choice of topics is in actuality, which has not yet been fully investigated and that in the period 2014th-2020th financial allocation is ten times greater than the total funds allocated so far and that the economic development of the Croatia and Croatian construction industry depends on the utilization of the allocations.The purpose of the study is to evaluate the impact of investments from EU funds in the construction sector. The study will provide an overview of investments by certain types of projects. The work can be used as an aid in planning of the development of construction sector and increasing of competitiveness of Croatian construction companies. Research methodology in this paper is based on the collection and processing of existing data. Research has shown that the largest investment in construction projects is planned in the area of environment and transport.

Keywords: EU funds, construction EU projects, competitiveness

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1. Introduction

The European Union is a regional organization of European countries through which members realize common goals such as the balanced economic and social development, high levels of employment and protection of the rights and interests of citizens. (entereurope.hr, September 2013.)
EU funds are allocated to meet the objectives of the common policy and strategy and program objectives.
Until of Croatian entrance to the European Union and in the last 15 years, Croatia has benefited from a number of EU programs from which Croatia has received around 1.6 billion€ in co-financing of various projects. Key programs that affected the construction sector are OBNOVA, ISPA and IPA - Component III program with a focus on the transport and the environment.
After accession to the EU, Croatia has the possibility of using European funds in significantly larger amounts than it was in the pre-accession period, but also in a different way than it has been present so far.
In this paper, we will analyze the implementation of infrastructure construction projects designed to meet the strategic and program objectives of the EU in the field of environment and transport namely projects of the construction of waste management centers, water supply systems, agglomerations and railways.
The area of the environment is an area that covers a multitude of set goals related to environmental protection at the national and European level. To meet the objectives it is necessary to implement a number of projects. The projects of major importance are large infrastructure projects in the field of waste management and water - utility services in which it is planned to spend most of the EU funds provided for the environmental sector in the period 2014th-2020th. Waste management in Croatia is defined by the national strategic and program documents, regulations and guidelines of the European Union. By joining the EU, Croatia has pledged to harmonize waste management with EU directives. In the area of waste management, the largest investments are expected in the construction of regional and county waste management centers. Also, Croatia should harmonize water - utility services to the requirements of EU directives. There are two basic directives that Croatia has to meet. Directives are related to water supply and waste water treatment. The Republic of Croatia has requested a transitional period for the fulfillment of obligations Directive.

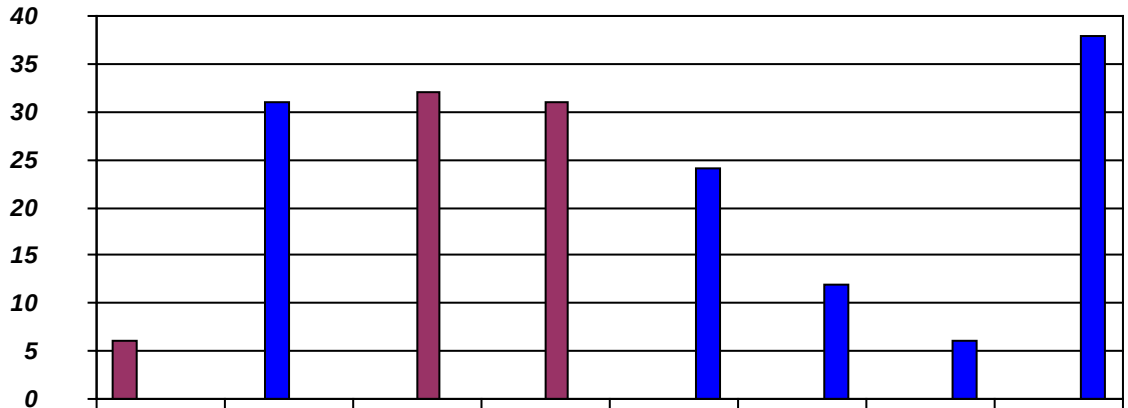
Transport Development of Croatia defines the Transport Development Strategy of the Republic of Croatian (NN 139/99) and a number of other documents that bind to the Strategy. In the period 2014th-2020th year priority investments will be investments in the Railways. Investments will be related to the modernization and construction of new and upgrading of existing shares, joints and connections. The largest investments are expected in V. and X. Pan-European corridor in accordance with the National Programme for Railway Infrastructure.
Funding sources are different but most of the funds are expected from the budget of the EU.

2. The analysis of approved and contracted projects in the period 2007th-2013th

2.1. Environmental

In the seven-year period 2007th-2013th, infrastructure construction projects financed from EU funds are mostly projects of Construction of waste management, water supply zones and agglomerations. These projects are co-financed from the Operational Programme Environment 2007th-2013th (IPA programme) which is the programming document for the absorption of EU funds allocated to Croatia in the environmental sector in the period 2007th-2013th.
The total value of all projects that are planned to be co-financed by the OP Environment 2007th-2013th is 330 mil. €. For projects in the field of waste is planned 87mil. € while for projects in the field of water and protection of water resources is provided 234 mil. €.
Projects co-financed from the OP Environment 2007th-2013th must be implemented by the end of 2016.

Graph 1: Total value (EU and national part) of all projects in the mil. € in the field of Environmental co-financed from EU programs contracted to 2013.



	Bikarac	Karlovac	Marišćina	Kaštijun	Sl.Brod	Knin	Drniš	Sisak
ISPA-WASTE	6							
ISPA-WATER		31						
IPA-WASTE			32	31				
IPA-WATER					24	12	6	38

Taken: Mišel Novosel: Postgraduate work: Analysis of options and the impact of the use of EU funds in the construction sector Croatia 2013th to 2020th, Zagreb 2014.

The graph shows the approximate total value (EU and national funds) of all the projects contracted in the period 2007- 2013, except of projects Bikarac and Karlovac, which are co-financed under the ISPA program, which has been available up to 31.12.2006.
The term WASTE refers to construction projects of waste management and WATER to building water supply systems and water treatment plants.

Table 1: List of environment WASTE projects financed from the EU programs to 31.12.2013. (ISPA, IPA IIIb) with the stated contractual amounts and nationalities of selected bidders

Num	Project Name	Contractual amounts	Country of selected bidders
ISPA (up to 2007.)			
1	**Regional waste management center Bikarac Phase 1**	**5.691.713,27** €	
	Sanation of landfill - Pirovac	378.180,00 €	Greece
	Construction - Bikarac	5.313.533,27 €	Greece
IPA (2007.-30.6.2013)			
2	**Marišćina**	**32.033.171,69** €	
	Design and construction	29.855.171,69 €	Greece
	Supervision	1.501.000,00 €	Spain
	Technical assistance	334.900,00 €	Italy
	Public relations	342.100,00 €	Croatia
3	**Kaštijun**	**31.391.233,26** €	
	Design and construction	29.209.153,26 €	Greece
	Supervision	1.395.375,00 €	Denmark
	Technical assistance	339.955,00 €	Germany
	Public relations	446.750,00 €	Denmark
4	**Sanation of critical point Sovjak**	**538.000,00** €	
	Project documentation	538.000,00 €	Denmark

Taken: http://www.safu.hr; www.fzoeu.hr, accessed: August 2013.

Table 2: List of environment WATER projects financed from the EU programs to 31.12.2013. (ISPA, IPA IIIb) with the stated contractual amounts and nationalities of selected bidders

Num	Project Name	Contractual amounts	Country of selected bidders
ISPA (up to 2007.)			
1	**Programme for water supply and waste water treatment Karlovac**	**31.439.211,93** €	
	Construction of water supply system	16.856.903,00 €	Austria
	Construction of water treatment plants	14.582.308,93 €	Croatia
IPA (2007.-30.6.2013)			
2	**Slavonski brod**	**23.679.069,00** €	
	Construction of water supply system	10.489.569,00 €	Croatia
	Construction of water treatment plants	11.605.000,00 €	Croatia
	Equipment	126.000,00 €	Croatia
	Supervision	1.458.500,00 €	Spain
3	**Knin**	**12.288.567,40** €	
	Construction of water supply system	4.702.613,40 €	Croatia
	Construction of water treatment plants	6.585.854,00 €	Austria
	Equipment	200.400,00 €	Croatia
	Supervision	799.700,00 €	Ireland
4	**Drniš**	**5.795.831,27** €	
	Construction of water supply system	2.185.109,34 €	Croatia

	Construction of water treatment plants	2.979.021,93 €	Croatia
	Equipment	97.100,00 €	Croatia
	Supervision	534.600,00 €	Austria
5	**Sisak**	**38.000.000,00** € **(Procjena)**	
	Construction of water supply system		
	Construction of water treatment plants	10.175.000,00 €	Croatia
	Equipment	590.000,00 €	Croatia
	Supervision	1.391.500,00 €	Spain

Taken: http://www.safu.hr; www.voda.hr, accessed: August 2013.

Based on an analysis of data on the implementation of the Operational Programme Environment 2007th-2013th it can be concluded that the total approved and contracted projects in this period are 2 projects in the field of WASTE (centers for waste management) and 4 of the projects in the field of WATER (water supply systems and treatment plants).

Projects for construction of waste management are implemented through four types of contracts (Design and build contract, Building Supervision Contract, Technical Assistance Contract, and Contract for Public Relations Work).
Projects for construction of water supply systems and treatment plants are carried out also through four types of contracts (The Construction Contract (water supply system), The Construction Contract (wastewater treatment plant), Building Supervision Contract and Equipment Contract.

For the implementation of projects for the construction of waste management centers all contracts were concluded with the foreign Contractor except for one contract (public relations).
Design and build contracts in both cases were concluded with Greek Contractor.

For the implementation of the construction of water supply systems and treatment plants most of the contracts were signed with local contractors.
Contracts on supervision were concluded with foreign contractors.

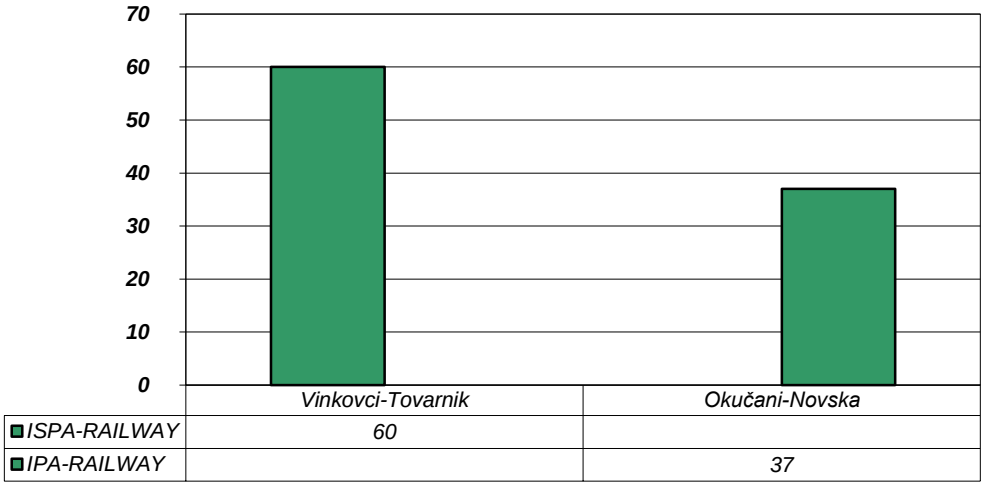
In all procurement procedures, selection criteria for the works was lowest offer, and to provide services best value for money.

2.2. Transport

In the seven-year period 2007th-2013th, EU projects in the field of Transport are co-financed from the Operational Programme Transport 2007th-2013th which is the programming document for the absorption of EU funds allocated to Croatia for the transport sector in the period 2007th-2013th.

The total value of all projects that are planned to be co-financed through OP Transport 2007th-2013th is 278 mil. €. Most of the funds (260 mil. €) is foreseen for the modernization of the railway infrastructure.
Projects co-financed from the OP Environment 2007th-2013th must be implemented by the end of 2016.

Graph 2: *Total value (EU and national part) of all projects in the mil. € in the field of Transport co-financed from EU programs contracted to 30.06.2013. (ISPA, IPA IIIa)*



Taken: Mišel Novosel: Postgraduate work: Analysis of options and the impact of the use of EU funds in the construction sector Croatia 2013th to 2020th, Zagreb 2014.

The graph shows the approximate total value (EU and national funds) of all the projects in the field of Transport (RAILWAYS).
Through OP Transport (2007.-2013.) only one project was contracted (Okučani - Novska) worth € 37 million while the remaining funds were spent mostly for project preparation. The project Vinkovci - Tovarnik is co-financed under the ISPA program that was available to 31.12.2006. and it is not co-financed from the OP Transport 2007th-2013th.

Table 3: List of Transport RAILWAY projects financed from the EU programs to 2013. (ISPA, IPA IIIa) with the stated contractual amounts and nationalities of selected bidders

Num	Project Name	Contractual amounts	Country of selected bidders
ISPA (up to 2007.)			
1	**Rehabilitation of Vinkovci - Tovarnik - state border**	**60.200.000,00 €**	Italy
IPA (2007.-30.6.2013)			
Num	**Project Name**	**Contractual amounts**	**Country of selected bidders**
2	**Renovation and reconstruction of the railway section Okučani - Novska**	**35.853.299,98 €**	
	Works on the tracks, Construction and Electrical installations of the railway Novska - Okučani	25.726.699,98 **€**	Italy
	Works on the signaling, security and telecommunication devices Novska - Okučani	8.566.800,00 **€**	Italy
	Supervision	1.559.800,00 **€**	Germany

Taken: http://www.safu.hr, accessed: September 2013.

Works on the section Vinkovci - Tovarnik are completed while for the project Okučani - Novska expected end is 2016 in accordance with Rule N + 3.

Based on an analysis of data on the implementation of the Operational Programme Transport 2007th-2013th it can be concluded that only one project has been approved and contracted in the field of RAILWAY in period 2007.-2013.
Railway Projects are implemented through three types of contracts.

For the implementation of Railway projects all contracts concluded with the foreign Contractor.

In all procurement procedures, selection criteria for the works was lowest offer, and to provide services best value for money.

3. Analysis of the possibility of financing construction projects from EU funds in the period 2014th-2020th

On the basis of the adopted operational programs 2014th to 2020th, national programs and plans for waste management, water - utility and transport economy, the largest investment in infrastructure construction projects can be expected in the field of environment and transport.

The total planned allocation for Croatia for the environmental sector amounted to 2.6 billion € while the total planned allocation for transport amounted to 1.3 billion €.
The largest investments in the field of Environment will be construction projects of Centers for waste management and the construction of water supply systems and agglomerations. Within the field of transport, the largest projects are constructions of railways (400mil. €).

Table 4: Awarded EU funds for construction projects to the Centers for waste management, water supply systems, agglomerations and railways in the period 2014th-2020th.

Area	Project Description	Assessment of the allocated funds (mil.€)
Environment	Centers for waste management	**425**
	Water supply systems and agglomerations	**1.009**
Transport	Railway	**400**

Taken: Ministry of Regional Development and EU funds: Operational programme competitiveness and cohesion 2014-2020, Zagreb 2014.

Due to the amount of funds allocated for the period 2014th-2020th, the impact of the use of EU funds in the construction sector should grow significantly especially after 2016 when it is expected a significant increase of investments.

Based on the analysis of the use of EU funds for the implementation of projects of construction of waste management centers, construction of water supply systems and agglomerations and railway construction projects, it has been found that in the period 2007th-2013th, a very small number of projects were approved and that none of them finished with implementation so the impact on the construction sector was negligible. There are many reasons for such a small number of projects, some of them are inadequate programming, long-term preparation and implementation, undefined location of waste management centers and the like.

In order to use the funds allocated for the period 2014th-2020th and achieve maximum positive impact on the construction industry of Croatia, certain assumptions are to be implemented, such as the existence of strong political will to ensure maximum utilization of the EU funds, the quality of project management including project preparation, the provision of adequate human resources, the national part of the funds needed for the project implementation and competitiveness of local bidders.

4. The impact of the use of EU funds in the construction sector Croatia 2014th-2020th

In the last 20 years until the arrival of the economic crisis, Construction in the Republic of Croatia has been very successful, construction companies were profitable both small and large companies. Sources of financing projects were the public and private sectors.
With the arrival of the crisis, construction companies have started to operate with a losses, construction projects disappeared especially construction of buildings. One of the reasons is overbuilding of buildings for private and comercial use during previous period of which part of them has not been in full use.
Projects financed from private sources are very rare and it is difficult to expect that this would be changed in the coming period 2014th-2020th.
Although we can not expect significant investment in building construction, national priorities defined in the program documents of the 2014th to 2020th and EU funds planned for construction projects give hope that the construction sector will once again flourish.

It is important to emphasize that the construction projects financed from public funds in the period 2014.-2020. will be mainly oriented on:

- Construction of Centers for waste management (425mil. €)
- Construction of Water supply systems and agglomerations (1.009 mil. €)
- Construction of railways (400 mil. €)

Estimated value of construction work performed for the year up to 2020 will amount to several hundred million euros.
Also, it should be emphasized the potential of preparation of projects and the potential for development of design companies that will prepare the construction projects as well as feasibility studies and cost-benefit analyzes.
Furthermore, analysis of the most favorable bidder for previous projects financed from EU funds in the Republic of Croatia showed that Croatian bidders fail to compete with foreign bidders.
Past practice in the area of waste is such that all the contracts for preparation and implementation of projects were signed with foreign contractors except one (Contract for Public Relations Work).
In the field of water, the situation is better, most of the contracts were concluded with local bidders, while contracts on supervision concluded with foreign contractors.
In the field of railways, all contracts were concluded with foreign bidders.
If the trend of contracting with foreign bidders continues, the expected wave of investment 2014th-2020th will not significantly affect to the development of the construction industry of Croatia.

The funds allocated for the environmental and transport can in the coming period 2014th-2020th turned Croatia into a giant construction site of Centers for waste management, water supply systems, agglomerations and railways which can encourage economic development and the flourishing of construction industry.

If Croatia fails to take advantage of EU funds, not only will fail economic development but Croatia will have to bear the consequences of failure to comply with EU directives related to the protection of the environment which will further negatively influence the further development.

5. Conclusion

The European Union is a regional organization of European countries through which members realize common goals such as the balanced economic and social development, high levels of employment and protection of the rights and interests of citizens.

The task of the EU funds is to accelerate the development of least developed member states and regions, to achieve economic and social cohesion of the European Union, to encourage sustainable development and reduce differences in the standard of living in the EU Member States and their regions.

Most of the above can not be achieved without the projects involving the construction works. Until of Croatian entrance into the EU, Croatia has benefited from a number of programs of European Union to co-finance construction projects.
Upon entry to the EU, Croatia has opened the possibilities for the use of EU funds in significantly larger amounts than it was in the pre-accession period.
The areas in which investments will be mostly related to large infrastructure projects and the construction projects are the environmental and transport projects.

The funds allocated for these two areas could in the coming period 2014th-2020th turned Croatia into a giant construction site of Centers for waste management, water supply systems, agglomerations and railways which can encourage economic development and the flourishing of construction industry.
If Croatia fails to take advantage of EU funds, not only will fail economic development but Croatia will have to bear the consequences of failure to comply with EU directives related to the protection of the environment which will further negatively influence the further development.

Of course, the funds will be used if certain assumptions will be implemented, such as the existence of strong political will to ensure maximum utilization of the EU funds, the quality of project management including project preparation, the provision of adequate human resources, the national part of the funds needed for the project implementation and competitiveness of local bidders.

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CONSTRUCTION DESIGN AND TECHNOLOGY

Minimizing of Energy Consumption of Construction Machine Groups Implemented into Soil Processes

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Abstract

Getting fuels, economizing with them and effective utilization of them belong to the most complex problems of the present and future. Energy saving is one of the most important environment factor in construction company with developed a implemented Environment Management system (EMS) according to ISO 14001. We try in contribution to refer to one of the ways as early in the building preparation/design phase to contribute in the suitable selection of the machines and the machine groups for the building processes leading to the lowering of their energy consumption. There is described at this paper structure of machine selection optimizing method for building processes, model example with results concerning the machine selection for soil processes and also basic features of software support, which leads to effectiveness of optimal machine selection.

Keywords: construction, machines, optimizing, energy consumption

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1. Introduction

Development of the national economy is closely attached many conditional factors, from which always more urgent comes to the forward the fuel and energy balance. Getting fuels, economizing with them and effective utilization of them belong to the most complex problems of the present and future. Energy saving is one of the most important environment factor in construction company with developed a implemented Environment Management system (EMS) according to ISO 14001. During the process of building planning planner must analyze suitable selection of building machines and its group for effective proposal of mechanized building processes. There are several criteria for selection of building machines. In our contribution there are analyzed: ability of machines to realize designed building process (quality aspect), duration of mechanized process (time aspect) and minimizing of energy consumption (cost and environmental aspect). From the above mentioned aspects results, that the lowering of the power requirement of the construction process presents an inevitable social-wide problem. We want to refer to one of the ways as early in the building preparation/design phase to contribute in the suitable selection of the machines and the machine groups for the building processes leading to the lowering of their energy consumption.

Considerable efforts have been made in development of efficient techniques and procedures for soil processes and many techniques have been developed so far. Recently, more researches are interested in earthwork operations and most of them use optimization and simulation as the methodologies that can be used for analyzing soil processes. CYCLONE and STROBOSCOPE are the commonly used simulation tools specified for construction (Zhang, 2008). These tools for construction modeling, such as STROBOSCOPE enable accurate and detailed modeling of any complex situation but these tools demand a level of training (Martinez, 1996). In the context of STROBOSCOPE Martinez developed an EarthMover, which is a discrete-event special-purpose simulation modeling tool for earthwork planning. This tool includes STROBOSCOPE as a simulation engine, Visio for the graphical and interactive model definition, Excel for tabular and graphical output and Proof Animation for dynamic output (Martinez, 1998). Halphin developed CYCLONE methodology for modeling and simulating repetitive construction processes (Halphin, 1977). Shi and AbouRizk introduced the resource-based modeling (RBM) methodology in order to automate the modeling process and by using this methodology can the project manager construct a simulation model for a project in a few minutes, but it consisted of only eight basic atomic models and is connected only with earthmoving operations (Shi & AbouRizk, 1998). Marzouk and Moselhi analyzed earthmoving operations by combining genetic algorithm (GA) with CYCLONE and other simulation techniques. Their simulation and optimization considered multi-objectives for selecting near-optimal fleet configuration for earthmoving processes, but could not select any potential combination of various type of equipment which are in the fleet (Marzouk & Moselhi, 2004). The work of Zhang formed a framework of multi-objective simulation-optimization for optimizing equipment-configurations of earthmoving operations and it is proposed by integrating an activity object-oriented simulation, multiple attribute utility theory, a statistical approach like the two-stage ranking and selection procedure and particle swarm optimization algorithm. His procedure is equipped to help compare the alternatives that have random performances and thus reduce unnecessary number of simulation replications. It can speed up the evaluation process, but this integrated framework is still developed (Zhang, 2008).

2. Characteristics of machine selection optimizing method for building processes (here after called "Method")

By suggesting the "Method" (see Fig 1) we have developed the present state of knowledge of the purpose of the machines and machine groups for building processes (Vávra,I., Zapletal,I., 1983) and also of the information which has been obtained by study of the theory of systems (Štach, J. ,1983) and optimization theory of the process (Niederliński, A.,1983). The "Method" consists of the five phases – introductory, preparatory, proposal, decision and optimization.

An analysis of all these phases except introductory is examined:

- the input universe of the system that is the set of the machines submitted for analysis in the given phase,
- the criterion, according to it being the input universe of the system of given phase,
- the procedural steps being necessary to realize the appreciation of the input universe of the system according to the criterion of the given phase,
- the output universe of the system that is the set of the machines fulfilling the criterion of the given phase.

The introductory phase contains delimitation of problem and objectives necessary to be reached by evaluating for example the type of building works, characterization of the final product of the mechanized building process, input information necessary for solving of the problem and so on.

The input phase

- The input universe of the system – the set of the machines from the suppliers being suitable for a given type of the building works.

The criterion – 1st eliminating - the usefulness of the machines for the realization of the final product of the building process.

The procedural steps:

- a study of the resulting product of the building process,
- the analysis of problems of the proposal on the machine for a given type of the building process,
- the collation of all the information including the performance data of the machines for their incorporation into a model of the mechanized building process.

The output universe of the system – the set of the machines from the suppliers suitable for realization of the final product of the building process.

The proposal phase

The input universe of the system – the output universe of the preparatory phase.

The criterion – 2nd eliminating – the applicability of the machines of the suppliers for the realization of the final product of the building process.

The procedural steps:

- the comparison of the need and the applicability of types of the machines of the suppliers for realization of the final product of the building process,
- the selection of the optimal types of the machines for realization of the final product of the building process.

The output universe of the system – the set of the machines by which is possible to realize the final product.

The decision phase

The input universe of the system – the output universe of the proposal phase.

The criterion – 3rd eliminating – production rate aspect (time required for the realization

of the final product or quantity of production in determined time)

The procedural steps:

- the construction of the verbal – graphic model of the real system,
- the choice of the variants of the machines, let us say of the machine groups for realization of the final building product,
- the selection and the choice of the model variables, their definition, symbol, dimension, quantification with the source of the quantification,
- the formulation of the particular mathematical relations of the model,
- the construction of the mathematical model for appreciation of variants of the machines according to the 3rd eliminated criterion,
- the verification, quantification, numerical solution using software, interpretation and implementation of the created mathematical model.

The output universe of the system – the set of the machines performing the requirements for realization of the final product.

The optimizing phase

The input universe of the system – the output universe of the decision phase.

The criterion – optimization – the minimizing of the energy consumption machines, let us say machines groups for realization of the final product of the building process.

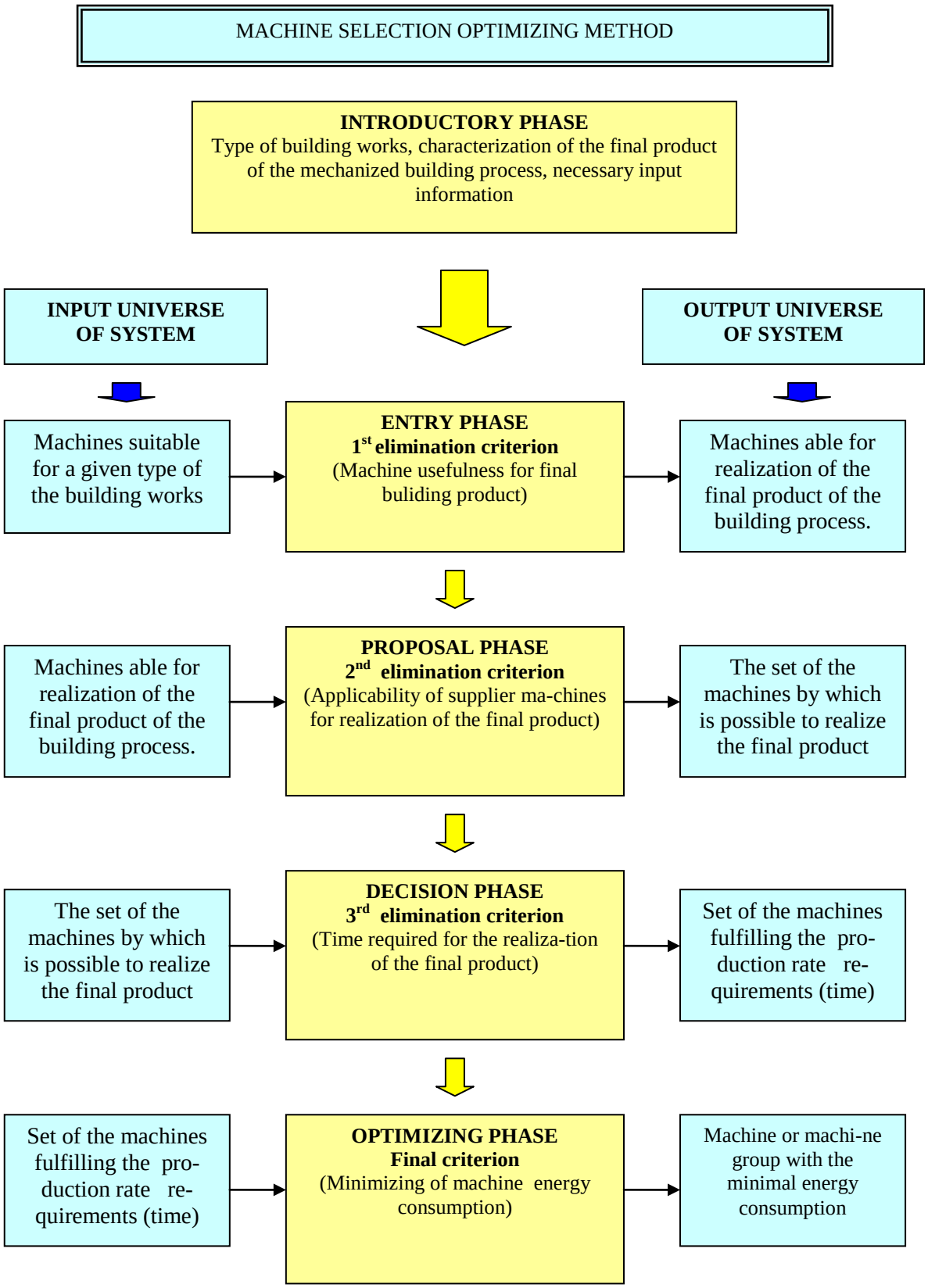


Fig. 1. Machine selection optimizing method

The proceeding steps:

- the selection and choice of the decision variables, their definition, symbol, dimension, quantification with giving of the source of the quantification,
- the construction of the mathematical model of the criterion of the optimization,
- the verification quantification, numerical solution using software, interpretation and implementation of the mathematical model of the criterion for optimization.

The output universe of the system – the machine – let us say the machine group with the minimal energy consumption for realization of the final product of the building process.

3. The application of the proposed "Method"

This "method" was applied in on two different examples. In the first case (Gašparík, J.,2007), it was a proposal for the means of lifting (vertical transport) of the materials of associated building production from the point of view of minimal electric power consumption. The second cas, there was by above mentioned "Method" proposed the machine group for the excavation and the removal of the earth at the given distance from the point of view of the minimal fuel consumption (here after next F.C.). There is described the second example in our paper. With regard to the great number of the model variables and the extent of the work this paper is considering the decision and optimizing phases.

3.1 Selection of the machines for excavation and removal of earth at the given distance from the point of required time and energy consumption minimizing

Base input data:

- final product of building process: building pit:
- width – 50 m, length – 90 m, depth – 3,5 m,
- soil type and class – sandy soil, the 2nd class of cohesion,
- required work capacity V_p = 15,750 m^3,
- transport distance L= 4 km,
- required time of duration of works T= 14,400 min. (30 shifts),
- season of year of realization of works – April, May,
- kind of road surface – mastic asphalt, plane on the whole length,
- presupposition of approximate identical operation of machines during shifts, time for lunch and inspection of machines at the beginning and the end of shift have not being included in time of shift duration.

The input universe of the system of the decision phase is being created by depth shovel excavator DH 411, DH 621, Cat 225 and folding transport means T 148 S1, T 815 S3, S 706 MTSP 24. The same transport means were applied to every type of the excavator.
There are 9 variants of the excavator machine group together with the transport means and in every variant it is being solved with 1 to 13 pcs transport means. For the evaluation of the machine groups in the decision and optimization phase the concept of centralized control is being applied.

The mathematical model of the 3rd eliminating criterion of the decision phase is in the form:

$$T_{sk} = V_p . t_{ca_j} (V_{na_j} . k_{ca_j} . k_{ka_j} . k_{da_j} . k_o . N_{a_j})^{-1} \quad (min) \qquad (1)$$

let us say

$$V_{sk} = T_p . V_{na_j} . k_{ca_j} . k_{ka_j} . k_{da_j} . k_o . N_{a_j} (t_{ca_j})^{-1} \quad (m^3) \qquad (2)$$

for j=1, 2, 3; N_a = 1, 2, …, 13,

where

T_{sk} – duration of work of machine group by earthworks of required volume (min.),
t_{ca} - duration of duty cycle of transport mean (min.),
V_{na} – volume of earth removed by transport mean in loosened state (m^3),
k_{ca} – plant factor of transport mean (-),
k_{ka} – coefficient of influence of operation of transport mean at its capacity (-),
k_{da} – coefficient of influence of transport distance at capacity of transport mean (-),
k_o – coefficient of calculation of soil in loosened state at volume of soil in natural state (-),
N_a – number of transport means in machine group (pcs),
V_{sk} – volume earthworks realized by machine group in required time (m^3),
T_p – required time of duration of works (min).

The output universe of the system of the decision phase follows from interpretation of Graph (Fig. 2), where suitable variants of machine groups are placed under line representing required time of duration of works T_p The suitable variants of the machine group of the decision phase are being evaluated in the optimizing phase from the point of view of the minimal F.C. (Diesel oil).

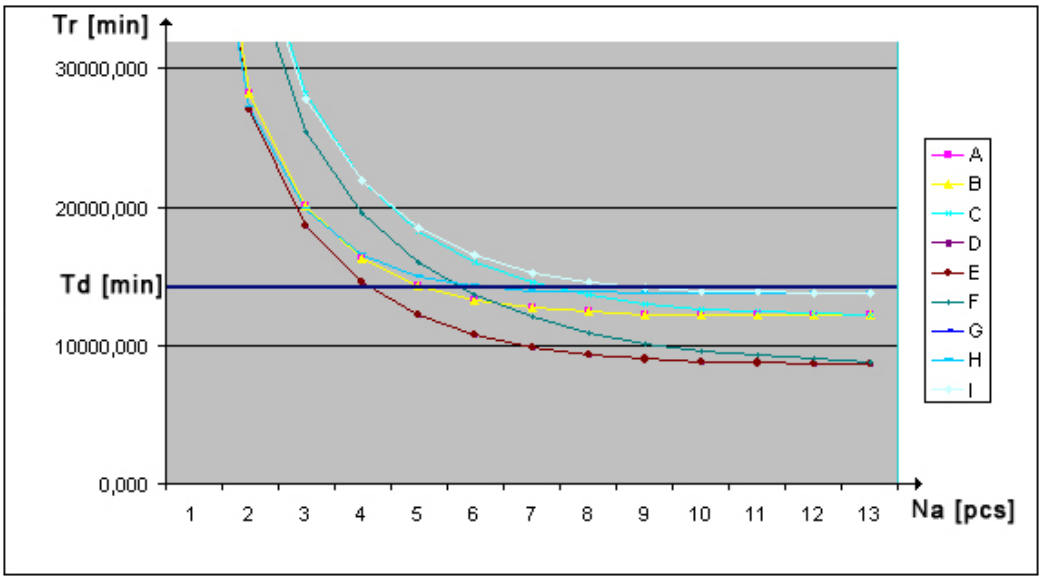


Fig. 2. Dependence of actual duration of earthwork T_r (min) on number of vehicles (pcs) of machine group variants (excavator + vehicles) by required volume of earthworks V_r = 15 750 m^3.

T_d = 14 400 min. (required time) for variants A – I

The mathematical model of the optimizing criterion is in form as follows:

$$MS = T_{sk} . T_{ps}^{-1} . V_p^{-1} . [T_{mr_i} . S_{mr_i} + T_{pr_i} . S_{pr_i} + (T_{ca_j} . S_{ca_j} + L_{na_j} . S_{na_j} + L_{pa_j} . S_{pa_j}) . N_{a_j}] \quad (1.m^{-3}) \qquad (3)$$

for i=1, 2, 3; j = 1, 2, 3; N=1,2, … , 13,

where
MS – specific F.C. of machine group, excavator + transport means by the required volume of the works (l. m^{-3}),
T_{ps} – duration of operation of machines during a shift (min /shift),
T_{mr} – time of excavator manoeuvre (min/shift),
S_{mr} – fuel consumption of excavator at manoeuvring (l/ min),
T_{pr} – duration of work regime of excavator except time of manoeuvring (min/ shift),
S_{pr} – fuel consumption of excavator in operating regime (l/min),
T_{ca} – duration of waiting regime of transport mean during running engine (min/shift),
S_{ca} – fuel consumption by waiting regime of transport mean (1/min),
L_{na} – length of road covering by transport mean with a load, from place of loading to place of unloading (km/shift),
L_{pa} – length of road covering by transport mean without of load, from place of unloading to place of loading (km/shift),
S_{na} – fuel consumption of transport mean by driving with a load (1/km),
S_{pa} – fuel consumption of transport mean by driving without a load (1/km).

The other decision variables are being given by the relations 1 and 2. Input data concerning the consumption of fuel were given by producers of excavator and transport means.
The best energy saving machine groups of each kind are being compared in Fig. 3. The most advantageous solution for the realization of output and removal of earth at given distance from the point of view of minimizing of fuel consumption is at analyzed model example a choice of the machine group Cat 225 + 6 pcs of T 148 S1.

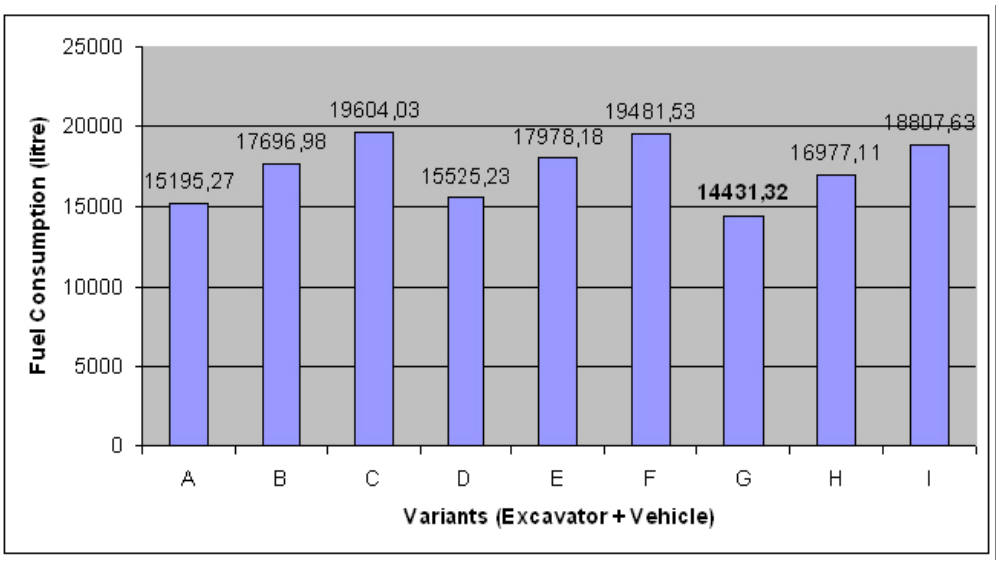


Fig.3 Machine group (excavator-trucks) variants evaluation from the point of minimum consumption of fuel for variants A – I

4. "Method" Software Support

The Machine Selection software has been created as a software support for method described in this contribution. Machine Selection is a desktop application, built in Java. Therefore it is runnable on all operating systems that support Java Virtual Machine.
Introduction screen (Fig.4) contains panels to enter input variables. User can choose number of excavator and vehicle types. For both - one as minimum and three as maximum. It is enabled to save inputs into file and load inputs. User can also change excavator and vehicle names.

Clicking *Check Inputs* button provides control of input variables values. Wrong values are marked as red, acceptable as green. Button called *Calculate* leads to result screen, which is divided into four sections:

- Optimal Solutions(s),
- Complete Work-time Table,
- Complete Earthworks Volume Table,
- Complete Fuel Consumptions Table.

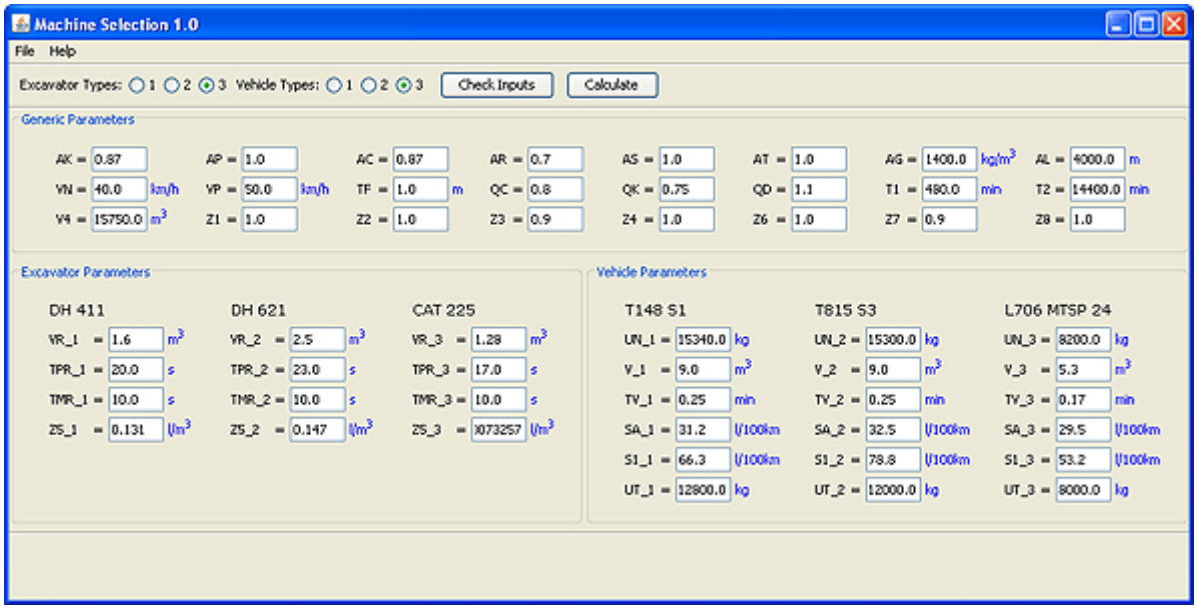


Fig. 4 Input screen of Machine Selection software

4.1 Optimal Solution(s)

This section contains a list displaying all variants of excavator and vehicle(s) able to solve the task in desired time and volume. Best variant is marked as green. It is also possible, that task in desired volume with desired work-time is not solvable with maximum number of vehicles 13. In this case, fuel consumption of variant is not calculated and this variant is marked as *out of range* error. This part of result screen is displayed on Fig.5.

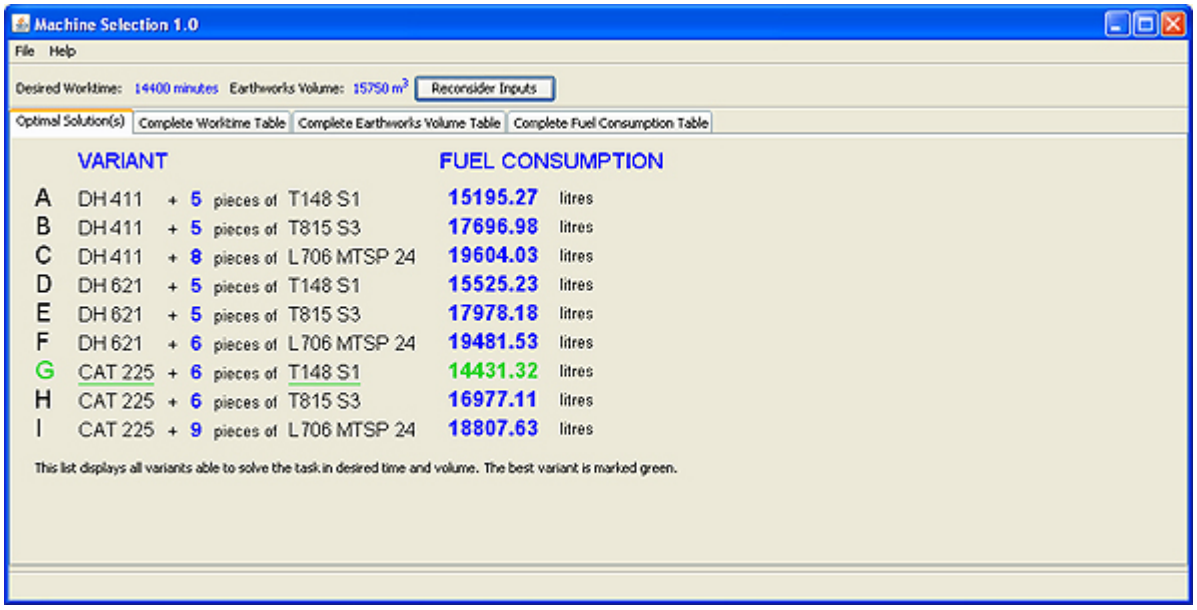
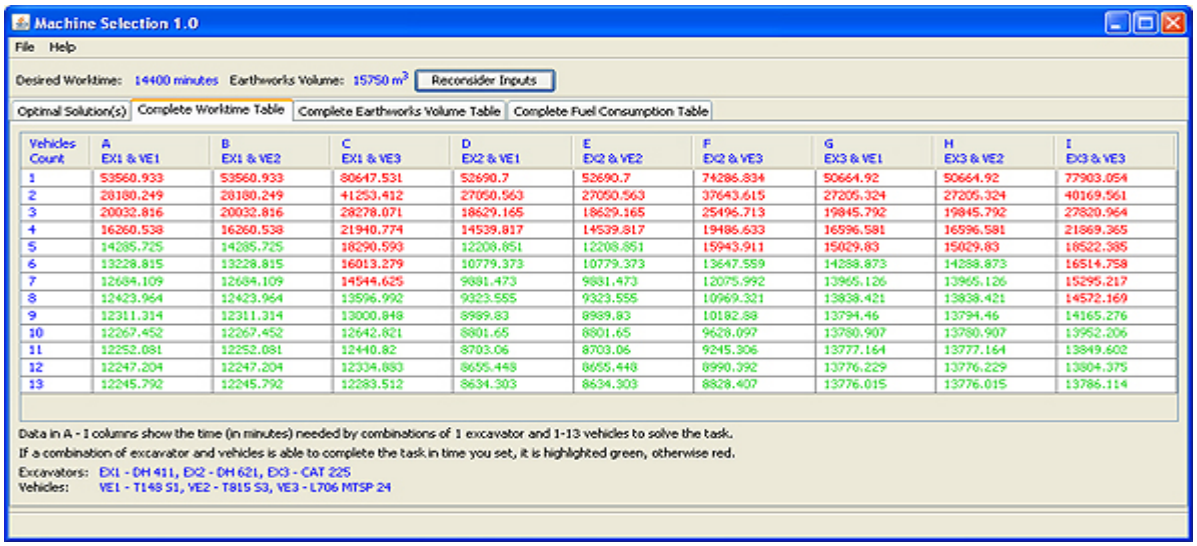


Fig. 5 Result screen, Optimal Solution(s) section

4.2 Complete Work-time Table

In this section there is a table created to display data for all combinations of excavator and vehicle types. Data show the time in minutes needed by combinations of 1 excavator and 1 to 13 vehicles to solve the task in desired volume. If a combination of excavator and vehicles is able to complete the task in time set by user, result time data is highlighted green, otherwise red. This part of result screen is displayed on Fig. 6.

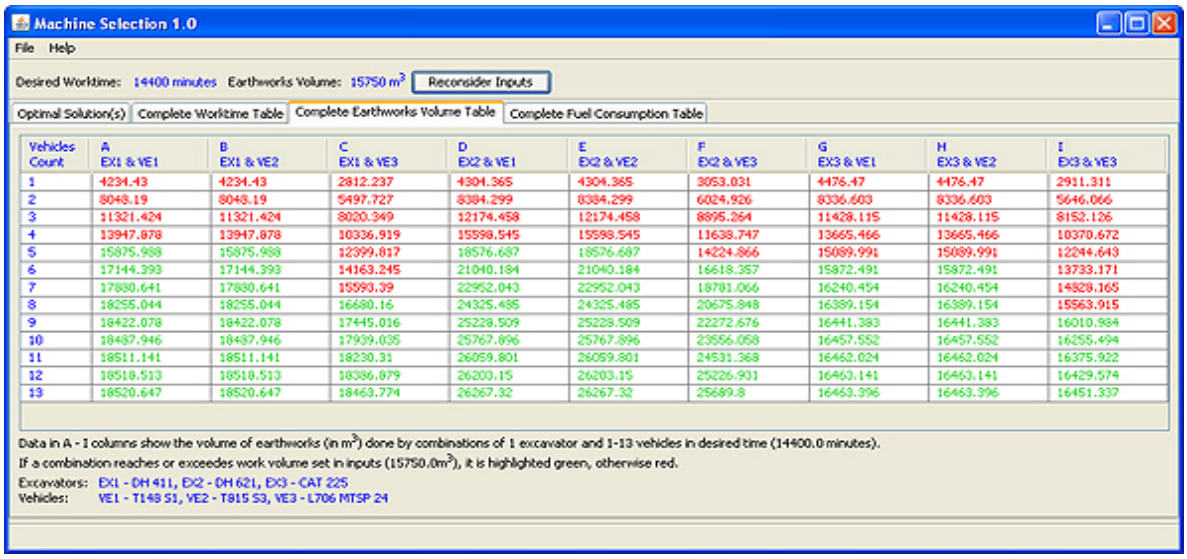


Vehicles Count	A EX1 & VE1	B EX1 & VE2	C EX1 & VE3	D EX2 & VE1	E EX2 & VE2	F EX2 & VE3	G EX3 & VE1	H EX3 & VE2	I EX3 & VE3
1	53560.933	53560.933	80647.531	52690.7	52690.7	74286.834	50664.92	50664.92	77903.054
2	28180.249	28180.249	41253.412	27050.563	27050.563	37643.615	27205.324	27205.324	40169.561
3	20032.816	20032.816	28278.071	18629.165	18629.165	25496.713	19845.792	19845.792	27820.964
4	16260.538	16260.538	21940.774	14539.817	14539.817	19486.633	16596.581	16596.581	21869.365
5	14285.725	14285.725	18290.593	12208.851	12208.851	15943.911	15029.83	15029.83	18522.385
6	13228.815	13228.815	16013.279	10779.373	10779.373	13647.559	14288.873	14288.873	16514.758
7	12684.109	12684.109	14544.625	9881.473	9881.473	12075.992	13965.126	13965.126	15295.217
8	12423.964	12423.964	13596.992	9323.555	9323.555	10969.321	13838.421	13838.421	14572.169
9	12311.314	12311.314	13000.848	8989.83	8989.83	10182.88	13794.46	13794.46	14165.276
10	12267.452	12267.452	12642.821	8801.65	8801.65	9628.097	13780.907	13780.907	13962.206
11	12252.081	12252.081	12440.82	8703.06	8703.06	9245.306	13777.164	13777.164	13849.602
12	12247.204	12247.204	12334.883	8655.448	8655.448	8990.392	13776.229	13776.229	13804.375
13	12245.792	12245.792	12283.512	8634.303	8634.303	8828.407	13776.015	13776.015	13786.114

Fig. 6 Result screen, Complete Work-time Table section

4.3 Complete Earthworks Volume Table

Data of this section's table show the volume of earthworks in m^3 done by combination of 1 excavator and 1 to13 vehicles in desired time. If a combination reaches or exceeds work volume set in inputs, it is highlighted green, otherwise red. This part of result screen is displayed on Fig 7.

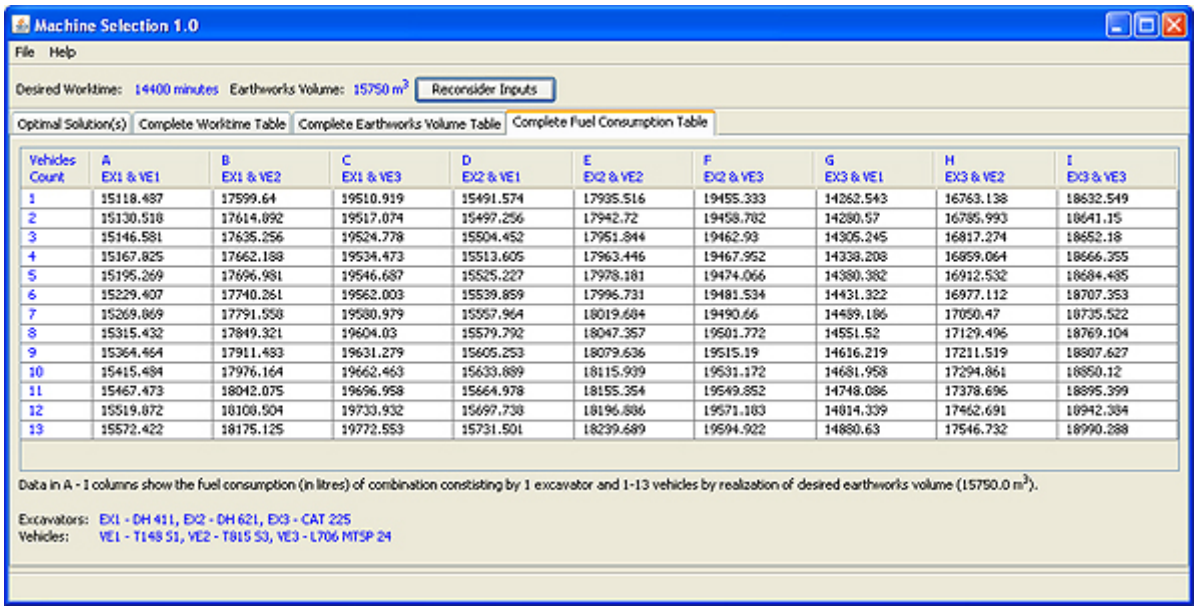


Vehicles Count	A EX1 & VE1	B EX1 & VE2	C EX1 & VE3	D EX2 & VE1	E EX2 & VE2	F EX2 & VE3	G EX3 & VE1	H EX3 & VE2	I EX3 & VE3
1	4234.43	4234.43	2812.237	4304.365	4304.365	3053.031	4476.47	4476.47	2911.311
2	8048.19	8048.19	5497.727	8384.299	8384.299	6024.926	8336.603	8336.603	5646.066
3	11321.424	11321.424	8020.349	12174.458	12174.458	8895.264	11428.115	11428.115	8152.126
4	13947.878	13947.878	10336.919	15598.545	15598.545	11638.747	13665.466	13665.466	10370.672
5	15875.988	15875.988	12399.817	18576.687	18576.687	14224.866	15089.991	15089.991	12244.643
6	17144.393	17144.393	14163.245	21040.184	21040.184	16618.357	15872.491	15872.491	13733.171
7	17880.641	17880.641	15593.39	22952.043	22952.043	18781.066	16240.454	16240.454	14828.165
8	18255.044	18255.044	16680.16	24325.485	24325.485	20675.848	16389.154	16389.154	15563.915
9	18422.078	18422.078	17445.016	25228.509	25228.509	22272.676	16441.383	16441.383	16010.984
10	18487.946	18487.946	17939.035	25767.896	25767.896	23556.058	16457.552	16457.552	16255.494
11	18511.141	18511.141	18230.31	26059.801	26059.801	24531.368	16462.024	16462.024	16375.922
12	18518.513	18518.513	18386.879	26203.15	26203.15	25226.931	16463.141	16463.141	16429.574
13	18520.647	18520.647	18463.774	26267.32	26267.32	25689.8	16463.396	16463.396	16451.337

Fig. 7 : Result screen, Complete Earthworks Volume Table section

4.4 Complete Fuel Consumption Table

In this section, data of the table show fuel consumption in liters of combination consisting by 1 excavator and 1 to 13 vehicles by realization of desired earthworks volume. This part of result screen is displayed on Fig 8.



Vehicles Count	A EX1 & VE1	B EX1 & VE2	C EX1 & VE3	D EX2 & VE1	E EX2 & VE2	F EX2 & VE3	G EX3 & VE1	H EX3 & VE2	I EX3 & VE3
1	15118.487	17599.64	19510.919	15491.574	17935.516	19455.333	14262.543	16763.138	18632.549
2	15130.518	17614.892	19517.074	15497.256	17942.72	19458.782	14280.57	16785.993	18641.15
3	15146.581	17635.256	19524.778	15504.452	17951.844	19462.93	14305.245	16817.274	18652.18
4	15167.825	17662.188	19534.473	15513.605	17963.446	19467.952	14338.208	16859.064	18666.355
5	15195.269	17696.981	19546.687	15525.227	17978.181	19474.066	14380.382	16912.532	18684.485
6	15229.407	17740.261	19562.003	15539.859	17996.731	19481.534	14431.322	16977.112	18707.353
7	15269.869	17791.558	19580.979	15557.964	18019.684	19490.66	14489.186	17050.47	18735.522
8	15315.432	17849.321	19604.03	15579.792	18047.357	19501.772	14551.52	17129.496	18769.104
9	15364.464	17911.483	19631.279	15605.253	18079.636	19515.19	14616.219	17211.519	18807.627
10	15415.484	17976.164	19662.463	15633.889	18115.939	19531.172	14681.958	17294.861	18850.12
11	15467.473	18042.075	19696.958	15664.978	18155.354	19549.852	14748.086	17378.696	18895.399
12	15519.872	18108.504	19733.932	15697.738	18196.886	19571.183	14814.339	17462.691	18942.384
13	15572.422	18175.125	19772.553	15731.501	18239.689	19594.922	14880.63	17546.732	18990.288

Fig. 8 Result screen, Complete Fuel Consumption Table section

Conclusion

The most-important factor in this “Method” is that it is able to eliminate energy variants of the machines, during the design and preparation phase of construction. By using a software it gives information about energy usage of machines when considering their use in the final product of the building process and gives the possibility to make fast decision for the choice of the optimal machine in a short time. At the same time it is necessary to stress that by this method the building machines are being evaluated from one point of view only (of the power requirement), which, it is true, is one of the most meaningful views of this time, but it needs not be crucial in every case. Therefore, it is necessary when proposing a machine to take the point of view to minimize the power requirement as a part of the polyoptimal proposal. For a practical application of the proposed “Method” it is necessary to improve the quality of input data, especially energy use information. The volume of savings of the operating expenses possible to be obtained already in the preparation phase of buildings by this “Method” are not negligible, vice versa, it shows the disclosure of reserves that are available in the choice of machines for building processes. This “Method” will find a full application only when these reservations will be removed.

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Monitoring of Neighbouring Structures During Underground Garage Construction

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Abstract

Construction projects that are being executed in urban areas are associated with specific challenges. One of them is the influence of the planned structure and its construction upon the neighbouring buildings, a challenge that is particularly present in historic centers of the settlements. Due to the traditional construction systems and age, the old neighbouring buildings are sensitive to vibrations caused by the construction activities, even when these are of moderate magnitude, as well as to the influence of various other construction activities.
The paper presents the construction of a 5-level underground garage, located in the vicinity of several buildings protected as built heritage. The construction is exposed also to the presence of underground water at two levels. During construction, as well as after the completed works, periodic 3D geodetic measurements of neighbouring structures' displacements, and the measurements of cracks that were advancing on these buildings were carried out. The vibrations and underground water level were regularly monitored as well. Despite the fact that extensive monitoring was carried out in the case under consideration, additional types of monitoring are proposed on the basis of the presented analysis.

Keywords: construction, construction pit protection, structural health monitoring (SHM), condition monitoring, measurements

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1. Introduction

Construction of larger engineering structures in densely built-up city centers is always challenging. The construction site is frequently limited with the available space, required for equipment, machinery material storage, management and other facilities, necessary for the operation of the site. Further, the supply of the necessary material for the construction can occasionally be interrupted due to rush hours and the related congestions. The greatest attention, however, is usually paid to the surrounding buildings that are located in the immediate vicinity of the site as they can be adversely affected by the on-going activities. Non-uniform settlements of their foundations causing cracking of structural elements can occur. Therefore, these buildings have to be subjected to monitoring at least during the execution of construction works. In some cases, such as execution of major geotechnical works, monitoring is usually extended and it carried out several years after completion of the structure.

The role of monitoring during construction of unique projects is very important. By providing additional data, the monitoring activities prevent emergency situations that may occur during the construction works in a dense urban setting and ensures the preservation of cultural, historic and architectural monuments (Il'ichev et al., 1999). During early construction stages, monitoring provides a factual basis for quantitative assessment of the proposed design and selected construction technology. Furthermore, systematic instrumentation measurements taken at selected control sections along can be utilized to document the overall performance. These valuable records can also be stored in a database, and used when similar constructions are designed and executed later on. From the viewpoint of applied research, field measurements gathered during construction monitoring provide badly needed records for reviewing and improving the existing design procedures and validating new analytical tools, as well as for formulating effective directions of future research that needs to match the increasing development of underground space. (Elnahhas, 1992). For demanding structures, monitoring and interval inspections need to be conducted throughout their lifetime with establishing of efficient and practical procedures to ensure their safety (Qin and Faber, 2012).

2. Construction site

The garage under consideration was built under the market platform in the Ljubljana inner city center (Fig. 1). The garage has a floor platform of 147 x 28 meters and extends five floors deep. Due to its depth and the close proximity of buildings with the status of cultural heritage, such as the Ursuline Church, University Headquarters, Philharmonic building, and a series of historical houses on the south side of the square, the construction was a large and challenging technical achievement. In addition, geotechnical investigations carried out prior to construction showed that specific geotechnical conditions are present on the site; as two layers of underground water were detected. The perched ground water layer, the quantity of which is directly dependent on the precipitation, is located approximately 7 m below the surface. The bottom groundwater layer located approximately 17 m below the surface is dependent upon the Sava River water regime. A thick layer of impermeable soil separates the two layers of water (IZTR, 2011).

The biggest challenge during construction was to ensure adequate protection of the construction pit. From the viewpoint of the neighbouring buildings that are under cultural

protection, any movement or settlement had to be prevented. Specific geotechnical conditions did not allow the use anchoring in order to protect the construction pit, therefore internal structure was used for this purpose. First, a reinforced concrete diaphragm that runs continuously around the building and extends to a depth of over 22 m, was built (Fig. 2). Then, the excavation from floor to floor to a depth of 18 m was carried out by using mining. Construction was completed with the execution of 1 m thick core slab that is permanently surrounded with lower ground water layer (IZTR, 2011).

Fig. 1. Construction site during the first year of building

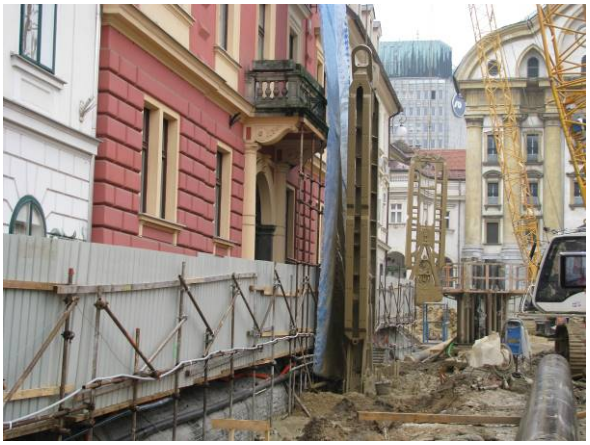

Fig. 2. Construction of 22 m deep diaphragm in immediate vicinity of neighbouring buildings

3. Monitoring methods

Extensive structural monitoring was carried out throughout the construction of the garage described in the previous section. Complete monitoring plan includes a five-year monitoring plan to be executed after completion of works, as well as reduced scope of monitoring that is planned throughout the lifetime of the structure. Hereinafter six methods (Umek et al., 2011b) of monitoring used during construction are presented.

3.1. Damage register

The basis for the execution of any monitoring of neighbouring structures is the damage register, in which existing and potential new damages that occur during construction are recorded. Location of damages are generally marked in plan view, but for more exposed buildings or buildings protected as national heritage cracks and other damages are, due to increased accuracy, depicted in front view (Fig. 3).

The measurements of advancing cracks can be conducted in several ways, three of which were used in the case presented. The most common was visual measurement with crack width gauge. The second method of cracks measurements was using control seals that were made of polymer cement mortar or thin slides. In both cases, we use fragile material that bursts at a small increase in crack size. The width of the newly formed crack in the control seal displays the exact increase of width of existing cracks on the monitored structure. Three-point markers were mainly used to accurately monitor the width and the lag of structural cracks. After the

markers were installed in the vicinity of structural cracks, the deformeter was used to regularly measure the precise difference of the distance between the cracks.

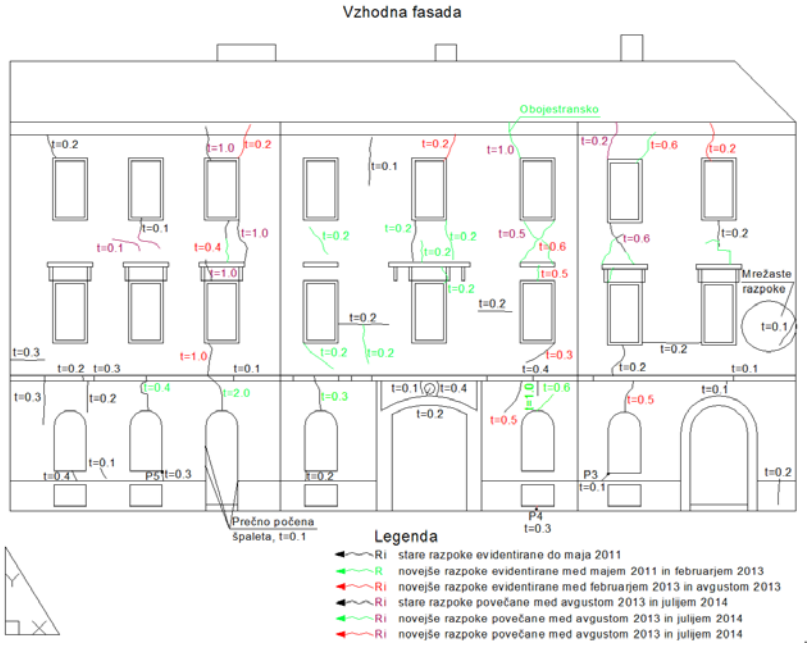

Fig. 3. Damage register depicted in front view (Kušar et al., 2014)

3.2. Geodetic measurements

Geodetic measurements of adjacent structures are extremely important when deep construction pits are being excavated. Regularly conducted measurements show the horizontal movement or displacements of foundations before visible damage on structures appears. As a consequence, early intervention in order to improve the construction pit protection is enabled, and extensive damage can be avoided.

In the underground garage under consideration, displacements as well as 3D measurements of neighbouring buildings were conducted. Approximately 100 geodetic markers in total were installed and measured during construction and after its completion. No movements were recorded for the majority of buildings. The only exceptions were four buildings that stand only 1 m or less from the construction pit. They suffered vertical displacement up to 16 mm, and due to uneven displacement of individual parts of these buildings (Fig. 4), new cracks appeared.

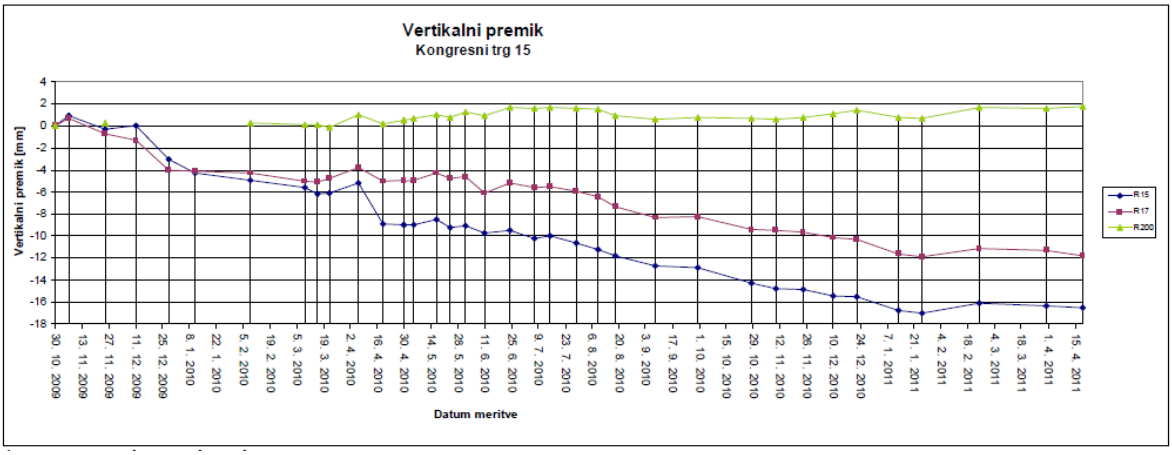

Fig. 4. Geodetic measurements for the neighbouring building with largest displacement during construction (Mlinar, 2011)

3.3. Vibration measurements

Vibrations were measured in cases where high intensity vibrations are expected due to the construction technology employed (e.g. pile driving, use of hydraulic hammers). There is no provision regulating the maximum permissible level of vibration in Slovenia. Therefore, German standard DIN 4150-3 was adopted as the guideline for the maximum vibration level allowed.

Interlocking steel piles were used for modifying the route of the existing sewerage pipes on the site. Their installation causes substantial vibration and although threshold values of vibrations were not exceeded (Kukec, 2011), several window glazings on buildings have cracked; surprisingly, they were not close to the loaction of pile driving.

3.4. Noise measurements

Although not directly linked to the structural health monitoring, noise measurements are an important part of monitoring of neighbouring buildings as well. Long-term exposure to noise affects human health, therefore appropriate measures should be applied. In practice, it can be observed that residents are likely to call the authorities if the combination of vibration and noise continuous over a longer period. If the noise measurements are already taken and results are known, appropriate measures can be taken to prevent the temporary construction site shutdown.

In the presented case, measurements were carried out according to the ISO 1996-2:2007 standard, during the time periods when of the loudest construction works were carried out. These measurements show that permissible levels of noise were exceeded throughout the day, but critical levels were not reached (Ramšak, 2011). Agreement was reached with the neighbouring residents regarding the daily time frame when the noise levels can be exceeded.

3.5. Groundwater measurements

Hydrogeological monitoring was conducted for both levels of groundwater. The height of the lower groundwater is changing slowly, independently of rainfall, as it is a part of the Sava river basin, which runs about 4 km from the construction site. It has no effect on the buildings surrounding the construction site. The height of the upper groundwater layer, however, is changing rapidly and is directly dependent upon the rainfall and possible leakage of utility lines. As such, it can have a significant impact on existing buildings foundation.

Regular measurements of underground water level were therefore conducted during the entire construction of the garage in multiple locations close to the construction site, as well as control measurements in remote areas (Prestor et al., 2011). Measurement results for a typical location are depicted in Fig. 5. The red and the green curves indicate the height of the underground water, and the operation of central cooling system of three large multi-story office buildings located nearby. Peak values of groundwater indicate days with heavy rainfall, however these high values rapidly reduce (i.e. within a few days) after the rainfall to 291,5 m above sea level. During summer months, when the rainfall is scarce and the cooling system of office buildings (that uses water from the nearby Ljubljanica river for its operation) is fully operating, the average groundwater level is at 293,5 m above sea level. The leakage of either inlet or outlet pipeline causes the increase of the water level, and although the drain of water from the soil is constant, the inflow of new water from the cooling system prevented the drop of perched ground water layer until the end of summer. The speed of the drained water can be significant and can cause rinsing of fine particles of soil beneath the foundations that presents significant threat to the garage structure.

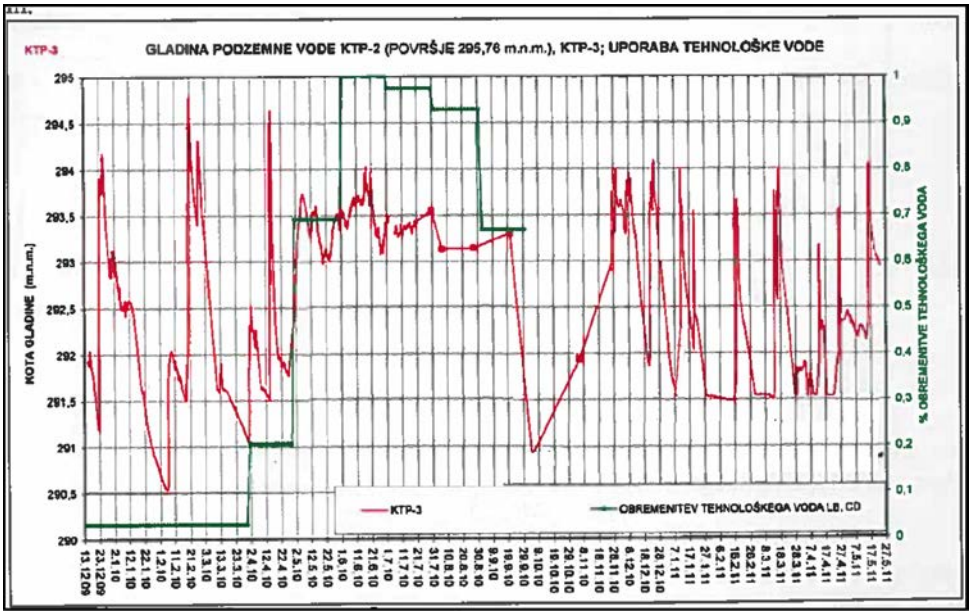

Fig. 5. Perched groundwater measurements – highest mean values were recorded during dry summer months as a result of leakage of central cooling system pipelines (Prestor et al., 2011)

3.6. Inclinometric measurements

During garage construction, its structural elements were regularly monitored as well. Geodetic measurements, deformation measurements and measurements of continuity of the

diaphragm by using inclinometer were conducted. The latter are indirectly connected with the monitoring of neighbouring buildings. Inclination measurements along the vertical diaphragm show horizontal deformation that can result in displacement of fundamentals of neighbouring buildings. Horizontal deformation can be caused by the pressure of the background water or construction pit excavation. No significant horizontal movements of diaphragm were detected during the construction process (Umek et at., 2011a).

4. The suitability of used and proposal of additional methods of monitoring

In complex construction projects, all presented methods have to be implemented, as they prevent the occurrence of serious damage on adjacent buildings. However, they are not necessarily sufficient to prevent the occurrence of moderate damage. As owners mostly have zero tolerance for the appearance of damage on their buildings, based on experience of presented case study, two additional methods of monitoring are proposed.

When use of technology that causes significant vibration is planned, it is required that verification of the surrounding buildings windows is carried out prior to the commencement of works. Old windows with single glazing can crack at vibrations that achieve only half or even less of permissible value. In cases of large number of neighborly buildings with such glazing (i.e. older buildings having the status of cultural heritage), the replacement of selected construction technology with alternative technology, that has a lower rate of vibration, needs to be considered.

In the presented case, the leakage in municipal and other pipelines in the immediate vicinity of excavation proved to be a noticeable problem. The cooling system mentioned above pumped up to 180.000 m3 of water per month. Given the large total amount of water pumped, even a low percentage of leakage can lead to rinsing off fine particles in soil beneath the buildings foundations. The discussion regarding the cause of settlements of four neighborly buildings is still not concluded. Shortly after the start of construction, leakage of a major heating system pipeline was recorded during routine monitoring of upper groundwater layer as its temperature rose to over 30° C; almost 20° higher than normal temperature. The system was leaking with approximate rate of 0,3 l of water per second. Prior to repair of leakage, settlement of the concrete fence in front of the university headquarters has occurred, but direct link between the two events has never been proven.

Based on the two examples presented, it can be concluded that verification of existing pipelines' waterproofing is very important, as with the construction of new structures, the space available for the absorption of water is greatly reduced. Consequently, the rate of underground water flow increases, creates new streams and consequently can cause erosion of soil beneath the buildings foundation.

5. Conclusion

During construction, six different methods of monitoring were used to ensure safety of neighbourly buildings. Despite all measures, some of them displayed visible damage. Two additional methods of monitoring are therefore proposed before the start of similar construction projects to avoid unnecessary damage on adjacent buildings or other structures. The newly acquired knowledge will hopefully be used when similar constructions are designed and executed in the future.

Acknowledgements

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Key Quality Indicators for Performance Based Building of Educational Facilities

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Abstract

The focus in performance concept of all decisions is on the required performance-in-use, and on the evaluations and testing of building asset. Particular application in building consists of translating human needs to user requirements, transforming them into technical performance requirements and quantitative criteria that do not dictate a prescribed solution, but rather compose a means for the investigation of various alternatives. Responding to these requirements during the various stages of conceptual, preliminary and detailed design could enable cost-effective construction of buildings that provide long-term satisfactory performance. Public facilities building projects bring a wealth of social and economic benefits to our communities. Results of literature and case studies review showed the establishment of standardized 'whole building' performance goals and indicators has proved to be a difficult and complex task for the building industry, especially in terms of energy and environmental performance. This is due to the fact that building energy and environmental performance varies significantly based on climate, building type, operational use profiles, and other variables. The main goal of this paper is to present a database of qualitative and quantitative indicators for construction, maintenance and utilization of educational system facilities as well as their possible implementation in performance based building that would lead to more rational solutions and improved management of government budget.

Keywords: educational facilities; qualitative indicators; quantitative indicators; performance based building

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1. Introduction

Public facilities construction projects bring wealth of social and economical benefit to the society. Among the most important sectors in social and economical growth is education, one of the sectors with the biggest allocation of government budget. In designing and construction of these complex projects capital forms public interest, therefore in conditions of limited financial funds there is a need for partial interventions into public space (Gudac et al., 2014).

A facility is a construction, a structure that serves a purpose of sheltering human beings while performing their regular activities. Its main function is to provide comfortable working and living space, and to provide safety from extreme weather conditions. Facility itself has no part in performing these activities, but it can alleviate or aggravate them. An educational facility is a symbol of physical and intellectual replenishment. It represents a place for knowledge transfer and dissipation, engagement of student community in the pursuit for social and cultural connotations.

The initial planning, design and cost calculation phases in educational facilities construction projects are time- and energy-consuming in a way that operational and maintenance phases of a facility aren't even being considered, and are left for someone else to worry about. Once conceived and built, however, these facilities take on a life of their own – often a very long and even permanent life. Whole life costs of facilities constructed in this manner often far exceed design and construction costs (Lavy, 2008). In order to fulfil all the benefits for building users and building itself, first step is to combine both technical and social aspects, together with environmental issues, and establish the basis of qualitative and quantitative indicators for further development of a holistic approach. This paper will try to establish certain criteria that would lead to more rational solutions and improvement of government budget management, and present a possible solution for planning, design and construction of educational facilities.

2. Building requirements

A facility is a structure that shelters people in doing their usual activities, while providing pleasant working and living space as well as protection from extreme weather conditions. Cost reduction is a primary concern to many facility owners and users. Educational facilities' sustainable attributes through their whole life cycle have become one of the focal issues and interest on a global scale. Rapid expansion of educational sector has made institutions and universities large employers and pillars of economical and social growth. The development of educational facilities inevitably leads to sustainability of educational facilities and support they must provide in their long life cycle.

Students, teachers and administrative staff spend more than 30 hours per week in an educational facility environment. Every year the number of students increases, considering the number of interested in higher education. According to research (Krstić, 2011) educational facilities are special on various reasons:

- There is no database on construction costs
- Educational facilities are sometimes considered as monuments and their displacement is not anticipated
- Some of the facilities are half of century old
- Construction, maintenance and use of educational facilities is financed from public budget
- During the year the facility is being used by a large number of people, but there is a short period of time when that number is especially low

As stated in (Khalil i dr., 2015), education buildings serve a purpose in knowledge dissemination and simultaneously function as a "hub" to local communities for various purposes. Their concept and construction technology have to change in order to keep pace with technological and societal changes. In order to keep pace with technological and societal changes, they have to be modified. In an era of declining resources and dramatically changing educational programs, it is essential that those individuals responsible for solving educational facility problems understand the issues if we are to effectively meet the needs of future generations of students. The large number of activities, as well as many connections between them makes up a major challenge when it comes to transparency and responsibilities within

the educational facility management system (Sioshansi, 2011). The initial planning, design and cost calculation phases are time- and energy-consuming in a way that operational and maintenance phases of a facility aren't even being considered, and are left for someone else to worry about. Once conceived and built, however, these facilities take on a life of their own – often a very long and even permanent life. Whole life costs of facilities constructed in this manner often far exceed design and construction costs (Lavy, 2008). Growing number of students, diversification of academic activities with sophisticated equipment and the increase in complexity of research activities that raise the energy cost also contribute to a higher operation cost (Altan, 2010). The technical and social aspects of an educational facility still haven't been explored in a holistic approach, and much work has to be done in that direction. In order to fulfil all the benefits for building users and building itself, first step is to combine both technical and social aspects, together with environmental issues, and establish the basis of qualitative and quantitative indicators for further development of a holistic approach.

The recent trend called "whole building design approach" asks the members of the design and construction team to look at materials, systems and assemblies from many different professional perspectives (El-Haram et al., 2002). The establishment of standardized "whole building" performance goals and indicators has proven to be a difficult and complex task for the building industry (El-Haram et al., 2002; Department of Design and Construction, 1999). In order to achieve certain goals, governments and international bodies are using wide range of laws and regulations to influence the efficient use of energy, management and removal of waste and other construction issues. For example, current construction codes and standards in the Republic of Croatia (Government of Republic of Croatia, 2010) determine minimal infrastructure, financial and human resource indicators for realization and development of primary education.

The increasing importance of sustainability and its wider variety of sustainability issues and drivers affecting and influencing stakeholders with different values, has initiated a debate on the appropriate issues and drivers that provide guidance towards sustainability assessment and improvement in the built environment. Although, at first glance, the wide range of issues may appear inundating, the aim is to reduce the multitude of issues and drivers to a limited set to "keep it simple" as voiced by stakeholders and policy makers (Elmualim et al., 2012).

The common aspirations are to reduce emissions of greenhouse gases through fossil fuel consumption, to reduce the consumption of scarce resources like water, to recycle resources and waste less, to reuse materials wherever possible, to use renewable resources, and to improve occupant comfort and well-being (Reed and Wilkinson, 2007). One of the important factors researched is the effect of maintenance of construction materials on the built environment sustainability. The current challenge is to create sustainable buildings, which are also healthy and comfortable (Van Ree, 2010), climatically-responsive, and in tune with its environment and context (Bougdah and Sharples, 2009).

One of the building sub-systems is workplace planning, linked to a complex social system. In the initial stage of a multi-user organizational project such as educational facilities the customer is divided into many departments (students, teachers, visitors, or non-academic staff). In the initial stage of the project there are a lot of specifications and wishes, many of them in contradiction to each other. The identification of valuable requirements in the facility management aims for a "good" solution among numerous working environment solutions that can be considered acceptable (Pennanen et al., 2005). Key indicators could answer the question on what are the criteria that differentiates the chosen solution from the bad ones and from the other good ones.

The key environmental end-users' objectives seem to be quite homogeneous. Energy consumption is the most important objective followed by waste minimisation and recycling. Furthermore, reduction of gas emissions seems to be increasingly important (Nousiainen and Junnila, 2008). A study by Elmualim et al. (2012) shows answers to questions about issues relating to sustainability policies and reports on waste management and recycling, energy management and carbon footprint, which are the key aspects covered by their sustainability policy respectively. Health and safety, and sustainable travel are also identified. Other aspects are targets, measurement and reporting, ethical purchasing and community engagement, specification of sustainable products and services. Only one third of the respondents reported that building disposal, biodiversity and staff productivity has coverage in their policies. Similar studies on a wider urban area was performed by Hanak et al. (2014), where the

indicators such as safety, clean air and noise were detected and weighted by a local population in order to determine the key indicators for policy makers.

In a study by Wan-Hamdan et al. (2011) authors emphasize eight most important elements in facilities management processes for National Higher Education Strategic Plan: sustainability, maintainability, flexible corporate real estate, information technology, optimum space utilisation, effective layout, financial management monitoring and increasing productivity operation. The sustainability elements need to be addressed in ensuring smooth operations and organization activities, for the guarantee of having the function and durability in the long run. The maintainability elements are essential for life span - facilities should be well maintained, to ensure value for investment and good condition. Flexible corporate real estate elements ensure flexibility in terms of space management, asset management, furniture and fitting, machinery equipment, building fabrics etc. The information technology (IT) element is stated as an important element because organisations depend on the information as one of key resources. In addition, information has high contribution and influence in communication and decision-making. Without proper and appropriate IT main business processes might be affected, especially in higher education institutions as centres of knowledge. The optimum utilisation element comes from minimizing wasting space in terms of building effective space, space function, tasks, activities and occupancy. Effective layout is not only the main optimum utilisation output but also assesses the space flexibility to meet the users' needs, the ability of the work areas and functions restructure as well as the ability for it to change into new operational activities. Financial management monitoring is an element that aims on producing high value output with lowest operation cost. Increasing productivity operation is an element with several factors such as air quality, noise control, thermal comfort, privacy, lighting and spatial comfort that are highly significant for education institutions.

From the case studies made by Nik-Mat et al. (2011), the priorities of the three major maintenance elements (service characteristics, building services and building image) from end users perspectives were analysed. It was found that the end users choose reliability as the first and foremost priority in service characteristics followed by responsiveness and assurance. End users have also placed cleaning, safety and security in the top most important building services. Priorities of building image were also analysed in (Lepkova and Uselis, 2013) and end users are in consensus with Internal Image as the top priority of building image as opposed to External Image. In case of bad economic situation, it is useful to minimize the scale of maintenance as much as possible but avoid crossing the limit below which the building condition deteriorates faster and the economically viable term of use shortens. For instance, laying a mud rug in the staircase might seem a needless waste of money; however, if refused, it increases the cost for cleaning significantly.

Traditionally, the design of learning and research space is the architects' responsibility. Architects usually don't have the perception of functionality and purpose of space they are designing. The perception of end users is extremely important for the insight in needs, experience and methods of use of classrooms, laboratories and educational facilities as a whole. The needs, thoughts and wishes for improvement were investigated in the study (Ramli et al., 2013), where students and teachers were analyzed to gain insight into their perspectives, demands and interests in the use of educational facilities. The survey showed dissatisfaction with temperature and spatial comfort, which greatly affects the learning process, as well as the lack of the IT equipment. The study noted a well-known problem of space design without the involvement of end users. Student's, teacher's or pedagogical view is important given the particular perspective of the area that was designed, and is of great importance in the creation of integrated solutions for the improvement of educational facilities.

3. Qualitative and quantitative criteria

The reasons for determining the indicators are various (Department of Design and Construction, 1999): raising expectations for the facility's performance among the various participants; ensuring that capital budgeting design and construction practices result in investments that make economic and environmental sense; creating partnerships in the design and construction process around environmental and economic performance goals; saving taxpayers money through reduced energy and materials expenditure, waste disposal costs and utility bills; improving the comfort, health and well-being of building occupants and public

visitors; construction of design buildings with improved performance which can be operated and maintained within the limits of existing resources; stimulating markets for sustainable technologies and products. The need for defining objectives, strategies, benefits and performance goals through indicators is pointed out by the government of Republic of Croatia in its "General program for construction and reconstruction of public facilities according to public-private partnership" (2012). Planning a new educational facility through use of qualitative and quantitative indicators represents a major opportunity for building optimization in an integrated way. By carefully selecting construction sites, design and construction planning from the beginning phases of a building life-cycle, significant capital and operating savings can be made. The indicators can apply to either renovation or new construction.

By incorporating environmentally sound materials and systems, improving indoor air quality and day lighting, the facility will be improved in the value of its interior public spaces and indirect returns through improved health and well-being of students, workers and other building occupants or visitors. The indicators that identify costs and benefits, thus encouraging long-term (life-cycle) approaches to capital decisions, as opposed to those driven solely by first cost are shown in Table 1.

Table 1. Qualitative and quantitative indicators (modified from Department of Design and Construction, 1999)

City process	Design process	Site design and planning	Building energy use	Indoor environment
program planning	client awareness and goal setting	understanding the site	site and massing considerations interior layout /spatial design	good indoor air quality (IAQ)
site selection and planning	team development	building-site relationship	building envelope day lighting/sun control	light sources, views to outside
budget planning	well-integrated design	sustainable landscape practice	light pollution high performance lighting	noise control, acoustics, vibration
capital planning process	resource management	encourage alternative transportation	electrical systems and equipment energy sources	thermal comfort spatial comfort, way finding and orientation
financial management monitoring	optimum utilization/ workplace planning		mechanical systems	privacy
flexible corporate real estate			energy load management	controllability of systems
Material and product selection	Water management	Construction administration	Commissioning	Operations and maintenance
selection for a healthy indoor environment	minimize the use of domestic water	environmental and community considerations	fully integrated operating systems	operating and maintaining building systems
selection for resource efficiency	water quality	health and safety	commissioning existing buildings	healthy and efficient custodial operations
selection for external environmental benefit	water reuse	construction and demolition waste management		waste prevention and recycling

The main idea in creating the basis for indicators database was the consideration of project's present and future anticipated capital requirements, as well as community and environmental impacts. The indicators were selected through a technological aspects such as cost, durability, functionality, performance and aesthetics of the building, as well as sociological aspects of enhancement of the indoor environment and positive contribution to

occupant's well-being and productivity through thermal and visual comfort, acceptable indoor air quality, humidity and acoustic quality. Collaboration among the various design disciplines and interdisciplinary design and resource management are critical factors for optimizing the performance of each of the building's components and systems, consideration of environmental and health issues and preservation of site resources and conservation of energy and materials during construction and in ongoing building operations. Optimized design should be energy efficient, reduce operating and custodial costs, avoid future excessive maintenance and repair costs and improve the building's long-term environmental performance with encouraging better waste management and lower energy consumption.

4. General idea of performance concept

The performance concept or approach in building is not new and can be traced back thousands of years. King Hammurabi stated the first regulation on building through the aspect of user requirements in Hammurabi's Laws nearly 4,000 years ago where is in Article 229 stated that "the builder has built a house for a man and his work is not strong and if the house he has built falls in and kills a householder, that builder shall be slain" (Gross, 1996). None the less this statement addresses only one aspect of user requirements of the house, it clearly addresses structural safety. About 2,000 years later, Roman architect Marcus Vitruvius wrote "Ten books of architecture" where he gave detailed descriptions on how buildings should perform to meet user requirements (1997). Although the concern with in-use performance is very old, it is in this century that formal performance concept methodology was developed and applied.

General idea of the concept was summarized by Gibson (1986) in the definition "the performance approach is the practice of thinking and working in terms of ends rather than means". In building, performance approach is concerned with what a building or a building product is required to do, and not with prescribing how it is to be constructed. Performance-based building focuses on the target performance required for the needs of the users, their fitness for a building purpose, or fitness of a building product or service.

User requirements may include various aspects, such as technical, psychological, physiological and sociological. These aspects are generally described as objectives for the building to fulfil. They are generally first thought of in qualitative terms, stated as a performance goal for the design team: "Building should provide a suitable standard (technical, psychological, physiological and sociological) for the planned activities or occupants". Through the building specialists qualitatively stated end-user's goals and objectives become performance requirements defined in quantitative terms (Gibson, 1986).

The performance concept of building is widely acclaimed and is applicable to both building procurement (design and construction) and to regulation (control), but has not been widely applied. It is based on two key characteristics: the use of two languages (one for the clients/users and the other for the supply of the performance) and the need for validation and verification of the results against performance targets. The use of two languages is shown in the "Hamburger model" as the performance-based building model, first used in Netherlands by Ghieling in 1986. The model (shown in Figure 1) represents the facility that distinguishes the Functional Concept on the demand side and the Solution Concept on the supply side of the building process. Performance concept offers the "performance language" to overcome the differences between functional needs and technical solutions.

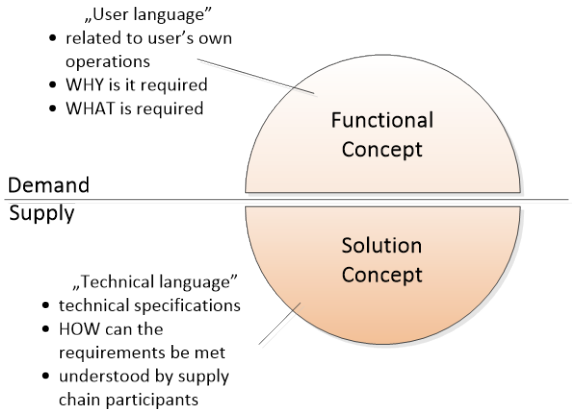

Fig. 1. The "Hamburger Model" – User versus Technical language (Spekkink, 2005)

With often wrong assumption that client knows what he wants and can clearly articulate it, a gap enlarges between clients and designers. The inexperienced clients may find difficulty in understanding the construction process, which affects them to specify the necessary requirements (Shen et al., 2013). The AEC (architecture, engineering and construction) industry has to turn not so clear client requirements into more accurate requirement descriptions or attributes. Archer (1968) defines the design process as involving four interlinked phases: (1) problem analysis, (2) solution synthesis (3) evaluation and (4) communication. The communication between different participants usually goes through the whole design process. During the briefing and design solution development process, the designer-client communication is intensive and significant (Shen et al., 2013). The client is capable of ascribing experiential qualities to buildings and other spaces; however no possibility of ascribing this to the virtual building when confronted with plans, sections and drawings. What he can do is to convert ascriptions of experiential qualities of the virtual building made by the architect into consequences to which he can relate his experiences as a building user (McDonnell and Lloyd, 2014).

Any building forms a system with a number of sub-systems, characterised by a large quantity of indicators that need to be considered during the design process. Spekkink stated that the performance concept can be applied to different levels of a facility in terms of demand and supply, as it is shown in Figure 2.

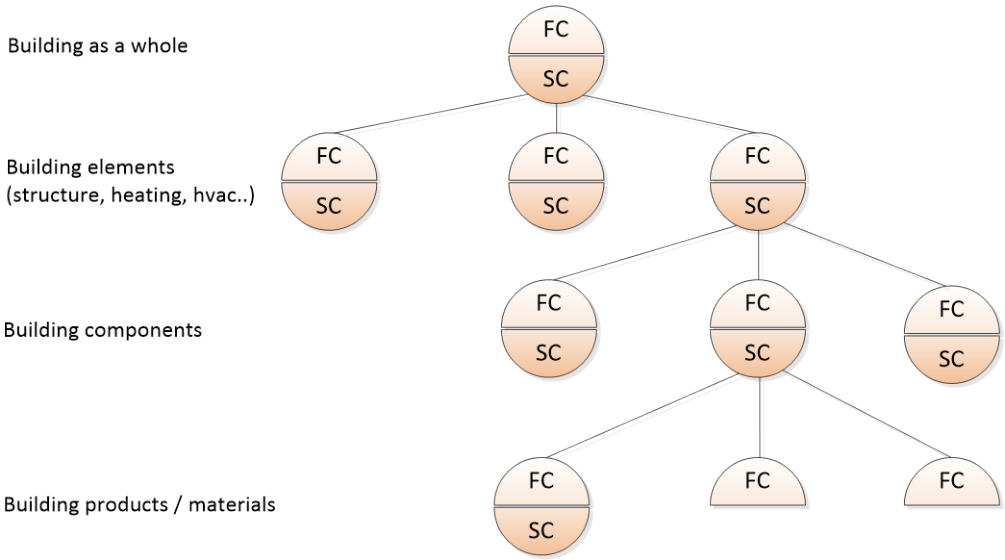

Fig. 2. Performance-based building applies to different levels of a built facility (Spekkink, 2005)

Usually the design process involves various design and engineering disciplines – architects, engineers, and others – which design, analyse and optimise different levels – building elements, components or materials separately. Nevertheless, all building parameters are inter-

related and affect each other. In order to optimise the dynamic interaction between different building systems and components, as Hensen previously stated in his research (2003), it is necessary to use a holistic design approach.

With performance language required performance can be defined using a variety of criteria. A criterion is a standard of performance against which the adequacy of a performance attribute can be judged. The client's requirements have to be interpreted in terms of the actual products from which buildings are created – ranging from large-scale industrialized components to basic materials – and reflecting the ways in which elements of construction can be designed and built in practice (Hensen, 2003). Although some requirement specification models have been established, it appears that there is still a lack of a systematic method to assist the clients to define the requirements and review design solutions against these requirements at the design stage, especially when based on a virtual environment (Shen et al., 2013). One method for simulating user's requirements in the construction industry is performance concept. With the support and communication between different project stakeholders, user's requirements could be easily analysed by the AEC industry.

While we have come a long way from "trust me, I'm an engineer", there is still much research needed, which pays close attention to the fine details of how design decisions are made and what are the types of justification suitable for different audiences, in a way that takes account of what it is reasonable to expect can be communicated, and under what circumstances (McDonnell and Lloyd, 2014). Performance based building is a means to enhance the professionalism and the client orientation of the building design sector. This implies designing building systems to provide a choice of multi-configurable components or products to shape not only the space today, but also the space required tomorrow.

The indicators stated above should set out a range of "best practice" for planning, designing, constructing and operating healthier, more energy – and resource – efficient facilities. By defining minimum and maximum values of qualitative indicators, clients/end-users can choose preferred value of any listed indicator. In case of educational facilities, end-users can be defined as investors (local or state government or private partner) or users such as teaching or other staff. The standard system must be brought into relation with structure classification according to the structure (educational) purpose – nursery schools, pre-schools, primary schools, faculties, or other public facilities with health, cultural or judicial purpose. The main spatial, technical, energy, function, quality and cost standards must be determined, as well as the limits of minimum and maximum standards. Educational facilities are symbols of physical and intellectual replenishment, and once conceived and built, take on a life of its own, a very long and even permanent life. Defining, developing and implementing performance concept in educational facilities management will provide an alternative method to improve the effectiveness of the designer-client communication and translating human needs to user requirements, thus enabling cost-effective construction that provide long-term satisfactory performance.

Indicators stated in the paper are just the starting inputs in suggested and quite obviously needed database of standards. Further research goes in the direction of establishing the database of standards and quantifying the stated key indicators, giving them minimum and maximum limits according to the facility type and purpose. The suggested performance language implementation is an idea of converting ideas, wishes and requirements into feasible possibilities and solutions with key indicators as guidelines for end-users, whether they are familiar with construction industry or not. With quantifying the indicators, a model for building cost calculation can be made, thus leading to more rational solutions and improved management of government budget.

5. Conclusions

Educational facilities building projects bring a wealth of social and economic benefits to our communities. An education building is a place for teaching and learning, and serves local communities for various purposes. In order to keep pace with technological and societal changes, they have to be modified. The large number of activities bring up a major challenge when it comes to transparency and responsibilities within the educational facility management system. Once built these facilities take on a life of their own – often a very long and even

permanent life. There is a need for a "whole-building" approach on the technical and social aspects that benefit both building users and the building itself.

Among many reasons for difficulties in communication between the AEC industry and the clients, poor management of stated requirements is one of the most important, resulting in lack of satisfaction with end results. In terms of the construction development process, professionals in construction industry (architects, engineers and others) have a better understanding of construction problems and can develop various solutions based on their knowledge and experience. Transmitting the knowledge in a form of information easily understandable to clients is a key factor in improvement of designer-client communication and realisation of client's requirements. The language of performance can become the basis for harmonization and globalization of building codes. Particular application in building provides an alternative method to improve the effectiveness of the designer-client communication, translating human needs to user requirements, transforming them into technical performance requirements and quantitative criteria that do not dictate a prescribed solution, but rather compose the means for the investigation of various alternatives, and responding to these requirements during the various stages of conceptual, preliminary and detailed design to enable cost-effective construction of buildings that provide long-term satisfactory performance.

Defined qualitative indicators should set out a range of "best practice" for planning, designing, constructing and operating healthier, more energy – and resource – efficient educational facilities. Further research goes in the direction of quantifying the stated qualitative indicators, giving them minimum and maximum limits. With quantifying the indicators, a model for building cost calculation can be made, thus leading to more rational solutions and improved management of government budget.

Acknowledgements

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Economic Aspects and Particularities in Building of Lightweight Tensile Structures

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Abstract

Indisputable advantage of a lightweight tensile structure lies in the minimum weight of used material. This is a cost effective solution that provides long spans of column-free space that cannot be achieved with other types of structures. These structures are interesting to observe from a design, building and management point of view because of the produced effect of the original design and the savings provided by the use of uncommon materials. Except because of the material, project benefits can be found in the production quality and erection speed due to high level of prefabrication. Furthermore, disassembly, transportation, reuse and recycling can be accomplished in an easier way in comparison to traditional construction methods. Also, energy savings are possible owing to soft diffused natural light and reflective qualities of used material which enables temperature stability. Because a non-linear analysis is required to shape a tensioned roof, this type of structures are lately subject of many modeling studies. However, there has been little written on the aspects of construction management and economic benefits of these structures and therefore this area demands further detailed examination. For this reason, this paper gives a literature review which emphasizes various benefits that these types of buildings bring to projects. The review especially focuses on the technology and particularities in the building process of the lightweight structures against the traditional built alternatives.

Keywords: lightweight tensile structures, project benefits, energy savings, construction management, technology and organization

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1. Introduction

The lightweight tensile structures, both temporary and permanent, have been present for over 50 years, ranging from simple free standing shade structures to complex wall and roofing elements that shape multiform buildings (Wakefield, 1999). Once it is build, the exciting architectural form of lightweight structure often becomes the symbol of the city. The lightweight structures are not only visually exciting and structurally interesting, but environmentally sensitive and economically competitive as well (Shaffer, 1996). The need for wide span enclosures has greatly increased to accommodate and facilitate the collective activities of the society. The tensile membrane structures can provide the advantage of enclosing large spaces using a minimal amount of material and rapid erection (Elnokaly et al., 2002). Potential investor interest for lightweight tensile structures is often based exactly on these two advantages. Because of the lightweight material, structures are extremely efficient in long span applications and the possibility of prefabrication makes the building process quicker and less stressful. The purpose of this paper is to carry out a state-of-the-art review of the economic aspects of lightweight tensile structures. Because of all special features of lightweight structures, the economic aspect, as well as the roll of construction management, is observed in all stages of project, from design and erection process up to final usage. Special emphasis is placed on the particularities of the building process and used technology. The building particularities that are presented in this paper generally apply to all types of lightweight structures but main focus is put on the tensile fabric structures.

(a)

(b)

Fig.1. (a) Ab-o-Atash Amphitheater (2009), Iran (Maffeis Engineering S.p.A.); (b) Al bayt Stadium (2012), Quatar (Maffeis Engineering S.p.A)

2. Particularities and benefits of lightweight tensile structures

"The design of lightweight stressed membrane surface structures has traditionally been set apart from that of more conventional structures. This is not because such design is particularly difficult, but rather that it is sufficiently different to require specialist treatment" (Wakefield, 1999).

As Shaeffer and Huntington (1997) had explained the conventional structures rely on internal stiffness to achieve stability and carry loads. On the other hand, lightweight structures are constructed of elements that have little or no bending or shear stiffness. Due to that, lightweight structures rely only on their form and internal prestress. These structures are behaving highly non-linear due to significant changes in geometry that occur under the load. That causes a different design approach. If the structure is designed properly, non-linearity can also be a desirable quality since the capacity of the structure to carry the load increase as it deforms. Actually, lightweight structures have a very high ratio of applied loads to self-weight in comparison to steel and concrete structures of the same spans. Horst (1999) gives a great example from a project he was working on: the weight of the Denver roof is 10 kg/m^2 and that is one-fortieth the weight of the most intense snow accumulation which this roof carries. Except the long span application, another mentioned advantage is shorter installation schedule enabled by the combination of high level of prefabrication and modern construction

techniques. Variety of tensile membranes allows a choice between performances corresponding to the flexible deployable application or the permanent durable structure. In comparison with conventional structures, fabric removal and even reinstallation can be accomplished as another special possibility provided by lightweight structures. According to their degree of movability, Canobbio (1995) classifies lightweight structures as:

- fixed/permanent,
- movable/seasonable,
- itinerant.

As it was pointed out in Tensioned Fabric Structures (1996) the cost of lightweight tensile structure varies widely with the choice of fabric and other parameters. Whether the structure represents cost savings or a cost premium depends on the type of structure with which they are compared. Cheapness of considered architectonic and functional aspects which are influencing the ratio cost/benefits in realization of lightweight structures is determined by the costs of designing, materials, production and erection.

Table1. Approximate cost distribution in a lightweight tensile project (Canobbio, 1995)

Structure	Project	Membrane	Bearing str.	Accessories	Erection	TOTAL
Fixed	10%	30%	40%	5%	10%	100%
Standard temporary	5%	40%	50%	1%	4%	100%
Itinerant tensioned	7%	49%	40%	1%	3%	100%
Airdome	5%	50%	5%	36%	4%	100%

Commonly lightweight structures are seen as seasonal or temporary primarily due to false assumptions about their permanence, strength, durability or energy efficiency (Barden, 2006). Properly designed and constructed fabric roofs generally require very little maintenance until occurrences such as degradation caused by UV radiation or other sources necessitates the replacement of the fabric. Because of developments in the field of membranes materials, the durability of tensile membrane structures has also increased. In general, fabrics are characterized by low insulating ability, low thermal mass, low moderate translucency and interior climate and high reflectivity of light. These characteristics have made their usage effective in warmer climates. In these conditions, the low insulating value does not result in high heating loads and the reflectivity reduces heat gain. The translucency can be utilized for natural daylight, thereby reducing lighting cost as well as the cooling of loads resulting from the heat produced by the light fixtures (Shaffer, 1996). Achieved translucency with most often used materials is around 25%. For usage in cold climates, it is possible to achieve thermal insulation similar to conventional wall and roof structure, but the profitability of the project is then questionable. The benefits of the environmental performance of a membrane structure can be multiplied by adding the possibility of generating free, clean energy from the sun. All parts of the exposed surface can be made with a thin film solar cell laminated into the membrane creating a translucent roof and offering free energy throughout the year. In a study carried out by the Mundo et al. (2009), the membrane can generate up to 534 MWh/yr in Mexico and 156 MWh/yr in the UK. Another advantage is the control of the acoustics by sound dissipating surface geometry combined with sound absorbing fabric surface. Due to the all mentioned characteristics and advantages, lightweight structures are most often used to build sports and event facilities, public buildings and traffic facilities like airports and train stations. The smooth surfaces of the membrane in combination with usage of creative lighting

in these kinds of public places can transform the structure into unique marketing tool providing the perfect background to display logos or corporate imagery.

3. Role of the construction management in building lightweight tensile structures

Even if lightweight structures appear as simple and elegant, behind the simplicity stands a great amount of specific and complex experience and knowledge of form finding and their specialized detailing. Bridgens et al. (2004) explain that in order for the lightweight structure to resist both uplift and down-forces (wind and snow) the surface has to be doubly curved and prestressed. It is highly important that the membrane shaped surface is minimal in order to achieve uniform stress distribution on the fabric. Non-linear fabric behavior, large displacements and the use of membrane action to resist loads, requires different approach in comparison to traditional structures. All of that demands the structural engineer to be versed in the usage of non-linear analysis computer programs required to shape and analyze a lightweight construction (Shaffer, 1996). Except the design, the lightweight structures are interesting from the construction management's point of view. Aforementioned advantages and disadvantages make an interesting ratio when it comes to question of time and costs of construction procedure as well as the costs of maintaining and final usage.

As it is known, it is sometimes hard in construction management to separate the economic and technical fields of activity. Seidel (2007) emphasizes that this particularly applies to wide-span lightweight structures where beside the finance and time, the method of construction depends on the material properties and the engineering design. Specificity of this type of structures is the dependency of the architect on the assistance of specialized engineers. From the form finding and patterning, to detailing and planning the erection, collaboration is essential between the architect, the engineer and the consultants representing companies responsible for production and erection. Lightweight tensile architecture represents a small portion of the construction market. Because of that, there are few specialized erection companies, but usually with wide experience in project development and implementation. The planning of larger-scale projects is mostly the responsibility of engineers so the structural engineer usually collaborates with specialized consultants (Seidel, 2007). An important factor in the scheduling process is the time required for project coordination. Teschner engineering consultancy in correspondence with Seidel (2007) claimed that the project coordination will have less impact if only the client, the architect and the structural engineer are involved. But in the case of agreements concerning contractual matters, formal decision and alterations between the client and consultants can use up to 50 % of the time allowed for the project implementation. After the design and form finding process, the determination of erection procedure is following. In the field of lightweight construction, a multitude of special structures is erected with even more varied solutions. To prepare the erection, the construction manager has to face with challenging technical demands for the production of erection schemes. Experience is a huge factor with this type of structures because of the application of highly developed materials and the complex load-bearing structure. The knowledge of design, production, transport, assembly and supervision plays a key role in the optimization of erection cost and construction time. Construction engineering implies the creation of all the documents for the individual assembly units and the coordination of design, production, transport and erection. It also includes making decisions about the size and geometry of erection units, as well as lifting capacities, temporary construction and erection sequence. In the case of lightweight structures it is crucial to exploit the possibilities of industrial production as much as possible. To summarize, the importance of the construction engineer is maybe best seen from Seidel's (2007) list of the fields that are his responsibility:

- advice about erection in the design process,
- creation of an erection plan,
- determination of the erection procedure,
- production or organization of all structural design checks for temporary conditions during erection,
- checking the alignment of the cut-out strips considering the erection sequence,
- checking the practicality of details and working drawings for the erection,
- production of all temporary work drawings and erection instructions,
- creation of a folding and packaging scheme,

- production of all construction component and transport lists,
- specification of all scaffolding, erection equipment and temporary works,
- organization of the site set-up
- supervision and documentation of the erection implementation.

One of the most important things in ensuring successful and trouble-free construction process is certainly scheduling. To effectively manage, supervise and control the sequence of work and progress in a larger project, Seidel (2007) advises to use a multi-stage planning system which is divided into general, project and detailed deadline scheduling. Project schedule includes dates determined for structural design, production design, ordering of materials, production, delivery of materials and erection. A detailed program of works containing the exact sequence of erection should relate to:

- construction site setup,
- provision and installation of erection equipment,
- preparation and preassembly work,
- implementation of the erection according to components,
- dismantling of cranes and other erection equipment,
- clearing the site (Seidel, 2007).

The size and complexity of the structure determines the time required to complete a lightweight project. From schematic design to design and achievement of building permission through the manufacture of materials and completion of the erection, the entire process normally lasts an average of 6 to 9 months. If the construction project is more ambitious and the structure more complex, for example the roofing over of a stadium, then the overall duration till handover can require 12 – 15 months. These time limitations are based on the experience of the company Ceno Tec specialized for tensile membrane structures (Seidel 2007).

4. The particularities in the erection procedure of lightweight tensile structures

Erection procedure is the gathering of the erection and assembly activities of prefabricated construction elements and units in the view of forming a structure. The erection procedure of lightweight tensile structures is influenced by many parameters that are concisely shown in the Fig. 1.

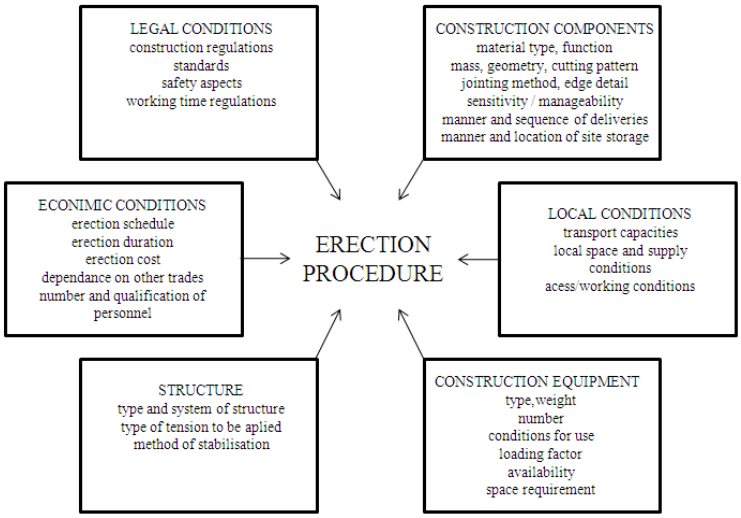


Fig.2. Diagram of parameters influencing the erection procedure of lightweight structures (Seidel, 2007)

After summarizing all the demanding tasks in the field of production, delivery and assembly of lightweight tensile structures, Seidel (2007) considers that the creation of erection schemes within the erection process is based on:

- the working principle of the structural system,
- the type of construction equipment used,
- the type and jointing of the materials to be used,
- the production, delivery and transport practicalities,

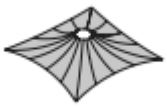
- the local conditions on the construction site.

4.1. Working principle of the structural system

Flexible load-bearing elements are divided into groups according to the type of support as:

- membrane surfaces supported at a point – mechanically tensioned high point and awning surfaces, whose edges are anchored to the primary construction from inside or outside at points,
- membrane surfaces supported along a line – mechanically tensioned arch and wave surfaces, which are edged by linear elements,
- membrane surfaces supported over the whole area – pneumatically tensioned pillow constructions and air supported halls, whose surfaces are supported by the increasing or reduction of pressure (Seidel, 2007).

Table 2. Types of membrane structures (Seidel, 2007)

supported at points	supported along the lines	supported by air
High point	Arch	Element pillow
		
Ridge and valley	Arch	Large pillow
		
Awnings	Arch	Hall
		

Flexible load-bearing elements have unstable form without pretensioning which leads to insufficient load-bearing capacity. That is causing differences in the erection states in comparison with conventional structures. For membrane structures, a structure loading on the construction elements during the erection is mostly higher than in the final completed state. The stability and structural safety of the entire structure is therefore compromised. Also, large deformations and oscillations can be caused by loading during erection, especially when flexible and stiff structural elements stabilize each other in the completed state. For the erection of a membrane structure, it is required to evaluate the strength and stability behavior in the structural system as well as the type of interaction between the primary and secondary structural elements. By the stability in erection state which affects the erection procedure, constructions can be divided in two groups (Seidel, 2007):

1. In the first group, primary structure is stable on its own without the flexible load-bearing elements. Any sub-structures may have to be stabilized before the installation of the membrane surface using ropes, belts or lightweight devices. The sub – structures are designed for erection state loadings and may have to be articulated. Temporary membranes and nets can be fixed to the primary structure, if the load-bearing capacity is sufficient, to provide anchorage locations for tensioning devices and equipment.
2. The second group consists of structures, which only have sufficient stability through the interaction of stiff and flexible elements. The temporary stabilization measures have to be provided for the primary structure during erection. The loads acting on the structure are only in equilibrium in the final state. The primary structure must be supported, held or anchored at all essential points until the structure is complete. Adequate anchorage points must be available for staying with tie-downs or ropes. This can be done with additional holes in fixed parts of the structure or the provision of temporary foundations.

4.2. Construction equipment

The erection of flexible sheeting and cables includes procedures like laying out, lifting and pulling into place, hanging and pre-tensioning which requires the use of specialized equipment and techniques. Main type of construction equipment used are lifting and tensioning tools as well as load attachment equipment belonging to them. Surface and linear elements used in membrane construction have to be lifted and installed on the construction site at great heights. The personnel entrusted with the construction must be qualified for the preparation and assembly work on site as well as cable-supported work.

(a)

(b)

(c)

Fig.3. (a) membrane hanging (Fabric investigation, 2013) (b) cable-supported work (Ceno Tec) (c) erection of a high point structure (Seidel, 2007)

The selection of suitable erection equipment depends on erection procedure. The erection of membrane structures is done by cranes and small lifting equipment. Wegener (2003) warns of the big influence that cranes have on total erection cost, due to their very high investment cost. The effectiveness and cost of the erection progress are determined by the number and type of cranes as well as the duration of use. The application of listed equipment considers high rental costs and requires exact planning of the duration of use. Cranes also influence the working environment and the organization of erection on a working site. In addition to load capacity, the lifting height and the terrain capability has to be considered. The most common types of cranes for the erection of membrane structures are presented on the Fig. 3.

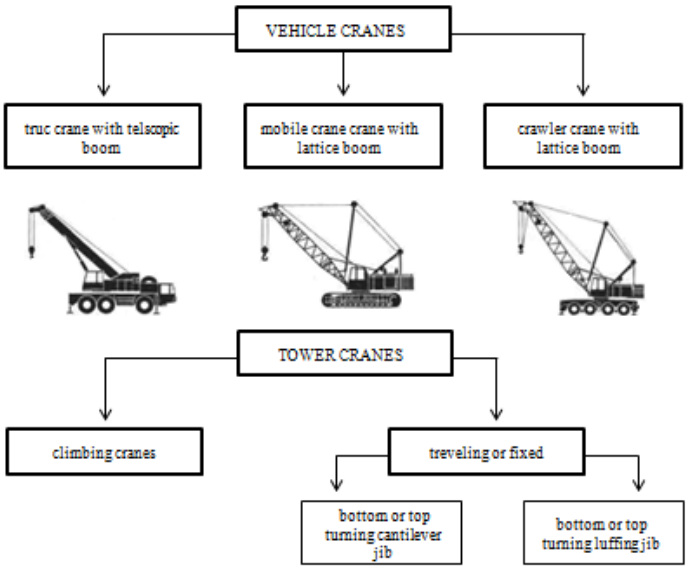


Fig.4. Diagram of crane types used in erection procedure of lightweight structures (Seidel, 2007)

Cranes with wheels are mostly used for erection work. Mobile cranes can move with limited speed and therefore they are mostly used within a small radius. Crawler cranes are useful for the installation of heavy elements especially in unfavorable terrains. Truck cranes are flexible which makes them the most-used large lifting devices in steel and membrane erection. They are very useful for short and quick changes in erection applications. For the lifting of loads to great heights tower cranes are used (Petzschmann et Bauer (1991). In rare cases, when access by road is restricted or impossible, helicopters can be used as transport and erection tools. Flying erection is very dependent on the weather conditions and can be dangerous. Also the lifting capacity is restricted. The preparation work is extensive and experience in erection work with swinging loads is needed. The cost of helicopter lifting is very high and special permission for the flight has to be obtained (Seidel, 2007).

Temporary structures are also needed for operations involved in the erection process. They serve as anchor points for temporary stabilization cables and as platforms for crews to perform the operations required in the erection. The support systems includes: hanging scaffold, wheeled scaffold and working platforms.

(a) (b)

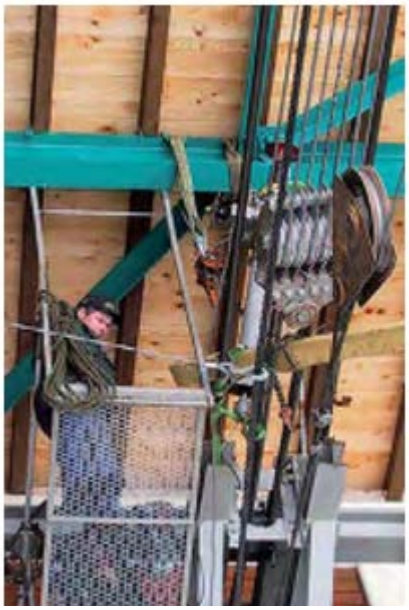
Fig. 5. (a) hanging scaffold (Ceno Tec); (b) wheeled scaffold (Ceno Tec)

Introduction of tension into the flexible load-bearing element is the most important process in erecting membrane structures. The method of pulling the edge is really a question of economy. The design of the edge details and the precise development of tensioning concept are important if we want to take the advantage of cost-effectiveness of lightweight structures. In order to reduce the unnecessary costs Seidel (2007) proposes that the construction company hands out a complete drawing list with:

- clear description of the component with details of weight, dimensions and maximum permissible loads,
- details of erection position, installation and transport location,
- number and layout of the panels to be erected and the assembly joints,
- details of assembly location, process and aids,
- details of stability, maximum loads and strengths,
- lifting points for lifting and transporting on the construction site,
- description of the connection points for applying the pretension.

The edge connection is assembled on the site by the construction firm while the edge hem or keder seams are prefabricated. Inauen in an interview at Vienna Technical University (Seidel, 2007) warns that the tensioning equipment for wire ropes can only be moved with a crane due to considerable weight, so the time taken to set up and relocate this equipment can take up to several days. Because of that, erection is more economical as lower numbers of tensioning set-ups are required and the equipment is lighter and more manageable. The application of lifting and pre-tensioning devices also needs to be taken into account in the design of the connections. Tensioning devices have a different mechanism which can be electrical, hydraulic or mechanical. Tensioning of membranes is usually done with hydraulic presses, tirfors, chain hoists or ratchet lever hoists, with the appropriate ancillary equipment. Hydraulic presses and strand tensioners are the equipment mostly used to tension wire ropes with high forces (Seidel, 2007).

(a)



(b)

(c)

Fig. 6. (a) electrical; (b) hydraulical; (c) mechanical tensioning device (Seidel, 2007)

4.3. The materials and the types of jointing

Already in the name of membrane structures we can see that the most important and defining component is fabric itself. Membrane structures are also often called textile structures. The material they are made from has a heterogeneous structure which consists of the textile core that represents load-bearing layer and the protective coatings ensuring the impermeability and protection from the influence of the sun and the chemicals in the atmosphere (Milošević et al., 2013). The most common materials used for textile core are fiberglass, polyester, nylon and aramid. The coating is usually made from polyvinylchloride (PVC), polytetraflouroethylene (PTFE) and recently silicon. The most popular combination of materials is PVC-coated polyester, PTFE-coated fiberglass and silicon-coated fiberglass (Fang, 2008). For air supported structures multi-layered ETFE (ethylene tetrafluoroethylene) foils are used.

The advances in the field of membrane structures are mostly related to developments of new materials with improved performances. To ensure that the membrane structure will be

able to resist static loads, expansion behavior of the material used has to be determined through biaxial test. Because of the heterogenic structure, difficulty with connecting the membranes parts appears. Connections are established through welding. Welded seams are pre-stressed during the welding process to prevent shrinking along the direction of the seam. High-frequency weld is used for PVC coated poly fabrics. The seam is placed between electrodes, heated and pressed together. In the area of the seam achieved, fabric strength is 70-90%. Heat weld is used for PTFE coated fiberglass fabric. In this case, the seam is placed between metal bars, heated, pressed together and then cooled. Quality of seams is ensured by correctly setting the temperature, weld time, pressure and cooling under pressure parameters. Also, due to the material's high bend sensitivity, careful handling of the material and the use of matched machine technology are required to assure good quality. With a procedure like that, 80-90% of fabric strength can be achieved (Fabric Investigation, 2013). For ETFE foils, heat pulse weld and laser weld is used. The seams are mainly made in a factory where conditions can be controlled. PTFE materials are more durable in comparison to PVC materials (Table 3). Milošević et al. (2013) had noted that they are also more expensive and very sensitive to double-axe folding which makes them unsuitable for retractable roofs.

Table 3. Comparison of the most used materials for lightweight structures (Huntington, 2008)

	PVC-coated polyester	**PTFE-coated fiberglass**
Base fiber tensile strength	350-1200 MPa	3500 MPa
Weight	800-1100 g/m3	-
Strip tensile strength	3100-5800 N/cm	1600-8800 N/5cm
Tear strength	Good	Poor
Stiffness	Moderate	High
Creep Behavior	Moderate	-
UV resistance	10-15 years	High
Light transmission	Up to 22% translucency	Up to 27% translucency
Fire Resistance	good	Moderately good
Cost	\$90-\$150/m^2 (fabric)	\$60-\$80/m^2(unfabricated)
	\$400-\$700/m^2 (entire roof)	\$500-\$1000/m^2 (entire roof)
Strengths	Least expensive	High durability
	Good tear strength	
Weaknesses	Relatively low durability	Requires careful handling, highly susceptible to water damage and tear

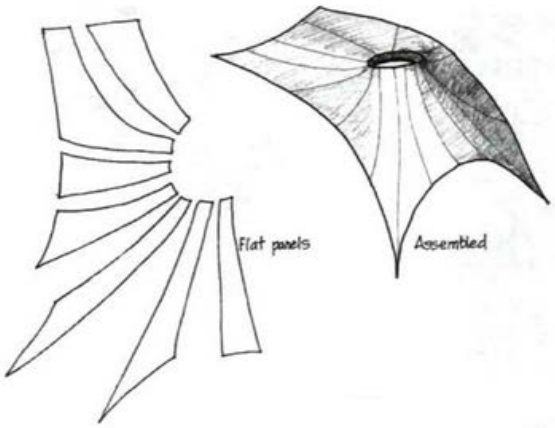
The effect of the material on a particular erection method is most clearly shown in the introduction of tension. The strength of the tensioning force and tensioning steps in time are determinate by the type of the material used. As tensile strength of material increases, the tearing strength will decrease. Temperature increase will cause fiber elongation so temperature limitations for working with certain fabrics and foils also need to be taken into account. Water accumulation on a fabric surface can cause freezing and degradation of the material due to microorganisms that are present. Another problem is the UV radiation. Degradation of strength for polyester material is 20% and for nylon 90 % in 110 days. Protection can be achieved adding light-resistant additives in the fiber material or UV absorbers in the coating. At certain sites, consideration must be also given to soiling effects from air pollution and to potential abrasion damage from wind –driven sand (Shaffer, 1996).

(a) (b)

Fig. 7. (a) Stadium Bunyodkor (2012) - PVC coated polyester (Ceno Tec); (b) Arena da Amazonia (2014) - PTFE coated fiberglass (Ceno Tec)

4.4. Production, transport and delivery

As it was already mentioned, one of the biggest advantages in building lightweight structures is high level of prefabrication. Although lightweight structures are highly prefabricated, the demand for even shorter construction time always exists. Manufacture and delivery times are determined by the size and the type of the chosen material. In order to use the advantage of prefabrication, membrane panels and cable lengths should be ordered the largest possible (Seidel, 2007). The desired 3D shape of the membrane structure is obtained by composition of 2D plane strips. To obtain the strips, the construction of the so-called cutting pattern needs to be made. Kim and Lee (2001) warn that in this procedure certain problems can arise from the material properties and numerical errors. Such deviations can cause unexpected structural problems, so the precise consideration in the cutting pattern of membrane structures is needed. Pattern pieces are traced and cut by an automated machine plotters. Plotters can be a part of an assembly with a plotting bed or can be used on the floor by utilizing a wall or a guiderail (Fabric Investigation, 2013).



(a)

(b)

Fig. 8. (a) cutting pattern (Fabric Investigation, 2013); (b) plotter (Ceno Tec)

In order to achieve the economic aim of shortening the project duration, Seidel (2007) proposes to take into account the factors, which can influence the delivery time:

- time from ordering the materials to delivery,
- manufacturing time for wire ropes,
- capacity to produce larger weights and diameters
- minimum production quantities for each diameter,
- type and size of the end fittings.

The time from ordering the membrane through design and delivery, if the construction methods are clearly discussed and agreed, is approximately 2 to 3 months for a project of average size (2 000 – 3 000 m^2). It is considered that the fabricator has already ordered the fabric before design and patterning using values from experience. The manufacturing time for wire ropes in standard diameters and lengths is about 4 weeks. For the special orders it can take from 8 to 12 weeks. (Seidel, 2007) The delivery time for wire ropes can be influenced by the availability, weight, material and construction of the rope, and the capacity of the production machinery. To avoid program delays and the need for extensive testing Stauske (2000) proposes that wire ropes, anchorages and pins are specified with general type approval. When working with foils and fabrics, it is important to consider the risk of damage from production and erection activities. The way in which flexible sheeting is laid out, lifted and fixed, determines how it should be packed and delivered. If membranes are significantly damaged during transport or erection process, they will have to be fabricated again causing significant delay. The method of erection also has influence on the production and transport conditions. Rolled membranes and foils are lifted and laid out in a different way to folded ones.

(a) (b)

Fig. 9. (a) Rolled membrane - transport and lifting (Seidel, 2007) ; (b) Rolled membrane - laying out (Ceno Tec)

4.5. The local conditions on the construction site

Spatial conditions strongly influence the construction site organization. A large area is required to prepare the membrane panels for lifting or erecting and for pre-tensioning. Also, special areas are needed for storing membrane and cable drums temporarily. The areas should be paved, leveled, without steps, ditches or other obstructions. Storage areas must be accessible for site vehicles. Suitability of ground for vehicles and assembly is also a local factor that should be considered. The preparation area should be laid out with a protecting foil, in order to protect the sensitive fabric surfaces from damage. The membrane, cables and load-bearing elements are, depending on the erection procedure, laid out, connected and prepared for lifting. In order to position construction elements in their intended location, they are often provided with temporary hinges. The additional space is required for the element to be hinged. Since the economic conditions at the construction site are also influenced by the choice of erection procedure, costs can be reduced by reducing the number of such temporary hinges or to consider another erection procedure (Seidel, 2007). If membrane panels are to be installed into an already existing primary structure, then access to relevant locations for the erection work must be ensured. The sufficient working space should be assured at the edge areas where the membrane is unrolled or unfolded and where the pretension is applied.

The weather conditions during the erection are also an important aspect of local conditions. Strong wind can considerably damage a membrane that is not tensioned and even bring down an insufficiently fitted primary structure. After the hanging and connecting of the elements, a preliminary tension is applied in order to stabilize the surface against the wind. Rainwater is also a big problem. Over a large area, rainwater can weigh up to several tones, remarkably increasing the loading.

5. Conclusion

Primarily, economic benefit is expected from the innovative form of lightweight structure, which leads to long span application and to reduction in the required building material. Possibility of prefabrication should enable fixed project duration without unexpected costs during the building process. Disassembly, reuse and recycling are another special feature in comparison to traditional constructions. Furthermore, special energy savings are possible owing to soft diffused natural light and reflective qualities of used material which enables temperature stability. In order to accomplish possible economic advantages of the lightweight project, effective collaboration of all the specialists involved in the design and construction process is needed. Connection between the design work, manufacturing and erection process is highly important in a lightweight project. These kinds of projects concern a great amount of specialist knowledge about practical design details as well as the experience in development of efficient erection procedures. Transport, construction site set up, completion deadline and finally the construction costs can be considerably influenced by limitations like availability of the construction infrastructure, tools and materials, little expert knowledge and small number of highly qualified workers.

The majority of literature on lightweight structures concentrates on the non-linear analysis and form finding process while the construction management, including technology and organization of the erection procedure, is neglected. Since the form of the structure needs to be adjusted to erection procedure probably more than in any other type of structures, the influence of technology and organization is even more connected to final cost of the project. The result of this disadvantage is often seen in impractical or even impossible erection process of designed lightweight structures. This often leads to alterations or even total modification of the design work after it is already completed, making the whole project ineffective. Obviously, the economic viability of lightweight structure is therefore significantly reduced leaving no reason for the investor to decide to choose this type of project.

Seidel (2007) presents in his book a detailed description of all the phases of a lightweight project as well as the interactions between design, erection and the quality of the finished product required for successful implementation of lightweight membrane structure. The importance of erection planning and its specific activities are explained with their economic and technological aims. The equipment used for erection is described, with an overview of the tools used for transport, lifting and tensioning processes. Tensioning systems for linear and sheet elements are described in detail. Also, the manufacturing and assembly processes are collected, categorized and evaluated. All of that makes this book highly important in filling a wide gap in the existing literature on lightweight construction. There are parts of this literature review that are mostly based on information provided from that book. That especially concerns the field of successful organization of the erection procedure with emphasis on the building technology and practical details. I believe that is the best indicator of deficiency of literature on construction management in lightweight projects. Another two books which I would like to point up are Tensioned Fabric Structures (1996) provided by the American Society of Civil Engineers and Canobbio's Economic Aspects of the Use of Tensile Structures (1995). These two manuals were written in time when lightweight architecture was at its peak. The Tensile Fabric Structures (1996) provides a short overall review on lightweight tensile structure including the economic aspect and project benefits that are possible to accomplish. The Canobbio's manual (1995) is the only literature that I could find concerning the economic aspect of these type of structures exclusively.

As we have seen, lightweight structures are in literature often mentioned as energy efficient due to savings provided by the use of uncommon materials. Unfortunately, all the listed possibilities of energy savings are rarely accompanied by specific studies with results or comparisons with conventional structures in the field of heating/cooling cost, lighting cost and other possible benefits (like solar gain study made by Mundo et al., 2009). Even Elnokaly et al. (2002) warn that further detailed investigation into the thermal and optical properties and studies of internal and external surface convection heat transfer needs to be made. It is also necessary to create models able to account complicated topology, time variant climatic inputs, internal temperature and airflow behavior. Lack of these models can explain the deficiency of literature that considers economic aspects which not strictly connected to the building process

of lightweight structures. These kinds of models will be able to provide quantitative descriptions of the behavior of these systems which will lead to the general design guidance.

Even though lightweight tensile structures have a great potential, there is still a lot of research that should be done in the field of technology and organization as well as developing models, which would make the listed advantages (provided by the special properties of the membrane) more measurable. In addition to that, we can hope that the lightweight tensile structures can become considered an equivalent application option to permanent structures.

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Applications of Unmanned Aerial Vehicles in Construction Industry

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Abstract

This paper presents applications of modern technology of unmanned aerial vehicles (UAVs) in construction industry. The rapid development of technology pushed the potential of the UAVs' use to a new level, which nowadays enables the operator to inspect a building site or construction from a single location. Furthermore, the employment of UAVs also allows monitoring temperatures of objects with thermal imaging camera as well as creating 3D surveys of a construction from aerial viewpoint. The first part of this paper shows basic principles of operation of various tools used in the UAVs, while the second part introduces some actual practices and applications in the field.

Keywords: unmanned aerial vehicle; UAV; construction; safety management applications; inspection; infrared thermography; 3D survey

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1. Introduction

Use of unmanned aerial vehicles (UAVs) has increased sharply in the last decade. Until recently, we witnessed military operations in which various UAVs were used, often described as drones. During the last few years, everything has changed and applications of UAVs have extended to various commercial projects especially to film industry and many others including construction industry. One of the main reasons is certainly the availability of new technologies that can help us constructing flying machines for commercial use. A key factor in the development of UAV devices are different precision sensors like inertial motion unit (IMU) including gyroscope and accelerometer, which recognizes the velocity, orientation and gravitational forces. A processor unit uses the data from different sensors and with the help of global positioning system (GPS) it is able to make autonomous navigation without the need for pilot's manual manoeuvring. Important factors in the rapid growth of smaller UAVs are production costs of all these sensors and the accuracy of the GPS for commercial uses.

The availability of commercial UAVs can on one hand improve workflows and facilitate the processes but on the other hand, a lot of issues and negative reviews can appear due to concerns about security and privacy, what seems to be an important issue for now. Use of UAVs is often controlled by the specific national administration and in general, the regulations are not yet fully adapted for use of UAVs, they there are intended primarily for use of conventional aircraft such as different airplanes and helicopters, see e.g. reference (Federal Aviation Administration, 2015). The main task of regulators is to find a balance between competing interests and set rules for the use of UAVs for commercial purposes.

Construction industry is usually considered as a more conservative-oriented, but the benefits of using UAVs are sufficiently attractive for various possible applications. The aim of this article is to expose the advantages of usage of UAVs in construction industry. In this way, the paper presents basic principles of operation of different tools employed in the UAVs as well as some actual practices and applications in the field.

2. Technologies used in UAVs

Range of various types of UAVs has increased significantly over the years and the development still rapidly continues. Manufacturers offer a diversity of systems and currently there is no official classification of UAVs for commercial purposes. Regardless of the form they can be divided into three major groups; fixed wing aircrafts, unmanned helicopters and multicopters. Table 1 shows a comparison between different types and their main characteristics.

Table 1. Comparison of UAV types and main characteristics

Type of UAV*	Payload	Range	Handling	Setup time	Costs
Fixed wing aircraft	Good	Very good	Poor	Average	Good
Unmanned helicopter	Very good	Average	Very good	Very good	Average
Multicopter	Average	Average	Very good	Very good	Very good

* There are also other UAV categories (airships, tilt-wing aircrafts, etc.). Types shown above are most common.

Based on performance characteristics of different UAVs we decided to use the multicopter type for our test and different applications in construction industry. Main advantages of multicopters are low purchase and operational costs, very good handling capabilities, sufficient range and possibility of assembling the UAV by ourselves due to the accessibility and a large supply of components on the market.

There are number of options for making commercially useable multicopters. However, the operating principles and basic components are often quite similar among the most available versions. In the last period, there are also many possibilities to purchase an UAV that is ready to fly (RTF) out of the box, however in most cases, such UAVs are not suitable for professional multipurpose use due to several limitations. The main disadvantage of RTF models is the fact that they are usually intended only for single purpose, in most cases to capture images or video clips and therefore, upgrade options are quite limited. For our tests of

possibilities of UAVs usage in construction industry, we decided to assembly the multicopter from different components to maximize options of possible uses, which was our main guideline.

The developed system of UAV is based on a hexacopter principle, more precisely on hexa-rotor V system. The main reasons for selecting a system with six instead of four engines are better reliability and greater lifting capacity in comparison with quadcopters. Six engines and rotors enable flying thus potential failure on one motor and provide safe landings. The latter is a key advantage in the use of UAVs over populated areas or over construction sites and buildings since it reduces the percentage of collision chances. Other advantages of a UAV based on multicopter principles (for example quadcopters, hexacopters and octocopters) are low maintenance costs and possibility of vertical take-off and landing procedure. On the other hand, main disadvantages are relatively low wind resistance and limited flight time which is approximately 20 minutes on average for an UAV equipped with load. Furthermore, in some cases operating range, which is normally up to few hundred meters, may represent a limitation. However, that is not of crucial importance, because many national regulations only allow line-of-sight (LOS) of UAVs (Siebert and Teizer, 2014).

Our test multicopter consists of carbon fiber frame and landing gears to preserve weight which enables longer flight times. Screws and lifting mechanism for landing gears are made of aluminium also for weight reduction. Powertrain contains six efficient brushless electrical motors, two lithium-polymer six-cell battery with a total capacity of 8000 mAh (22.2 V) each and weight of approximately 2 kg combined. In order to ensure greater safety during the flight and to extend the time of operating, two batteries are used during the flight. Maximal absolute thrust of UAV is 18.4 kg and it is produced with six 45.72 cm long carbon fiber propellers, with the total size of 1425 mm in diameter. Average flight time is around 25 minutes and it mostly depends on flying style, wind and load. Total weight of the UAV prepared for take-off is approximately 8 kg including a camera stabilization system (3-axis gimbal), two batteries and a camera with 14-42 mm lens or similar.

The main part of every UAV is the flight control unit (FCU), which in our case consists of four different components, namely main controller (MC), power management unit (PMU), GPS antenna and LED light. Main function of FCU is to process incoming signals from remote control (RC) via RC receiver and then communicate with motor controllers (also known as electronic speed controller) and consequently with brushless electrical motors. For easier flying, there is also the inertial measurement unit (IMU) which detects alignment, barometrical altitude and accelerations of the UAV. In combination with GPS antenna and compass, it can fly in three different modes. First mode works with GPS, where the UAV is positioned via satellites and is able to maintain altitude and position in the air. This function is useful in most scenarios while flying is relatively easy and safe due to enabled hold position in the air, so possible winds have smaller effect on the movement of the multicopter. In case of lost GPS signal, altitude mode is enabled after few seconds to prevent possible failures. Second option of flight type is altitude mode, where UAV is controlled by altitude meter by monitoring barometric pressure and this way maintains desired height. Third mode is manual, where the pilot needs to control the UAV completely by himself and without interruption of safety systems.

Other major components (see Fig. 1) are video transmitter for sending live picture from multicopter to the pilot's LCD screen, three axis camera stabilization system (also known as gimbal) which enables smooth movements during the flight and electric retractable landing gear for safe landings. Due to powerful and efficient motors on gimbal, it is possible to attach different cameras, including IR thermo-camera.

Fig. 1. Major components of developed multicopter for multipurpose use

Multicopter is capable to fly with maximum speed over 20 m/s to maximum distance or flight altitude up to two kilometers from the pilot if the area is open (without physical objects like trees, buildings and other barriers). Average traveling speed is around 5 m/s and maximum flight altitude does usually not exceed 100 meters.

3. Practices and applications in construction industry

Usefulness, convenience and affordability are the key benefits, among many others, of using UAVs in various industries. Almost every week we can notice new applications in different parts of the world. Due to the wide variety of possible uses, we decided to show some of the currently most frequent ones in construction industry.

3.1. Construction site monitoring

Effective monitoring of a building site represents a challenging task for a project manager due to several factors, such as complexity, risk of occupational injuries, frequency of visits and many more. Observing the construction from aerial viewpoint can bring positive effects on several segments. For example, reducing the time needed to patrol the site. Engineer can use the UAV equipped with camera and flies over the wide area and capture high-resolution images (see Fig. 2). During the flight, it is possible to control the camera and with video transmission, live aerial picture can be seen on the screen by the pilot in real time. Photos or videos are captured from ground by using the radio remote control and are stored into the camera. Recorded material can be transferred to a computer and saved for subsequent use. Such way of monitoring of construction site certainly cannot replace the established workflows but can contribute to improve safety, for instance to monitor the use of protective equipment.

Fig. 2. (a) Aerial photography of construction site; (b) Magnified picture to monitor the use of protective equipment

3.2. Examination of different constructions

In construction industry, we are often facing different examinations of constructions in hard to reach locations. Inspection of poorly accessible places can increase the risk of occupational injuries, costs due to use of scaffoldings, ladders, lifts and other protective equipment as well as it increases time required for work execution. With use of modern UAVs, we can examine construction from aerial viewpoint, without the need to bring scaffoldings and other protective equipment on work location, without organizing road closures and often even without a specialist for inspection on site (see Fig. 3). Reviewing process may start on the take off point, which can be up to few hundred meters away from construction. Pilot can fly the UAV to the required point and then the second operator may start taking high-resolution images. Both can employ live video transmission in order to see details and monitor location of flight. After that, the pilot can return the UAV back to starting position and land. Captured pictures may be then transferred to the computer and prepared for further analysis. One of the main advantages is that pictures can be analysed by different experts simultaneously from their offices. Since all captured pictures contain GPS coordinates, the experts are enabled to relocate them for further use, for example when the renewal of construction is needed. Such way of examination reduces costs and time but cannot entirely replace existing methods.

Fig. 3. (a) Examination of construction of the base station; (b) Detailed view of the construction

3.3. IR thermography

Reviewing objects by applying the IR thermography is useful in several scopes and some of them are presented below. IR thermograph camera is a well-known and useful tool in many industrial fields (Vetter et al., 2013). Rapid development of UAVs provided variety of new options for on-site usage of such equipment. For example, with some minor modifications, we can install IR thermo-camera on UAV and monitor temperatures of objects (Mavromatidis et al., 2014). Scanning for faults on electricity grids is one of various possible applications.

Namely, locating defects on electrical network can be done by scanning the area using UAV equipped with IR thermo-camera. The camera operator is therefore enabled to see and capture hot spots on wires. Possible faults may be seen as bright dots due to increased temperature compared to surrounding areas. Cause for higher temperature can be damaged cable, where the electrical energy flow is raised due to smaller intersection of the cable. Faults can be located fast enough without lifts or ladders and without interruption of electricity supply.

Another possible application is identifying errors on photovoltaic panels (see Fig. 4). Alternative production of energy has become more popular and many investors as well as managers are curious about efficiency of their power plants. Using the UAV equipped with IR thermo-camera, we are able to inspect large areas of photovoltaic power plants and to locate possible faults as well as to identify non-working panels. As mentioned in the previous example, the operator is enabled to see and locate possible errors on panels via live streaming picture from the air and also capture or record the area of plant. Possible errors can be usually seen as lighter spots and the temperature of a panel is not homogeneous. An important issue that should be taken into account in executing measurements is to select a suitable scanning angle, which should be between 70 and 90 degrees to achieve correct recordings. Consequently, it is often difficult to adequately gather such data by using handheld operated thermo-camera.

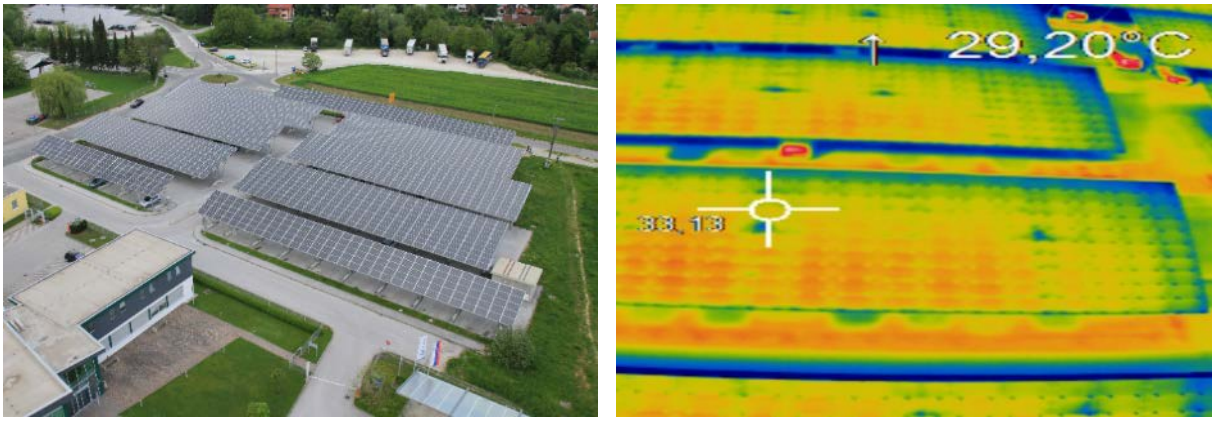

Fig. 4. (a) Common photo of photovoltaic power plant; (b) IR thermography review of photovoltaic power plant

3.4. Photogrammetry

In the construction sector, we are often dealing with the calculation of surfaces and volumes. There exist many different calculation techniques in practice. For example, one of widely used approaches is calculating the volume by interpolating and summing up cross (Draeyer, Strecha, 2014). Now we can measure volumes or areas on site employing the UAV equipped with the camera and adequate software for developing a model. Photogrammetry represents a widely used technique where a camera is installed on the UAV and is usually pointed vertically towards the ground. Multiple overlapping photos of scanned terrain are taken during the flight of an aircraft and afterwards processed with suitable software (see Fig. 5). Overlapping photos are aligned and stitched into a model using a computer, where camera position and orientation for each photo is located by software. After completion of this process, a sparse point cloud model is obtained. After finishing the first step, building of a dense cloud is necessary. In this step, a dense cloud is built based on the calculated depth information for camera on each position. The result is a single dense point cloud, where all gathered data is combined. Thereupon, in the third step, a mesh is created and after removing all secondary faces leaving only the surface to be considered in calculations, we are able to close holes of a model and measure volumes and areas (see Fig. 6).

Fig. 5. (a) Realistic photography of construction site; (b) 3D model generated from aerial photos using UAV

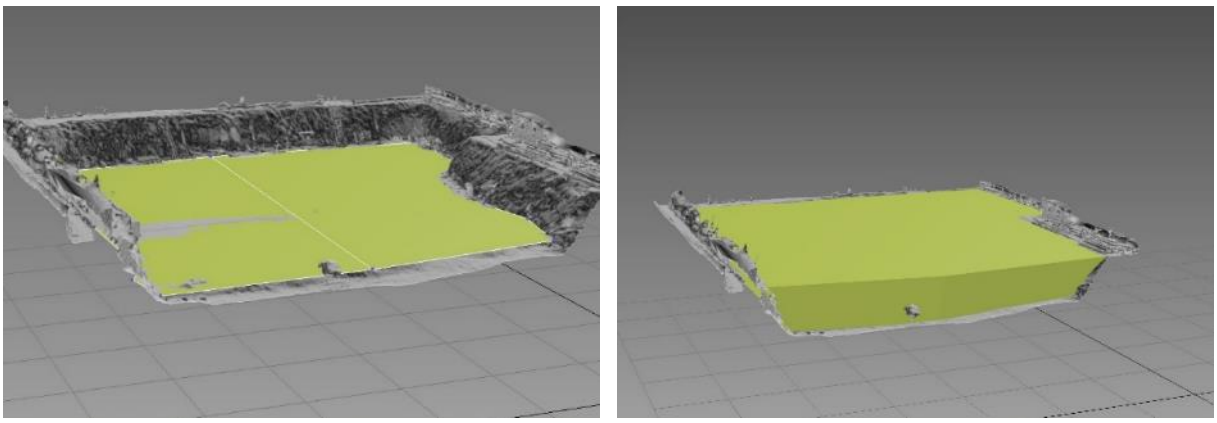

Fig. 6. (a) Area measurement of construction pit; (b) Volume measurement of excavated material

3.5. Marketing solutions

UAVs can be also suitably applied for marketing purposes in construction industry. At this point, unmanned flying machines can be used for project presentations as well as introduction of reference objects. For example, Fig. 7 shows a case of a photo presentation of successfully finished project of building a roundabout for Ministry of Infrastructure (Berčič et al., 2013).

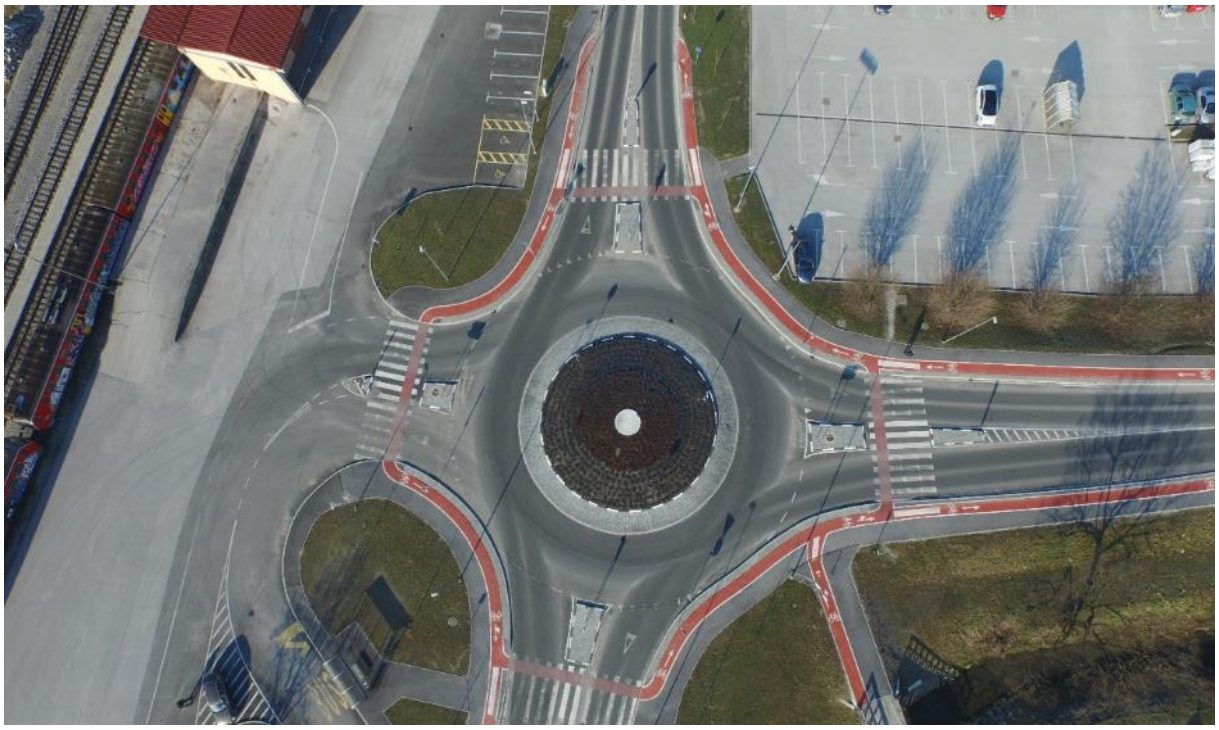

Fig. 7. Showing reference object for marketing purposes

One of the possible marketing applications of UAVs is also sale promotion of real estate projects. Potential buyers may more easily decide to purchase real estate based on well-prepared visual elements such as images or videos. In many cases, money invested in marketing quickly pays off, especially for larger projects where expected returns are higher.

The third possibility of innovative marketing usage of UAVs is promoting the company or a brand with attached advertising banner on ropes. This type of advertising often attracts a lot of attention especially in urban centres and densely populated areas. However, this kind of marketing activity can be prohibited in some countries and may constitute a potential danger to passers-by if not adequately organized and performed. For this purpose, special UAVs can be applied for ensuring greater safety, since they are lighter and are equipped with more than four rotors in case of possible failure.

3.6. Transport of loads

With the development of more efficient electric motors and particularly more powerful batteries, UAVs can be used for transporting lighter loads to hardly accessible places. Modern UAVs are capable of lifting 20 kilograms or even more with larger blades, uprated electro motors, and reinforced frame. For example, the logistic applications are already taking place in Germany, where DHL is shipping packages to island Juits at the edge of the Lower Saxon Wadden Sea in the southern North Sea (Kückelhaus, 2014).

In cases of construction site transportations, it is clear that UAVs cannot replace cranes or other important lifting devices but can be used as auxiliary tool for the transfer of lighter objects on locations that are hard to reach. Imagine the objects in high hills where accesses can be difficult to reach and usages of conventional helicopters are often find to be quite expensive. Here, UAVs may often prove to be capable enough to suitably transport required loads to such locations and, what should be exposed, without environment contamination by exhaust gases or high noises during flying.

4. Conclusion

This paper presented an overview of basic principles of technologies used in UAVs that can be suitably applied in construction industry. Starting with presentation of basic components of a UAV, its operation capabilities and various application options, this paper was focused on possible uses of the UAVs. With the use of modern UAVs, we are able to monitor construction sites, examine different constructions, seek for possible faults with IR thermo-camera and even use them for commercial purposes or as transporting tools. All the above-mentioned applications enable time and cost savings, increase work efficiency, take the pressure off the labour factor and reduce occupational accidents frequency. Current limitations for more frequent use in the field can be attributed to relatively short flight time on account of limited battery capabilities, engine's efficiency and particularly, it is often challenging task to implement new technologies into traditional, proved well-functioning system of work activities in construction practice. However, with the vast development of new technologies we can expect to find solutions to overcome these limitations and thereby contribute to more rational execution of works in construction industry.

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Multidimensional Preemptive Coordination as Multidisciplinary Project Management Tool

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Abstract

Cost and schedule overruns are quite common in construction projects. Research has shown that they are not caused by a single, catastrophic event, but by numerous small disruptions and delays which are undetectable until their cumulative effect becomes significant. A large part was due to lack of communication and poor collaboration of the stakeholders. Collaborative technologies proved profitable in B2B communication. Inside an enterprise, the project manager coordinates the activities on the construction site and interdepartmental interaction with employees outside his jurisdiction. This leads to poor accountability and slow response to emerging challenges. This paper describes the model of Multidimensional Preemptive Coordination and its role in coordinating project efforts across the enterprise. A group of people, originated from different departments and different levels of Organizational Breakdown Structure are gathered together in a corporate social network environment in an enterprise wide effort to monitor, track and solve a business problem. The system provides an audit trail of actions performed and pushes alerts, status changes and missed deadlines both horizontally and vertically providing accountability across the enterprise. The group is focused on a single topic and problem, suggestions and progress reports are posted on the *topic wall*. Numerous topic social networks are coexistent, each one private to the participants. Each participant may be part of any number of topic networks. The model allows for arbitrary number of subtopics with different scope of visibility allowing participants external to the enterprise to collaborate in a safe way.

Keywords: enterprise collaboration, enterprise coordination, project management, enterprise accountability

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1. Introduction

In today's adverse business conditions, there is more pronounced pressures in the enterprise to deliver the project on time and inside the planned budget. The risk of construction cost overrun is considered one of the most important (Banaitiene and Banaitis, 2012), classified as high and frequent.

Research done by Flyvbjerg et al. (2004) showed the cost performance in transport infrastructure projects. The sample used was large, 258 projects in 20 nations (America, Europe, Japan and 3rd countries) worth approximately US$90 billion. The findings were quite extraordinary. The cost overrun happens in almost nine out of 10 projects (86%). On average the costs were 28% higher than the forecast. Geographically, cost escalation in Europe was on average 25.7% against 23.6% in North America. In other geographical areas, the average cost escalation was 64.6% but the sample was rather small (16 projects). Analysis of cost escalation over time based on the date of completion led to conclusion that the cost performance has not improved over time. The cost overruns are in the same order of magnitude as it was 10, 30 or 70 years ago. If there where improvements in cost estimation and forecasting procedures, if more sophisticated software tools and practices were used to predict and manage costs, this does not show in the data. The cost overruns, however, were not caused by some specific catastrophic event, but by numerous small delays and disruptions which were undetectable until their cumulative effect became significant.

A study led by Ahmed et al. (2003) for Florida Department of Transportation (FDOT) to a review the performance of cost overruns in transportation construction projects showed interesting results. The purpose of the review was to understand to what extent are construction cost overruns avoidable and what actions can be taken to minimize the cost overruns and improve accountability for these problems. 102 projects were analyzed with initial budget of US$ 302.7 million. It was found that the total cost overrun was US$ 28.6 million (a 9.5% of the budget) with more than half of those (US$ 15.6 of the budget) were classified as avoidable costs. About US$ 4.2 million (1.4% of the budget) in avoidable cost overruns represented wasted money. The responsibility for cost overruns was found to be shared among consultants, third parties and FDOT staff. The review recommendation was to take additional steps to hold the participants accountable for the cost overruns.

In the survey of construction owners conducted by Construction Managers Association of America (CMAA) in 2004, when asked to select top three responsibilities that needed improvement among 13 options offered, the owners put "Make timely decisions" in the first place, following by "Communicate clear work scope", "Require good project definition" and "Provide leadership for project collaboration". When asked which changes will most significantly contribute to improving the quality of the project delivery process resulting in a greater number of successful projects, over 60% selected more effective communication as number one.

Saram and Ahmed (2001) conducted a research to answer the following three questions:

- What activities do project managers perform to achieve coordination in a building project?
- What coordination activities do they consider most important?
- What coordination activities consume most of their time?

The six most important coordination activities were found to be: identifying strategic activities and potential delays, ensuring the timeliness of all work carried out, maintaining records of documents (drawings, information, directives, verbal instructions and documents received from the consultants and the client), maintaining proper relationships (client, consultants, and the contractor), managing the quality of all work carried out and liaison with the client and the consultants.

However, the one that consumes most of the time is conducting regular meetings and project reviews. Among the first six in this set, we can also find

- Analyzing the project performance, detecting variances, and dealing with their effects
- Identifying/gathering information on requirements of all parties and consolidating for use in planning Interpreting all contractual commitments and documents
- Resolving differences/conflicts/confusions among participants
- Liaison with the client and the consultants

2. Coordination

The success of a company depends heavily on the ability of the management to implement effective organizational structure with fluid communication of information both horizontal and vertical.

The importance of coordination was addressed by Malone and Crowstone (1994) who defined it as "coordination is managing dependencies between activities". They suggest that look into the type of the dependencies would reveal the direction of best approach. They numerated basic approaches to coordination as managing shared resources, managing producer/consumer relationships, managing simultaneity constraints, managing task/subtask dependencies and managing other dependencies.

According to the CMAA/FMI survey (2004), when asked what practices they use to improve communication in the enterprise, almost 70% respondents selected four main courses of action:

- Assemble the project team early and meet frequently
- Provide clear contact for decision and approvals
- Openly share project information
- Meet with service providers to share missions and goals for the project

When asked what internal system they use for project control, an appalling 70% still use plain phone calls and faxes. This, however, is preceded by simple spreadsheets (over 80%) and office and scheduling tools (about 70%).

2.1. Coordination process today

In practice, coordination is done in meetings and through one on one communication by means of any modern technology tool (phone, email, etc). The efficacy of such procedures is quite low, not because face to face communication would be worse than other means, but because one on one communication with multiple participants cannot be done in a time frame necessary to achieve performance.

Romano and Nunamaker (2001) researched meetings efficacy. They defined the meeting as "a focused interaction of cognitive attention, planned or chance, where people agree to come together for a common purpose, whether at the same time and the same place, or at different times in different places". A profile of typical meeting in corporate America, based on 903 meetings surveyed and selected based on most frequently reported value, was found to be: staff meetings (45%), held in company conference rooms (74%), starting at 11.00 AM, lasts 1 hour and 30 minutes, involves 9 people (2 managers, 4 coworkers, 2 subordinates and 1 outsider), two hours prior warning, no advance written agenda (63%), completely covers the agenda only 50% of the time, 11% of the time is spent discussing irrelevant matters. The majority of surveyed executives concluded that 20%-30% of the meetings were unneeded.

Research by Castellina (October 2013) shows that one of the main characteristic of project management is communication. Communication is important both between team members and clients, internal or external. Based on 560 respondents of the Aberdeen's 2012 Project Management Survey the project pressures call for collaboration were need to use project resources more effectively (38%), customers frequently change their mind mid-project (33%), contention for specific limited resources (33%) and too many late projects (29%). Organizations with social project management practices complete 73% of their projects on time or early compared to 64% for the organizations without the technology.

If a business problem is to be solved, it always takes a group of people, multidisciplinary professionals from different departments of the enterprise in a joined effort. In today's frantic search for performance, it is quite difficult to coordinate such a group of people with dissonant schedules. Present information technology tools do not coordinate in an enterprise wide joint effort, but provide individual channels of communication between shareholders which are based on individual initiatives. Corporate portals and computer technology provide an abundance of data without proper individual focus which result in information overload.

Radujković et al. (2012) distinguish data overload to be one of the main reasons for project control failure. Inconsistent computer systems with unrelated flows of information cause

miscommunication among the shareholders. Different computer segments need to work in unison to allow effective planning and project control.

2.2. Social collaboration trends

Traditional autocratic top down management directive enforcement and communication is gradually shifting towards social network paradigm, where the workforce is not just executing orders but is participating in goal achievement and improvement. This means that a group, a "social group" (or "task force" in corporate context) has to be formed around a business problem or goal which includes individuals from different departments, including their middle (and top) management.

Castellina (August, 2013) researched the effects of social networking functionalities in corporate ERP systems. He found that 48% of organizations with social ERP capabilities enable real-time collaboration across departments and divisions. Those functionalities are mostly used through portals. However, the same research revealed top challenges in collaboration, the first being data overload which inhibits to effectively share knowledge across the enterprise. In the top five, the 344 surveyed respondents also highlighted the inability to convert collaborative data into business execution and inability to aggregate too many voices into a single solution to the problems. This suggests that although social network capabilities are used across the corporate, those capabilities are not integrated into the management process.

The model of Multidimensional Preemptive Coordination addresses those issues. It governs fluent information flow horizontally and vertically across the enterprise integrating multidisciplinary efforts into the management process via multiple coexistent corporate social networks.

3. Multidimensional Preemptive Coordination

In its most simple form (Bacun, 2013) a supervisor (Sender) issues a Request for Action (RFA) to his subordinate (Recipient). The Request has a header and a history log (Fig. 1). The header contains a description, specifying task or problem details, a deadline and initial status. The Sender controls the scope of the Request and decides whether the Request may be considered finished and closed. The Recipient reports progress, problems and new developments by posting to the history log. The deadline is used to alert the participants of the approaching milestone, elevating a yellow flag predetermined number of days in advance. If the deadline is missed, both participants are alerted by a red flag. Each RFA is identified by a unique ID.

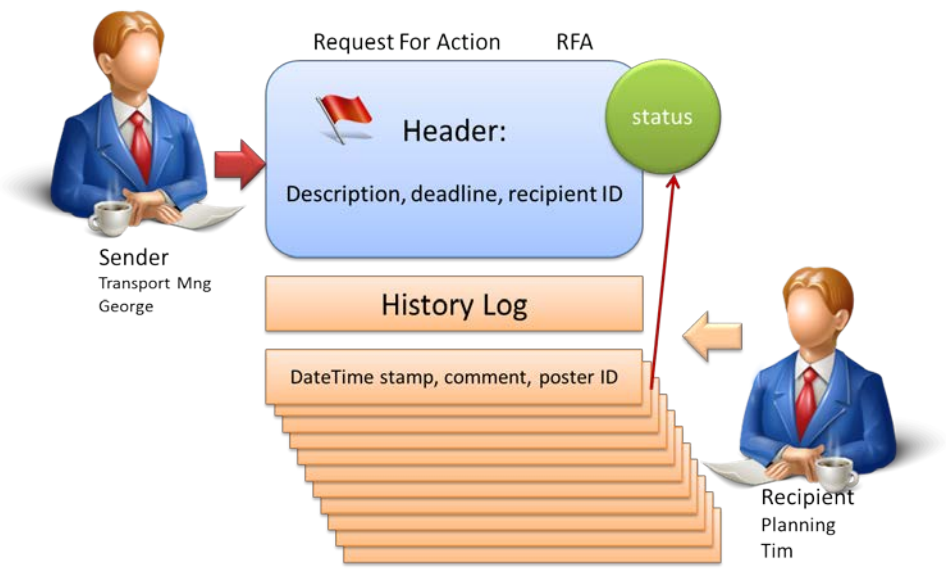

Fig. 1. Simple Request For Action (RFA)

The Recipient cannot change the Request header details but can change the status, signaling the Sender that new development has emerged, or Sender action is required. Both participants communicate by posting to RFA's history log. Neither of them can delete or change log entries. When the Sender changes any of the of the header data (Recipient change, deadline change, etc.), the system makes an entry in the RFA history log, making an audit trail of actions performed.

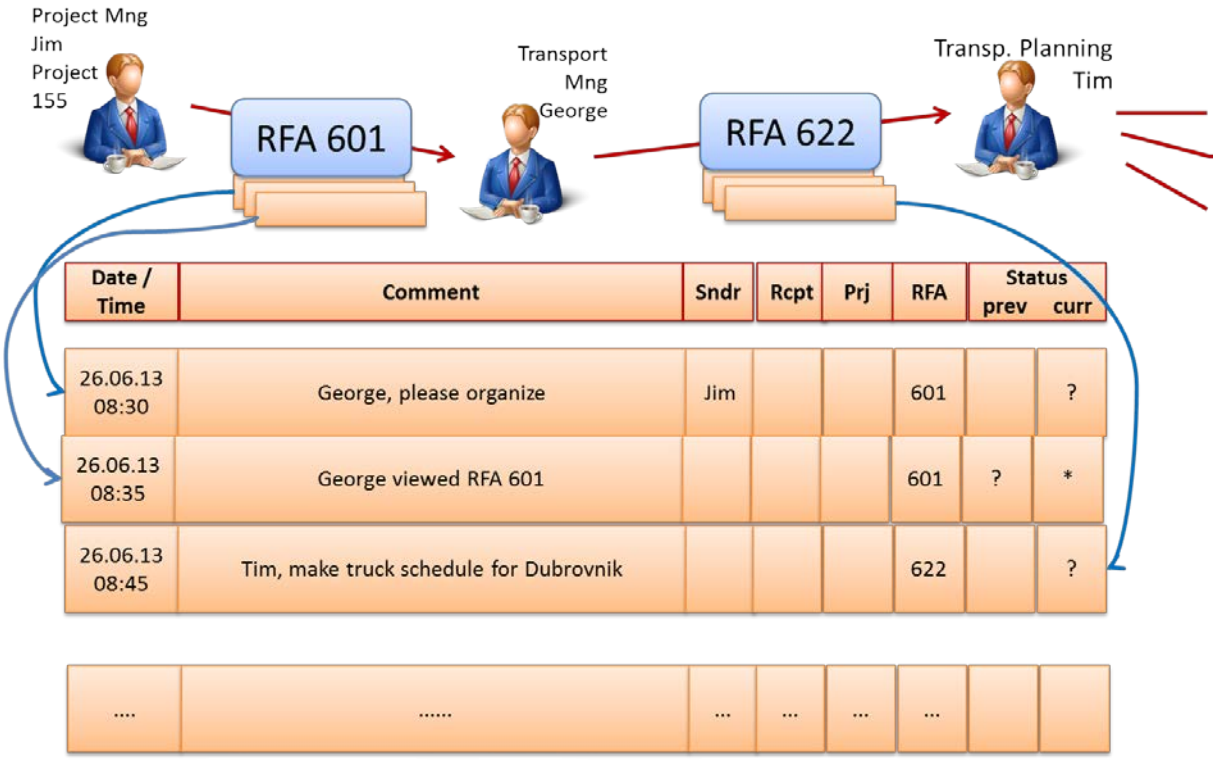

Fig. 2. Linked RFA in a topic thread

Status is user definable and should reflect the actual business state of the problem, like "In progress", "Waiting for subcontractor", "Deadline change needed", "Finish confirmation needed" etc.

The Sender may invite other participants to monitor the thread if he feels they should stay informed. Invited participants may reside in other departments or even be external to the enterprise. They may read and post at the thread altitude they are invited to. An invited participant may decide the depth of the thread that will be displayed on his personalized News Wall. Safe integration of external participants was described by Bacun (2014). The system will always recognize an external participant by lack of HR record in login procedure and will restrict the horizon of visibility accordingly.

In real corporate life, the Recipient will often need further assistance from a subordinate or an employee in another department. He would issue another RFA and update the original RFA status appropriately. For example: the site manager might issue a RFA to a official the concrete Manufacturing Plant, requesting concrete delivery according to project's schedule. The Recipient at the plant might issue a RFA to production and, at the same time, another RFA to Transport department, requesting appropriate truck. The system links all three RFA into unique thread of actions needed to supply concrete to a particular construction site. The history log of the three RFA are combined into a single topic, creating a corporate social network topic News Wall, where different participants discuss and report joint effort to supply the project with concrete needed (Fig. 2).

However, each participant has a different horizon of visibility. The project manager, who originated the thread, will be able to monitor all three RFA, view their history logs and post comments. He will be alerted of any missed deadlines across the thread. He can decide the depth of the thread that will be presented on his personal Wall, and change it as needed. The

Recipient in the Manufacturing Plant will see only the RFA sent to him and the ones he issued to the Transport official. The Transport official will not see the original RFA, but will be able to respond to a comment the project manager posted on RFA he received.

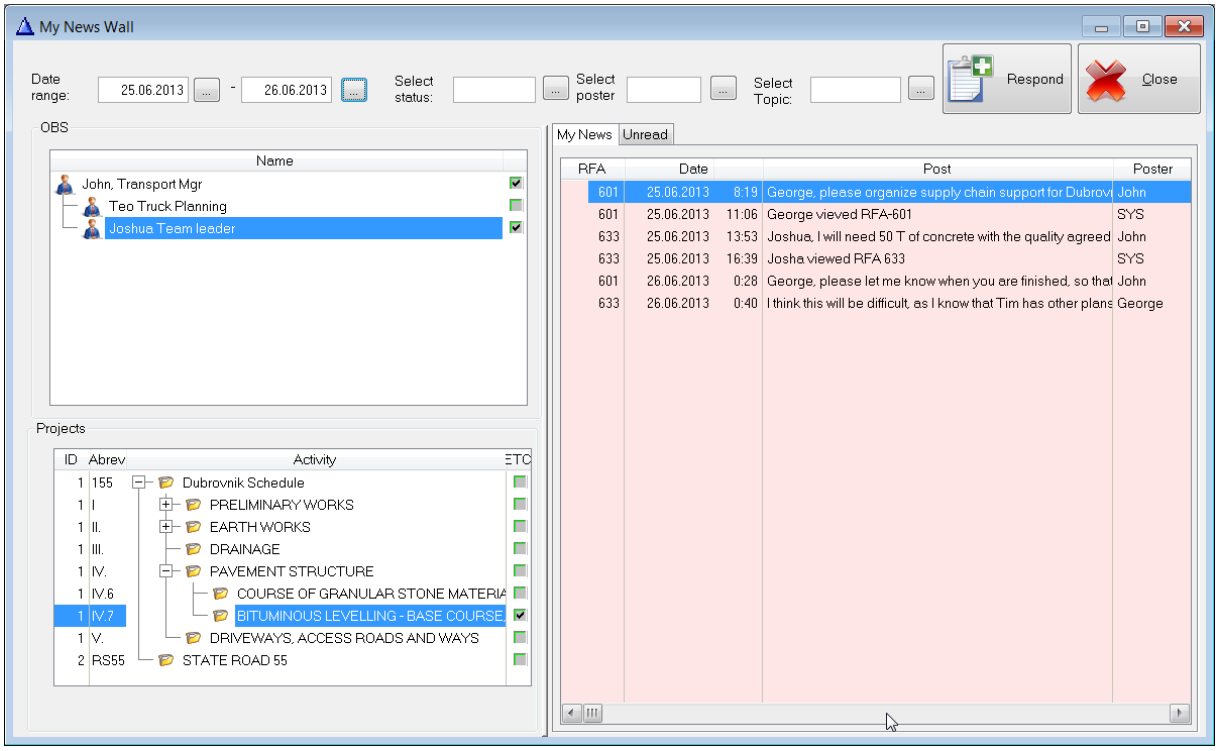

Fig. 3. Personalized corporate topic News Wall

The employee at the Manufacturing Plant receives multiple requests from different sources. He will receive RFAs from different site managers, but he also might receive requests from Sales, if the concrete is sold to third parties as a resource. He manages his everyday work with his personalized topic News Wall and personalized My Requests Wall. The News Wall displays posts from all the participants in any of the threads he participates in (Fig. 3). He can easily filter the posts by topic, date, status, poster etc. He can respond to any post, and the system will place the post in the proper RFA and thread, and make it visible to the topic participants. My Requests Wall has two sections: Received RFAs and Issued RFA arranged by deadline, making it easy to understand the scope of work at hand.

The history log is secured by the system. Each post receives a system unique id and date/time stamp, as well as poster id and status data, which guarantees consistency and auditability. The system will automatically detect actions that change the context of the RFA and post it to the history log.

A special case is when the Sender issues a RFA to himself making himself the Recipient. In that case the deadline becomes a reminder. Writing posts to such a RFA creates a personal diary related to a topic, which, in context of system wide time stamping might prove valuable in interdepartmental disputes.

Sender decision to invite different participants into a topic News Wall makes it possible to create a small dedicated team focused around the effort to solve a business problem. Each team can be tailored for a particular topic. As the topic News Wall is visible only to the participants, they form a closed corporate social group. At any point in time there are multiple topics coexistent in the enterprise and thus, multiple corporate social networks, horizontally and vertically coordinated by the system.

3.1. Vertical dimension of the RFA

The coordination topic thread seldom follows corporate Organizational Breakdown Structure (OBS). It is common practice that the site manager coordinates with a particular employee in Production Plant or Transport. In larger enterprises, there might be multiple

employees assigned to monitor and handle different projects. If a particular employee receives a RFA, it would be extremely valuable if that RFA automatically enters into the upper level scope of visibility. The supervisor should be automatically alerted of extra strain his subordinates face. He should be alerted of approaching or missed deadlines, so he could intervene and reallocate resources more efficiently. The alerts propagated through the topic thread will fork vertically through the enterprise OBS (Fig. 4). Each upper level executive will decide which alerts will be triggered at his altitude and what thread depth will be shown on his personalized topic New Wall. He will be able to post to any of the threads his subordinates participate in. He may reassign a request to another employee, even if he is not the original Sender, because his executive altitude allows such a change. The system will log such change in the appropriate history log, and hence alert the Sender.

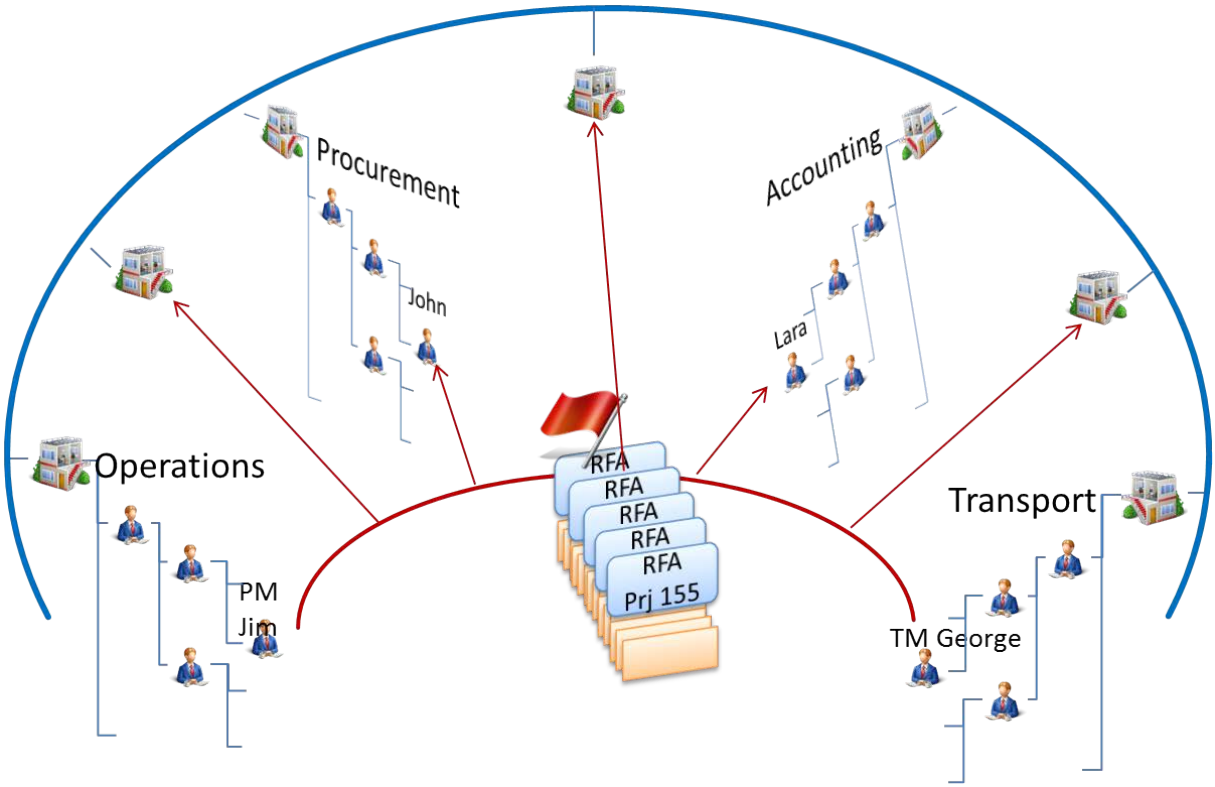

Fig. 4. Vertical coordination

The Recipient's vertical dimension of any received request allows for automatic coordination and alerts across the entire enterprise, facilitating flow of information and directives and making problem detection and management more efficient.

3.2. CRM dimension of the RFA

Any RFA may have a partner id assigned to it, indicating that the RFA is a task related to a corporate partner. The partner can be an investor, a subcontractor or supplier. If a partner is tagged in a particular RFA, that RFA is visible on the partner Customer Relationship Management (CRM) record. If an employee is given permission to access this segment of the CRM record, he can immediately assess the situation of the partner across the enterprise.

In the case of a subcontractor, when he is doing work for different projects in the enterprise, this would allow to evaluate an auditable trail of information regarding the subcontractor from different sources. System wide time stamps increase credibility for subcontractor evaluation.

In the case of a customer, the audit trail may help argue disputes.

3.3. Project dimension of the RFA

Project manager faces many challenges during the life of a project. The concrete supply procedure, described previously, is a typical situation where an obscured problem in another department, not directly under project manager's jurisdiction, may cause unexpected delay. If the activity is on the critical path, the whole project might come to jeopardy. The employees in Transport may not even be aware of the consequences. An alert across topic thread would be extremely valuable to the project manager enabling him to prevent challenging situations.

The RFA header may contain a project id, identifying the task to be pertinent to the project. Such a request is not necessarily sent by the project manager. It can be originated internally in Procurement Department, by an employee in charge of a supplier, or between two employees in accounting. The project manager should be aware of this information and it will automatically show on his News Wall, making him a participant with permission to post to this topic.

If the activity schedule is developed for the project, the Sender may register the activity id in the RFA header. This allows assembly of an enterprise wide team, with a task to focus on successful activity completion. Alternatively, multiple teams, each with different participants, could be tailored to focus on few key activities on the critical path. The project manager could easily manage emerging situations and coordinate professionals from different corporate altitudes in an effort to complete the project with success.

The schedule activities are linked to bid estimates and participants from estimating department are easily included into the monitoring process.

3.4. Collaborative Risk Management dimension of the RFA

A recent study (Gallagher, 2013) analyses Enterprise Risk Management implementation failures and shows that it takes 18-24 month to develop appropriate risk registry after which the Enterprise Risk Management effort gets stuck due to lack of appropriate tone at the top management, poor monitoring of emerging risks, decentralization, lack of accountability and lack of effective communication and training. Existing approaches to risk management lack two essential components:

- Except for aspects of frequency and severity, the risks have altitude, a level at which they are best managed in the enterprise
- To manage enterprise risk effectively it is important to introduce collaborative effort using functional network structures, a concept of corporate social network

Risk mitigation involves planning the steps to be taken, which propagate through the enterprise, forming complex threads of actions across multiple departments. Multidimensional Preemptive Coordination allows the risk owner to link the risk to a particular Request for Action (Bacun, 2015). The link contains the information about thresholds that would change the status of the risk. The risk can be linked more than one RFA, in fact, to any number of RFA in the enterprise, each one with its own threshold information. A particular Request for Action can influence more than one risk, thus, each request may be linked to more than one risk, with a different set of threshold data. The request can be viewed in different contexts, and its contribution to the risks at different levels may be different. The recipient logs daily progress, which is the basis for risk status update.

The Risk Management Structure may be different from the standard Organizational Breakdown Structure. The Request for Action integrates both structures into a coexistent and coordinated monitoring system.

Risk monitoring presents one of the biggest challenges in Enterprise Risk Management, mostly due to poor risk data gathering. Tasks related to risk monitoring fall outside regular business processes (PriceWaterHouse Coopers, 2008). Multidimensional Preemptive Coordination integrates risk monitoring into everyday business activities and makes risk data collection a continuous process.

The risk code, embedded in the RFA header, enables multiple focused social network groups, at different risk altitudes, to collaborate in risk management issues of a particular project, or particular risk across multiple projects.

3.5. Employee time tracking

The Recipient should report progress at least once a day. Each post to the history log contains information about the date and time spent on the task, which differs from the system time stamp. The time may be marked as billable, in which case the hours would be billed to a customer. Hours spent by the each subordinate on different requests are logged and should match the data on the time sheets. Posts that contain time spent data are visible only to vertical upper level in the Organizational Breakdown Structure.

4. Conclusion

Multidimensional Preemptive Coordination governs horizontal and vertical communication across the enterprise and represents the backbone of corporate management and communication. It alerts of approaching and missed deadlines and provides an auditable trail of actions performed, introducing accountability in all segments of the enterprise. The project manager steers problem resolution with Requests for Action issued to participants from different environments: other departments, subcontractors, outside partners, his subordinates and other parties necessary to ensure smooth completion of the project. The RFA's history log becomes a corporate social topic wall, where a particular problem is discussed and progress reported. Each social topic wall is visible only to the invitees and their horizon of visibility is limited only to the topics invited, so that participants external to the company can safely be invited. A Request for action can be linked to a partner (subcontractor), a project, a schedule activity or risk code providing multidimensional views of the same corporate activity. Any Request for Action, issued in any department in the enterprise and linked to a particular project, will be visible to the project manager, alerting him of status changes and new developments pertinent to his project. An employee participates in multiple social topic networks which are visible on his News Wall, narrowing his focus to problem at hand and protecting from data overload. Multidimensional preemptive coordination is a tool both for the management and field personnel. It enables preemptive action, establishes accountability across the enterprise an increases management performance.

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Process Chain Simulation Model of Production, Transportation and Asphalt Paving

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Abstract

Fragmentation of the construction project's life cycle, as well as the fragmentation of stakeholder responsibilities, is known global problem of the construction industry. In business of production, transportation and paving of great quantities of asphalt mixture, solving this problem has been emphasized by previous researchers as high priority. Detached process modeling and optimization without taking into account constraints of interrelations among sub-processes cannot offer the optimal or quality solution. Thus, it is necessary to structure a developing and easily adjustable model which will be able to integrate all sub-processes with their interrelations. In this paper authors have structured a developing simulation model for planning and optimization "*just in time*" chain of processes of production, transportation and paving of great quantities of asphalt mixture. Model has been proved, by scenario simulations of generated events, to be dynamic and adjustable for input parameter changes and updates. Authors also discuss the possibilities and constraints of applicability and interoperability of the structured model with the building information modeling concept (BIM).

Keywords: modeling; simulation; process chain; just in time; asphalt

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1. Introduction

Current trends of developing methodologies in processes modelling and simulation are mainly focused on incorporating the constraints of the production and environment, as well as the interpretation of the interaction and dependences among system's main components. The aforementioned trends are reflected in the need and application of such tools for processes optimization in large-scale projects where quantified explanation of the decisions are needed the most. Engineers have been facing problems of finding the quantitative confirmation of the plans for large scale asphalt paving projects. By the usage of common mathematical method, in literature known as transportation problem (TP), it was highly questionable and risky to declare the suggested solution as optimal. There are two main reasons underlined by the authors Galić et al., 2013a:

- only one objective function (i.e. minimization of the total transportation costs) without taking into account all significant integral processes,
- balanced model which assumes that offer has to match demand, practically meaning that all the appointed sources will be involved in the programme.

Planning the asphalt paving projects was concentrated on planning the efficiency of the paving operations, while asphalt mixture, plants capacities and reliabilities, as well as the transportation means, have been taken as already fulfilled assumptions. In order to ensure optimal and continuous work, but also the quality of the final product, it is crucial to include the complete chain of processes with belonging assumptions: production, transportation and paving. This fact was elaborated by author Zhang et al., 2013 and hypothesize that it will not be crucial only for the paving process efficiency, but for the production as well.

In this paper authors give a literature review and suggest a simulation model which involves all of the sub-processes in the chain of processes in hot mixture of asphalt (HMA) production, transportation and paving. Suggested model is called developing model because of its ability for adjustments to constant changes of input parameters, which are common in all of the mentioned processes in chain, and regarding the quality of input parameters through project's life cycle phases (conception → realization).

2. Literature review

Computational modelling of the organizational processes as a methodology for making, monitoring and optimization of the project plans various researchers worldwide Wynn et al., 2013; Corona-Suárez et al., 2014; Beloglazov et al., 2015 Galić et al., 2013b recommend as an excellent reengineering of the construction industry. Optimization methods of linear and non-linear programming have been neglected for many years, since their expansion in 1970's when mathematical (theoretical) models were developed. The main reason why those methods have been neglected authors Márquez, 2010; Kall and Mayer, 2005; AbouRizk et al., 2011; Hsie et al., 2009 have identified in rather complex application for modelling and optimization of stochastic processes, which are common for construction.

With today's highly developed IT sector complexity and issues of the mentioned methods aren't critical. Optimal solutions are gained in short period of time and what is very important: gained results are surely optimal meaning that they are ensured from the sub-optimality which is common for mathematical models earlier mentioned. Thus, modelling and optimization is once again in the focus of scientist researching the problems of organization, planning, control and optimization of the construction processes and production.

Transportation problem (TP) is just one of the methods and models which are under the scope and which application is being expanded and modified (shown in figure 1). The

main problem of the TP was complex application for large matrix forms. Nowadays, simulation models have been proved not just as efficient in solving large problem of TP, but as well as a visualization tool of the material flow, resource allocation, bottlenecks detection and prevention, and various scenarios simulation (*i.e.* what-if scenarios) noted by authors AbouRizk, 2010; Mariz et al., 2013; Tang et al., 2014. However, author Tang et al., 2014 has underlined that available simulation software often tends to have complicated input and export of the data, and suggests that further researchers should detect alternative software and work on more general approach of processes modelling in order to be more understandable and user-friendly. For TP available computer algorithms are proved to be effective. Although, those algorithms are primarily developed only for solving and optimization the transportation of the goods (denoted in Figure 1 as "X_{ij}") from sources (denoted in figure 1 as "$A_{1\rightarrow m}$" with belonging capacities "$a_{1\rightarrow m}$") to sinks (in figure 1 denoted as "$B_{1\rightarrow n}$" with belonging demand "$b_{1\rightarrow n}$"), but they can be modified for purpose of simulation and optimization of the expanded models including other integral processes and constraints, but in the domain of TP according to Galić et al., 2013a.

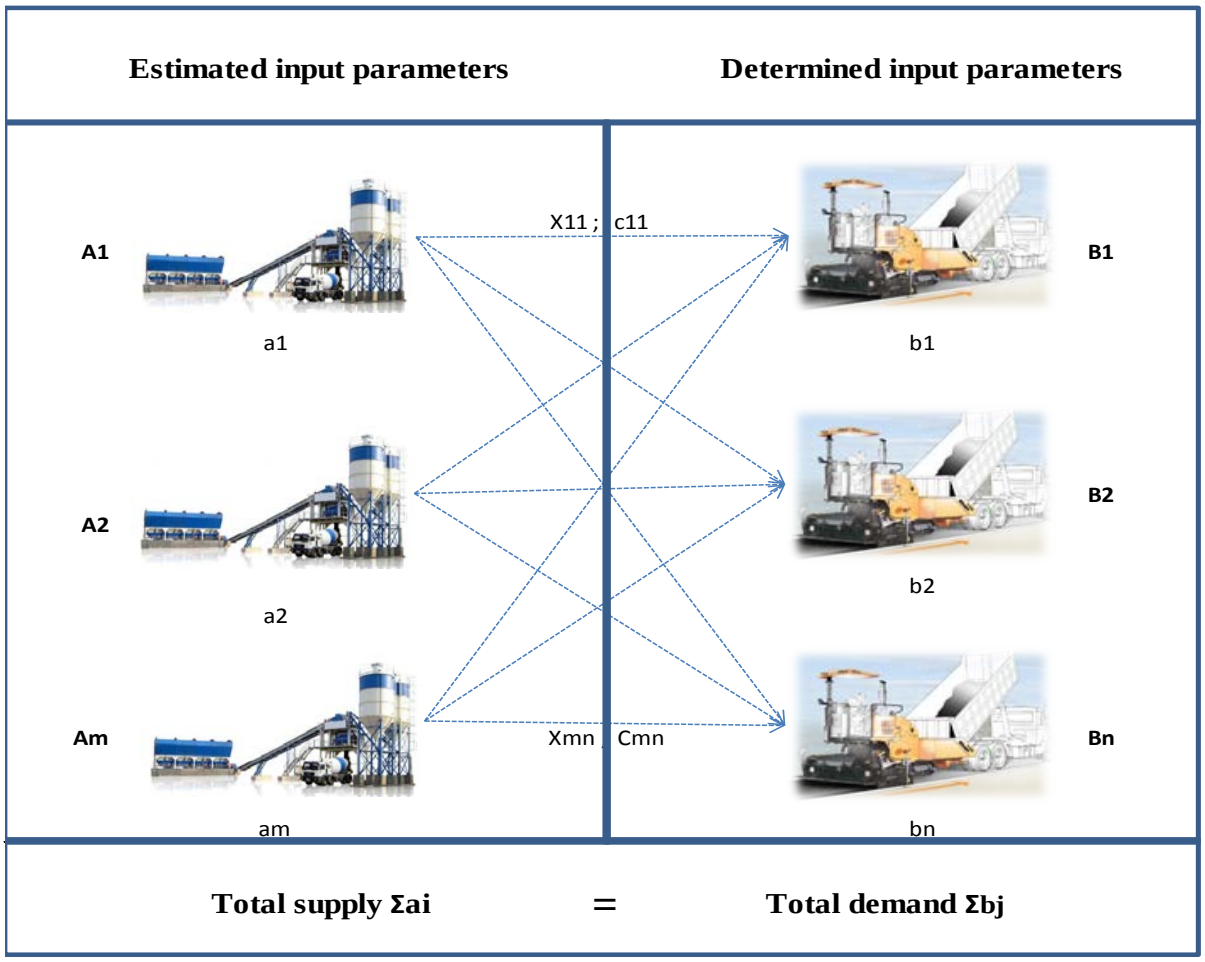

Fig 1. Graphical presentation of the TP definition

Numerous researchers have suggested models which haven't analysed the holistic problem of the production, transportation and asphalt paving, rather as sequence of detached processes. According to the recommendations for further researchers published by the authors Nassar et al., 2003; Peyret and Tasky, 2004 simulation software should allow user to model the

mentioned chain of processes (i.e. asphalt mixture production, transportation and paving) as a holistic processes and optimize it taking into account interrelated constraints of integral sub-processes. This approach of modelling and simulation will offer final optimal solution and reduce the risk of sub-optimal results.

3. Process chain simulation model of production, transportation and asphalt paving

1.1. Description of the model

Optimization of the complete chain of processes has a form of expanded TP which has two sides of constraints (beside TP's belonging transportation constraints): on one side there are constraints of the production and on the other there are constraints of the asphalt paving operations (shown in Figure 1). The main characteristics or assumptions of the problem which have to be fulfilled are:

- Construction sites are demanding large quantities of the asphalt mixture in short time period,
- Storage of the asphalt mixture is not an option (production and paving "just in time"),
- There is a significant difference between efficiency among processes in chain
- Dynamic (stochastic) environment and influences on the project.

According to the mentioned assumptions, sources (asphalt plants) have to be defined with their capacity, availability and reliability for both (i.e. capacity and availability). As it was mentioned earlier authors propose a model which has to be developing and adaptable to changes in the project. Therefore, in early project's phase capacity could be estimated by the given plants nominal capacity, while availability of the potential plants depends on the plants schedule but more importantly on the mixture which is required and the distance of the plant from the given site locations. The type of asphalts mixture is given and it is analyzed through its quality requirement which is indicated by its temperature. The temperature is decreasing from the point of production and loading into the transportation vehicle, to the point of paving. Therefore, the distance between asphalt plant and construction site is defined by the allowed temperature drop. For HMA the production temperature is in the interval of 160°-180°C, while required temperature of paving is in the interval of 110°-135°C elaborated by the authors Wang et al., 2014; Miller et al., 2011.

1.2. Sensitivity of the model

Asphalt plants as sources are critical processes in the chain. In comparison to other sub-processes in the chain they are not easy to replace without influencing the entire project and optimal program. Thus, plants reliability is significant factor for project planning, program's post-optimal analysis and scenario evaluation. Each source (plant) engaged in the optimal program has to be quantitatively evaluated through its reliability for fulfilling the demand gained by the optimal program.

1.3. Mathematical interpretation of the model

Authors are taking the mathematical model of TP (objective function equation 1 and belonging constraints equation 2) as a starting point for the model modification by adding the constraints (dependences) among components.

$$\min Z = \sum_{n}^{m} \sum_{m}^{n} c_{ij} * x_{ij} \tag{1}$$

$$\sum_{j=1}^{m} x_{ij} = a_i; \quad \sum_{i=1}^{n} x_{ij} = b_j; \quad x_{ij} \geq 0 \tag{2}$$

First and the most important is the dependence of distances between the plants and construction sites "L_{mn}" on temperature drop "Δt" during the transportation (Equation 3) for the HMA. This dependence is actually a physical constraint of the model. The potential asphalt plants are those in the circle in which the time of the HMA transportation will not influence the determined temperature for paving (110°-135°C).

$$L_{mn}(\Delta t) \leq 70\text{-}80\text{km}; \quad \Delta t \leq 50\text{-}70°\text{C} \tag{3}$$

The second dependence is the influence of the construction site on paving operations efficiency "E_{RP}^{n}" (i.e. rollers and asphalt pavers) on the transportation "E_T" and production of asphalt mixture "E_P^{m}" (Equation 4). By this the model will appreciate site's efficiency and adapt production and transportation efficiency to matching.

$$\sum E_{RP}^{n} \rightarrow \sum E_T \rightarrow \sum E_P^{m} \tag{4}$$

The last dependence, but not the least, is the reliability factor "R" of each plant based on its nominal capacity which will be a part of the researchers' further work based on the following mathematical expression for estimation of the reliability of technical systems given by author Birolini, 1997 (Equation 5):

$$R(t) = \sum_{i=k}^{n} \binom{n}{i} [1-F_i(t)]^{i} [F_i(t)]^{n-1}; \quad t = \frac{x_m}{E_P^{m}} \tag{5}$$

The given equation 5 is used for analysis of semi serial processes with "k" elements (k>1) where number "n" is the number of required operable elements for the systems fully capacity and "$F_i(t)$" is the function of failure in time "t" which depends on the amount of asphalt "X_m" from the asphalt plant "m" gained by the simulation (optimization) and its production efficiency "E_P^{m}".

1.4. Model's scheme

The first step of the model structuring is data collecting and forming the input data file (data about plants: number, capacities, locations, reliabilities regarding the capacities; transportation means: their number, capacities, distances from plants to the sites; construction sites: their number, locations, needed quantities of HMA, paving technology and its efficiency). After that it is possible to structure the computational model in simulation software and to setup the scenario simulations.

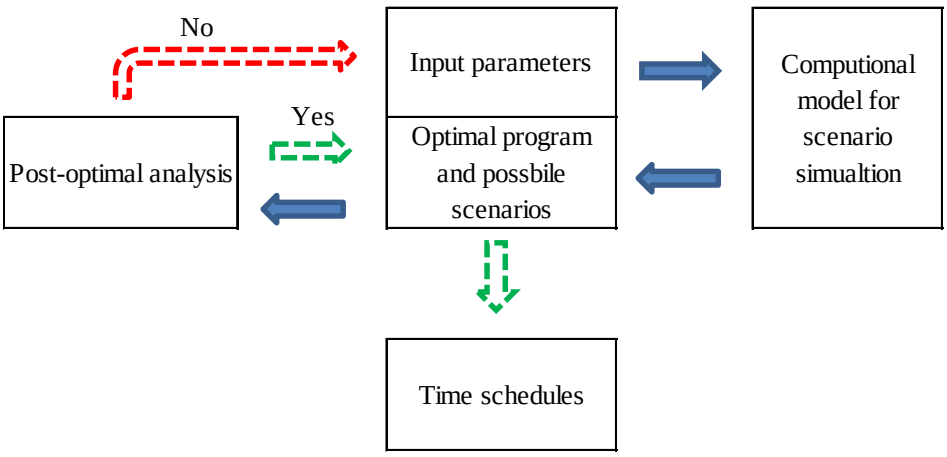

Fig 2. Function scheme of the developing model

In processes of setting up the simulation time it is necessary to connect the input parameters to the models entities in the simulation software. Third step is to run the simulations and to export the results into the file (different place) of the input parameters for further analysis. The result of the simulation will provide one optimal solution (program) and given number of scenarios with belonging programs. The fourth step is the post optimal analysis on the basis of risk assessment of the plants reliabilities engaged in the program (Figure 2). Risk assessment through the plants reliability in the optimal programme is significant for post optimal analysis and evaluation of the possible scenarios. Each of the sources has to be quantitatively evaluated by its reliability factor for accomplishing the requirement of demand for that quantity and production time. As it is shown in Figure 2 and in Table 1 the user has to make final decision about the total risk of the optimal program and possible scenarios, and make a decision either to go back to the models input parameters and setup a new simulation set or accept one of the given scenarios with the total risk defined.

Table 1. Matrix form of the post optimal analysis for the decision making gained by simulation

	Total costs	Total duration	Risk assessment
Optimal program	C	T	R
Scenario 1	C_1	T_1	R_1
Scenario 2	C_2	T_2	R_2
Scenario 3	C_3	T_3	R_3
Sceanrio N	C_N	T_N	R_N

4. Conclusions and plans for further research

Process modelling and scenario simulations in construction industry are becoming more important. Scenario simulation is becoming vital tool for decision making through the entire project's life cycle. Thus, crucial requirement put before models is their incorporation and acknowledgment of the projects stochastic and dynamic environment. The difference between static and dynamic model lies in its ability to adapt itself to constant changes of input

parameters and their priority. So, it is logical that sensitive spot of the modelling and simulation is input parameters. Suggested developing model allows the user easy and secure update of the input parameters regarding to their constant change (change of their presence, priority and quality). Input parameters data file (location of sources and sites) in author's plan for future research will be connection to internet databases (e.g. GPS maps for locations and routes for transportation; weather forecast, etc.) for making a step closer to the real-time simulations. With this improvement control of the input parameters is done in one place outside of the models interface in a connected file, keeping in mind that the input parameters for the model are usually collected and therefore the input parameters data file has to be in a compatible format to the data base oriented software (e.g. Microsoft Excel or Access). This will enhance the communication among the participants in projects. Concept of the suggested developing model is similar to the Building Information Modelling concept (BIM). While BIM has already a firm point of application in public highway construction projects worldwide, concept of processes simulation still hasn't. The logical connection of the two modelling and simulation concept is something what future improvement should tend by firstly bridging their different orientations. The final goal of establishing the bidirectional connection between them is their synergy for the ultimate simulation tool in planning and optimization the chain of processes of production, transportation and asphalt paving projects.

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Evaluation of Stone Construction Works Related to Historic Buildings Restoration

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Abstract

Generally, when we speak about budgets and bills of quantities evaluation, the matter in question is in principle always a structured summary of costs arising from the human activity. Every participant of construction management has to sooner or later deal with budgets on construction works. And the same goal applies in any case - we all need to find out how much building erection or construction works will cost us. In the area of restoration, however, due to the current absence of the pricing policy, one can observe a decline in the quality of restored buildings. The recession in the construction industry continues to deepen; the decline in demand has resulted in lower prices of restoration works which often fall down below the profitability level. The recession leads to increased rivalry among competitors in the market. This may result in a decrease in prices of restoration works below the threshold of profitability and subsequent liquidation of many professional companies. The aim of this paper is to analyse the current situation of restoration works evaluation. The collected data and information will be used for subsequent statistical analysis and evaluation. This work will serve as a starting point for determination of the evaluation methods for stone construction works in the process of restoration of historic buildings.

Keywords: restoration, database, costs, prices, norms, masonry works;

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1. Introduction

Currently there is no unified approach to the issue of restoration works valuation in the Czech Republic. The current situation in this sphere is formed by the private sector and is based on the experience of individual budget planners and restorers. Taking into consideration the fact that there are no maximum and minimum limits in the scope of performed works we often deal with incorrect valuation of works. In result, subsequent realization may or even do bring harm to restoration activities as such.

The aim of this work is to create a method for determining standards in this area with an example of creating a database of prices for selected stone restoration works which would give investors and interested institutions better orientation in the area of costs and prices of these specific type of works.

2. Research methods

2.1 Overview of the current situation in this field

Restoration of "works of art - monuments" can be generally defined as "activities aimed at reducing the rate of their breakdown and consequent extinction of information carried via visual communication through time". It is possible to use the word "restoration" (in its narrow sense) in relation to the "works of art - monuments" to describe the different ways of their professional treatment, which, unlike conservation, presupposes some changes to their preserved appearance. In the Czech Republic, restoration of monuments is governed by the Act of Czech National Council no. 20/1987 Coll., on State Historical Preservation, as amended.

In the Czech Republic there are currently no standards addressing the issue of costs determination of historical objects restoration works.

If we look back into the history, in the period from 1960 to 1989 restoration works were carried out under the auspices of "Dílo", an enterprise of the Czech Art Fund. The main mission of the Czech Art Fund - its restoration department - was making decisions on allocation of the state funds on restoration works via artistic restoration committees. The value of the restoration works was determined by the committee of the Czech Art Fund. Events in 1989 and the tax reform of 1993, which abolished the special tax on literary and artistic activities, allowed practicing art activities as the so-called liberal profession not limited by any regulations. From that time on the value of all restoration works is determined only by individual restorers and budget planners of individual companies. To my best knowledge there is no methodological background to solve this issue.

2.2. Analysis of the determination of the calculation methods

The basis for the determination of the calculation method is a database of restored items which has been compiled since 2003. The database’s core consists of own analysis and comparison of already realized projects of similar character. The database relies on my own work experience (twelve years in GEMA ART GROUP a.s. in the position of a construction manager, my foreign experience is from the same position for SKANSKA in London, UK). Further important database source is National Heritage Institute of the Czech Republic. Overall the database is based on 45 various construction projects. The structure of the database is outlined in Table 1.

The available information was analysed with the focus on identification of the standards of the time consumption for individual works in the process of stone restoration and the standards of material consumption. Qualification requirements are already set by Act no. 20/1987 Coll., on State Historical Preservation, as amended (specifically by a person with a respective authorization - license for restoration)).

Table 1. Assessing data resources

Materials	Wages	Machinery	Unit price	Others budget items
Dealers‘ price lists	GEMA ART GROUP a.s – company information	GEMA ART GROUP a.s. - company information	Authors’ calculations and estimations	Realized budgets – GEMA ART GROUP a.s., SKANSKA a.s., National Heritage Institute
Manufacturers‘ price lists	Labour market statistics and observations	Competition survey	Competition survey	
		Price lists of machines’ lessors	Realized budgets - GEMA ART GROUP a.s., SKANSKA a.s., National Heritage Institute	

3. Findings and discussion

Using our own investigation, analysis of construction company documents and the documents from the archives of the National Heritage Institute acquired between 2003 and 2014 we aggregated the information serving as a basis for the analysis of the current situation in this field. A survey among professional public about the current state of the studied field confirmed the importance of finding a comprehensive solution of the issue.

There is a wide range of programs for the construction works budgeting designed by specialized engineering budgeting organizations such as URS Praha, RTS, Callida Ltd. and others. These organizations issue pricing documentation in the form of printed catalogues (price lists) of works, materials and technologies. In result, the literature devoted to construction works budgeting is relatively abundant in the Czech Republic.

However, the publications dealing with the calculation methods and the determination of prices of restoration works in the construction industry are very scarce, and those few that are available can be perceived rather as technical and organizational overview than the budget allocation manual.

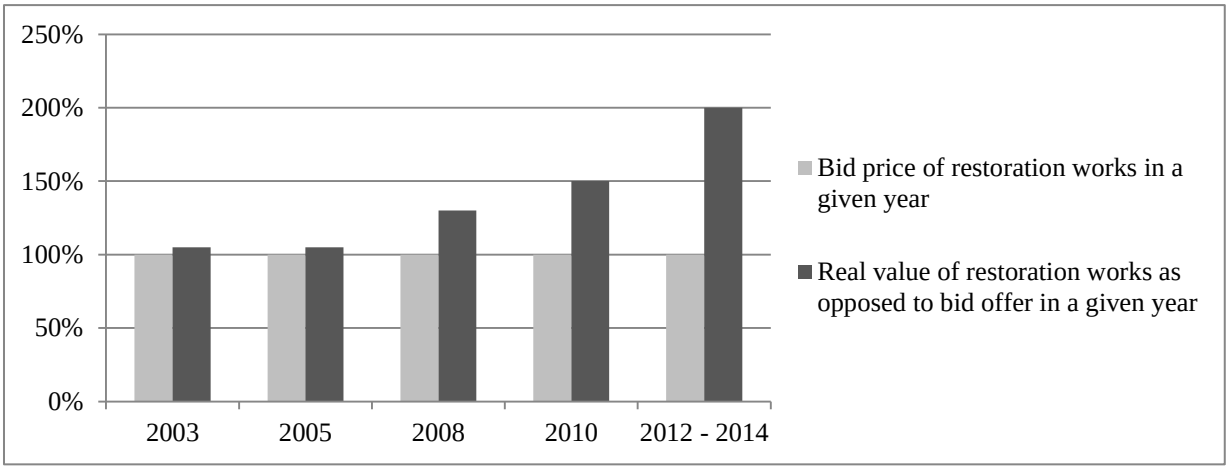
3.1. Analysis of the information, documentation and available literature

Calculation method for restoration work valuation was determined on the basis of the existing published methodology for construction works. It carefully summarizes the technical, technological and conservation requirements. It is focused on defining and practical verification of the selection criteria for most appropriate type of stone intended for restoration of historic buildings and best practices and methods of works realization. Using this methodology, it is possible to make adequate structural and historical, technological and mechanical, construction and technical surveys and then propose the optimal procedure of restoration applicable to a specific historical building. The methodology is based on the results of material research conducted in recent years in all studied workplaces and the current requirements of practical monument restoration.

The accuracy of restoration work valuation is highly dependent on the well-executed pre-project phase. It is particularly important to implement the required surveys diagnosing the state of the object (the basic engineering and technical survey or partial diagnostic surveys - survey of biotic infestation, study of moisture conditions, climatological survey and others), its development and value (engineering and historical research and archaeological restoration research), as well as to perform quality inventory of elements and to identify the main focus of the construction works. It was established that pre-project preparation contributes to the accuracy of the restoration works valuation to a significant extent. On the other hand, omitting of the required surveys leads to the subsequent cost increase of the realized works by 50 - 100%. The discrepancies between the budget estimation in tender procedures and the real

budget for actual realization of the works occur, according to the analysis results, especially in recent years (the period 2009 – 2014) as the construction projects often fall under the trend of "low bid prices" (see Table 2, comparison was done to those projects that were realized during the same calendar year).

Table 2. The influence of the project documentation and pre-project preparation on the evaluation of the restoration works (Source: authors' calculations)



The key factor affecting the valuation method was the identification of the standards of time consumption (performance standards) on a single item of restoration works in stone restoration. In our database it was established that the majority of the stone restoration works are always composed of various combinations of activities (see Table 3) carried out in relation to the restored element. This uniformity is mainly due to the same technologies used in restoration of stone elements. The differences are mainly related to the time period (performance standards) needed for each activity.

The performance standard *VN* is defined as an adjusted average of relevant items from the database, specifically

$$VN = \frac{\sum_{i=1}^{n} VN_i}{n} \cdot \gamma \qquad (1)$$

An adjustment parameter γ reflects specifics of the considered restoration work and its value (which can be lower of higher than 1) is determined by a skilled specialist. Of course, the bigger and more complex database is, the less need the parameter to be different from 1.

Table 3: The influence of the project documentation and pre-project preparation on the evaluation of the restoration works

activity No	Description of the activity
1	Mechanical cleaning
2	Washing by means of pressed steam (sensitive and only locally)
3	Removal of vegetation, micro flora, biotic dirt
4	Chemical cleaning (including crust removal)
5	Desalination
6	Removal of coloured sprayer marks and signs
7	Removal of a film of concrete powder

8	Removal of hydro isolation coating and asphalt drops
9	Repair of grouting
10	Filling of micro cracks
11	Deep grouting and injection of the open interstices and cracks by use of insets without drilling of the stone
12	Repair of dilatation cracks by an elastic sealant
13	Modelling or sealing of the missing or damaged parts (plastic retouch)
14	Replacement and addition of stone elements - including the fitting of the replaced or additional stone elements on stainless steel or bronze pivots and their sealing by lead filling (done only in the most indispensable cases)
15	Reinforcement by consolidating means
16	Biotic protection
17	Colour retouch
18	Hydrophobization

Another issue is to set the standards of material consumption. In our database it was established that the material is always determined in accordance with the type of stone damage and depends on the location of the restored element relative to the interior or exterior of the building. Consumption of the material for restoration works, especially with regards to stone elements, differs primarily by the degree of damage of original elements (see Fig. 1. a, b, c). The complexity of the performed works made no difference in this case, since the matter in question was only the quantity of material used, which in most cases is the same on flat surfaces, as, for example, on sculptural items.

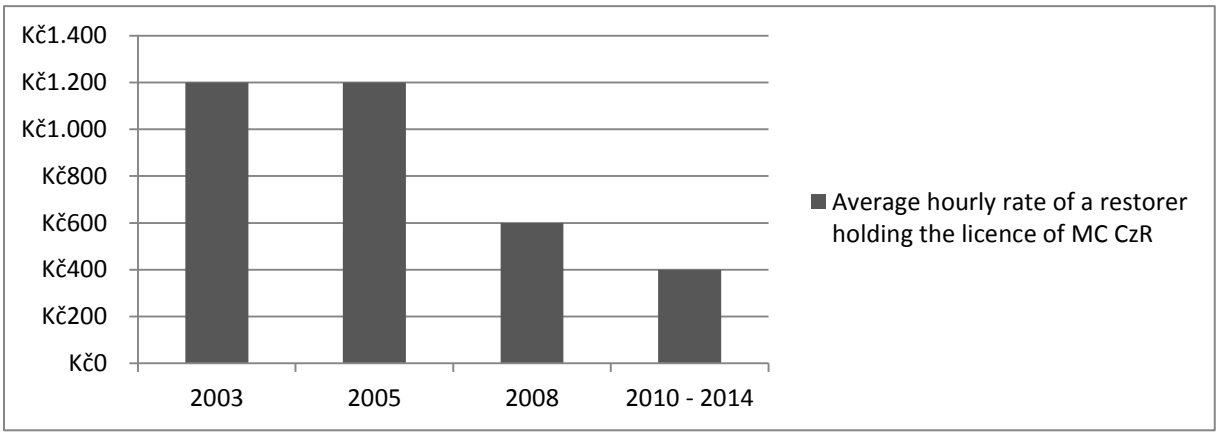
Fig. 1. (a) light damage; (b) medium damage
(c) *heavy damage*

(a) *(b)*

(c)

Tariff qualification requirements and rates for individual tariff levels in the indicative prices were identified from own company investigation, own database and were subsequently compared with other entities that perform similar works. It was found out that the rates of restorers with a valid permit for the restoration of the Ministry of Culture of the Czech Republic granted for the period 2003 - 2014 underwent major changes, and were decreased by up to 67% (see Table 3).

Table 3. Average hourly earnings of a restorer holding the licence of MCCzR for restoration of sculptures of stone (Source: Authors' calculations).



3.2. Evaluation

In the years 2003 - 2014 we carried out collection of data and documents from 45 realized projects related to the stone restoration in the area of construction activities. The analysis of the prices and costs of stone restoration was performed on that database. We have managed to identify key factors to determinate a method of valuation for these specific types of works.

4. Conclusion

It is possible to develop a relevant database of prices and costs of restoration works and such database can be used as a tool for experts, professionals and institutions dealing with restoration. Finding a solution to this issue could prevent financial underestimation of these services and its subsequent implementation could serve as a kind of guarantee that the restored object will get appropriate evaluation and appraisal at least from the budgeting point of view.

Based on the analysis and investigation it is necessary to address this issue, also with respect to the fact that several lawsuits regarding the prices and costs associated with restoration of a real historical building have already took place. In case of more complicated lawsuits this issue is unfortunately shifted into the field of the existing building databases, where forensic experts attempt to degrade the hourly rate of each qualified restorer and cost of materials needed for restoration (price, its usability, consumption, etc.) is questioned.

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Investigation of Water Absorption and Compressive Strength of Resin Coated Mortar

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Abstract

Nowadays various advanced techniques are used to enhance the performance of materials in the field of construction engineering. Structures exposed to aggressive, humid and hostile environment are experiencing severe negative impacts which leads to premature failure. Polyester resin is one of the advanced material used for improving performance of structural materials especially for repair/ refurbish purpose of structures and protection from contaminated environmental effect/ hazards. This study investigated the aptness of polyester resin as coating agent on mortar and assessed its performance in ambient environment of Pakistan. Cubical specimens of mortar were fabricated. These specimens were tested for water absorption and compressive strength after one day and sixty days. These tests were performed under different exposure conditions (ambient environment and submerged in water). The specimens were coated with one, two and three layers and results were compared to control (no/ zero resin layer) specimens. Test results indicated that there is a significant decrease in water absorption of mortar coated with resin when compared to controlled specimens. The compressive strength test results revealed that resin coated specimen had higher strength when compared to controlled specimens. The results suggested that resin is a promising material and can be used effectively in structures which are exposed to high temperatures. The study would be helpful in improving performance of structural material in hazardous environment.

Keywords: polyester resin, mortar, coating, ambient environment, water absorption, compressive strength

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1. Introduction

Concrete structures are facing hostile environment and excessive rainfall in some areas. To preserve such huge investment incurred during construction of structures, various techniques are used which includes but not limited to: liquid membrane, polyethylene sheets, bitumen coating, cementitious waterproofing, and sodium bentonite. The efficiency and performance of such measures is still questionable and researcher are looking for an optimal solution which can sustain and resist even in high temperatures.

With advancement in high performance materials, polyester resin is getting worldwide attention due to its versatility and easy adaptability. Resin is also used as one of constituent of concrete and termed as resin concrete. This composite concrete is very famous and under the maintenance and rehabilitation of structures. Resin has shown good qualities in repair because of its quick setting, easy usage, controlled shrinkage, and water resistance (El-Hawary & Abdel- Fattah, 2000). Estabragh et al., 2011 used resin as agent to soil-cement to enhance mechanical properties of soil mixture like shear strength and stiffness. This study concluded that strength of soil is increased considerably when resin is added. Polymer concrete (PC) also uses polyester resin as basic ingredient because of its quick setting, high strength properties and endure to corrosive environment, which makes it viable and surrogate to cement concrete in range of engineering applications like construction and repair of structures, highway pavements, bridge decks, waste water pipes and even in structural and decoration panels (Garas and Vipulanandan, 2003). There are various types of resin including epoxy which is commonly used as epoxide or ehtoxyline resins; incorporating epoxy groups. Waste applications of epoxy resins are enlisted like high strength adhesives and cementing agents in building industry and road surfacing. Epoxy has low shrinkage with immense toughness and capability to be used by various techniques (Satapah et al., 2005). Anagnostopoulos, 2007 used resin as filler and grout material for reduction of water penetration to substructure facilities or in dam foundation where loss of water is severe. Researchers have reported that polyester resin is one of the advanced material used in the field of civil engineering due to its wide range of applications. These applications include controlled shrinkage during curing, availability in different viscosities, easy and quick setting, high strength, chemical and wear resistance (Lim et al., 2009; Ahari et al., 2105). A study determined permeability of self-compacting concrete having supplementary cementitious material (SCM). The objective of this resarch was to study the effect of SCM on the compressive strength, water absorption, and sorptivity. Results indicated that replacement of cement by SCM yielded higher strength and lower water absorption (Ahari et al., 2015). Kirchheim et al., 2015 carried out comparative study of white and ordinary concrete with respect to carbonation and water absorption and concluded that water permeability or surface water absorption tests presented a good correlation with carbonation.

Extensive literature have indicated research and urgency in the field of construction materials especially for structures which are exposed to humid and corrosive environment. Cognizant to need of water ingress material, this study used polyester resin as water retaining (water proofing) material to reduce the water absorption (permeability) and hence increasing service life of structure by ensuring maximum safety.

2. Objective and Scope

The objective of this study is to investigate the water ingress (permeability) of mortar coated with resin layers, exposed to local ambient environment and dipped in water upto 60 days. The compressive strength of resin coated mortar was also compared to controlled (zero resin layer) mortar. This study uses specific type of resin i-e polyester resin alongwith cobalt, hardener. A

mortar of 1:6 was prepared using ordinary portland cement using water cement ratio of 0.50.

3. Methodology

The experimental design adopted for this study is shown in Fig. 1. The detailed methodology is described in ensuing paragraphs.

3.1. Selection of Material

The detail of materials is given below

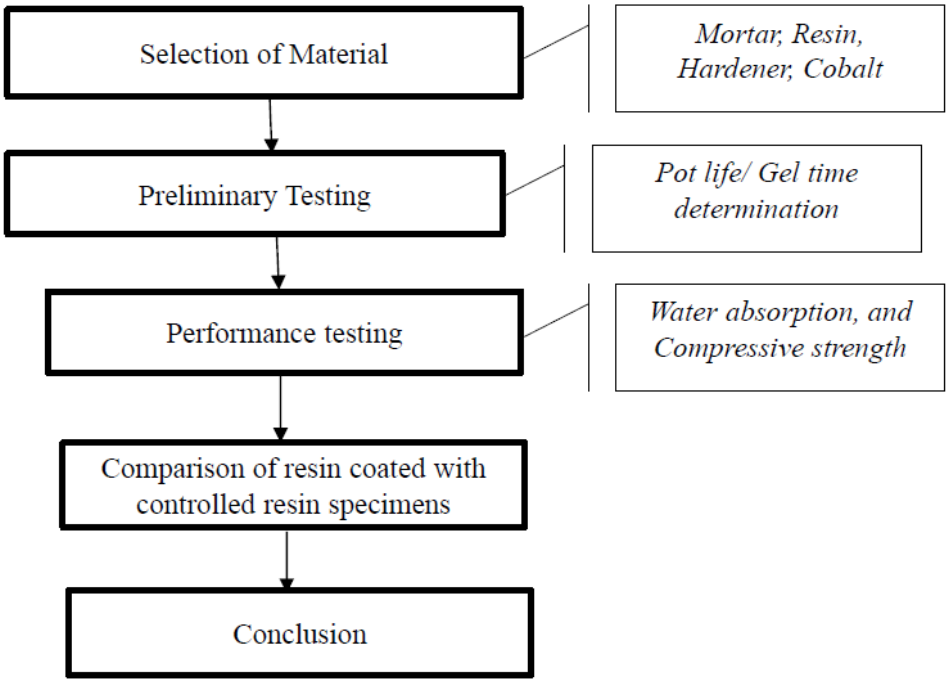

Figure 1. Experimental design of study

- **Resin**: Polyester resin is the material used this research and it is easily available in local market.
- **Cobalt**: Cobalt is the one of the constituent mixed with resin used to initiate the hardening process
- **Hardener**: Hardener is another ingredient which imparts plasticity and gel time. It is in liquid form.
- **Sand**: Fine aggregate (sand) is used in mortar for preparation of specimen and is passed through sieve # 16
- **Cement**: Ordinary Portland Cement (OPC) was used.
- **Proportion of Mortar (Cement: Sand):** The ratio of 1:6 was used and kept constant during the study.
- **Proportion of Resin to Cobalt:** A constant proportion of 1:0.01 was fixed for this study.
- **Gel time:** The quantity of hardener was adjusted to obtain Gel/ Pot life (initial hardening time) for 30 to 45 minutes. Whereas, final hardening time was observed to be between 24-36 hours.

3.2. Preliminary Testing

The precursor to final testing is the optimization of the resin proportion to hardener which would yield required Pot life/ Gel time and solidification. The proportion was so adjusted that

it could give Pot life/ Gel time of around 30 minutes and complete solidification upto 36 hours. The result of preliminary testing is shown in Table 1.

Table 1 Details of preliminary study

S.No	Proportion (%)	Quantity (milliliter) Resin	Hardener	Pot life (minutes)
01	1:1	05	05	Nil*
02	1: 0.5	10	05	Nil*
03	1: 0.4	03	1.2	Nil*
04	1: 0.3	08	2.4	Nil*
05	1: 0.1	09	0.9	25
06	1: 0.08	08	0.64	26
07	1: 0.05	10	0.5	27
08	1: 0.03	09	0.27	28
09	1: 0.02	10	0.2	28
10	1: 0.01	10	0.1	30

* These ratios are those on which either resin does not harden or it become precipitate.

3.3. Final Testing

The final testing program which includes water absorption and compressive strength test was carried out on specimen coated with 0, 1, 2, and 3 resin layers (0 layer means no resin or controlled specimen). These specimens were subjected to two different exposure conditions i-e ambient environment and submerged in water. The exposure duration and time was one and sixty days.

4. Results and Analysis

4.1. Water Absorption

The water absorption test was performed in accordance with BS 1881, Part 122. Triplicate specimens were tested for water ingress after one and sixty days exposed ambient environment and immersed in water. The percent absorption is calculated by equation 1.

$$W_a = \frac{W_w - W_d}{W_d} \qquad (1)$$

Where

W_a = Percentage of water absorption

W_w = Weight of wet specimen

W_d = Weight of dry sample

The results obtained from the water absorption test is presented in Fig. 2 and 3. The resultsare self-evident regarding the tremendous effectiveness of resin coating in terms of water absorption. The results suggested that water absorption reduces with increase in application of number of resin layers. In case of the specimen exposed to the ambient environment and tested after one day, the average water absorption varies from 2.9% (controlled) to 0.13% (three resin layer) when exposed to ambient environment for one day. The results indicated that water absorption was reduced significantly with application of resin when exposed to ambient environment (under open sky) for sixty days and the identical behavior of specimens was observed. During this course of time, specimens were not only exposed to high temperature as 50°C in day time but also experienced change in temperature and rainfall as well. It should be worth mentioning here that besides the deterioration of

resin coating, resin solidifies and showed extended performance when three layers are applied and exhibited nearly 0% water absorption. It can be observed that water absorption varies from 8.25% to 1.01% for controlled to three layer of resin when submerged in water for one day then after tested for water absorption. Whereas, the absorption increased to 11.12% to 10.02% for aforesaid layers when dipped in water for sixty days. It can be inferred from these results the resin coating is effective in reducing water ingress to specimen in both conditions (ambient and water) and three layers of resin coating is found to be relatively better than one and two layers of resin coating. The effectiveness of resin coating diminishes with the passage of time when continuously dipped in water. This aspect may be investigated further.

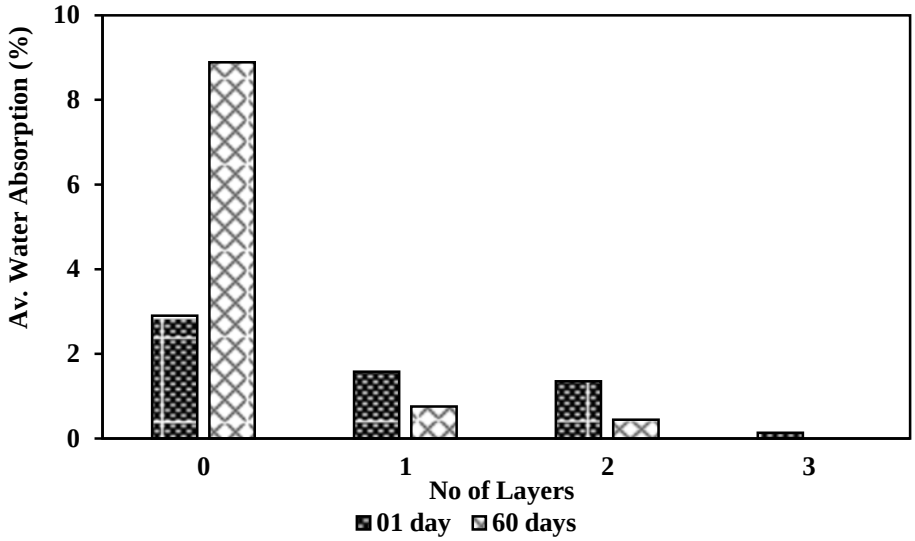

Figure 2. Average water absorption (%) in ambient environment

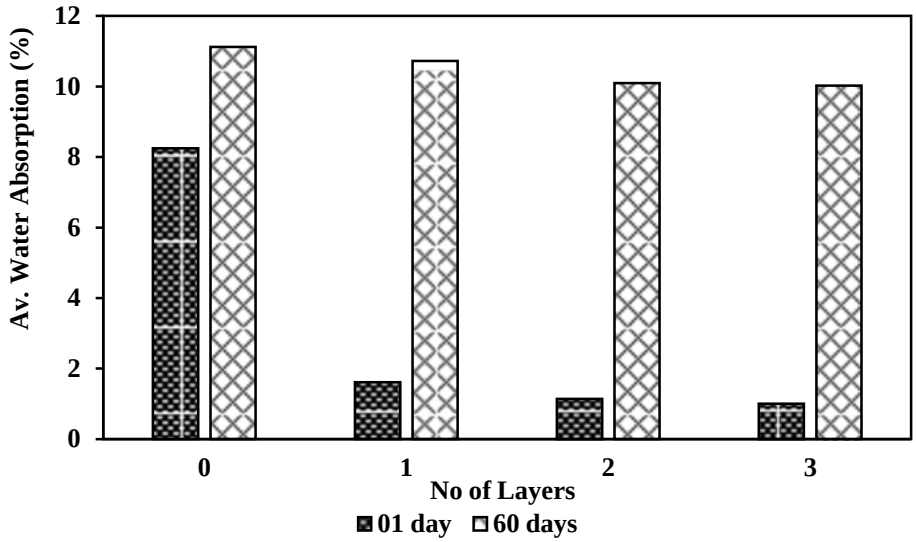

Figure 3. Average water absorption (%) dipped in water

4.2. Compressive Strength Test

The compressive strength test was carried out using universal testing machine (UTM) as per ASTM C109-05. The test results indicated the efficacy of resin coating in terms of compressive strength (Fig. 4). The compressive strength results are opposite to water absorption as number of layers increase, strength of mortar is increasing and vice versa. The trend of results is

analogous in both exposure conditions: the specimens tested after exposing to ambient environment and submerged in water. It can be inferred that maximum compressive strength is 15.27 MPa for specimens coated with three resin layers which is 76% greater than that in case of the specimens without coating exposed to the same environment and time before testing. However, for without resin coating, the minimum compressive strength observed is 8.5 MPa. This illustrates the importance and effectiveness of polyester resin in strength gain as obtained in continuous curing process of resin coated specimens unlike the wax curing technique which applies the curing sealant to enhance the compressive strength. Thus, the evaporation of water is restricted, resulting in continuous and prolonged curing, thereby, exhibiting a significant gain of strength.

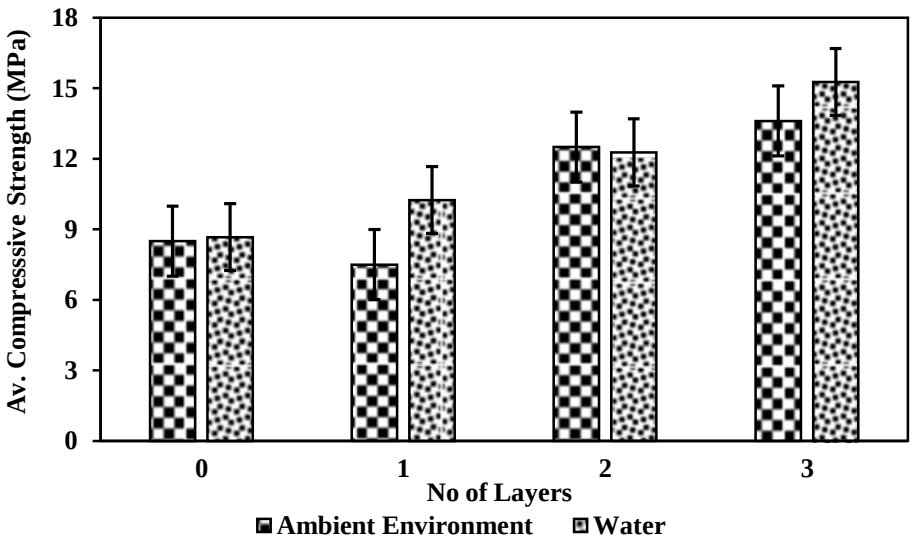

Figure 4. Average Compressive strength (MPa) of mortar

5. Conclusions

Given the resin to hardener ratio of 1:0.01 and 1:6 (C/S) mortar, the water absorption is reduced drastically when resin layer are applied. The number of layers are directly proportional to reduction of water absorption which may be attributed to proper solidification of resin layer over the passage of time when exposed to ambient environment and thereby behaving like sealing coat to the mortar. The water absorption of three layers of resin coated mortar is nearly zero when tested after exposure of sixty days to ambient environment incline high temperatures of 50°C and heavy rainfall. The resin coating was diminished in case of specimens dipped in water for one day and sixty days. The compressive strength is also enhanced by 76% after application of three layers of resin coating when compared to controlled specimens keeping all other conditions similar.

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CONSTRUCTION / PROJECT MANAGEMENT ISSUES

Optimal Project Scheduling under Non-Convex Time-Cost Trade-Off Relationships

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Abstract

Cost effective time scheduling represents an important issue in project management. The optimization of project schedule with time-cost trade-offs is concerned with crashing and scheduling the project activities in order to minimize the total project cost. Considering the continuous representation of project time-cost relationships, the existing solution techniques were focused on project scheduling problems with linear, concave, convex and hybrid concave-convex functions. However, the non-convex time-cost relationships may occur in industrial projects, especially in cases when various different duration options are available for project activities on account of optional technological processes for their execution or wide accessibility of production resources. In this way, the aim of this paper is to present the optimization of project schedules under non-convex time-cost trade-off relationships by global nonlinear programming approach. An example from the literature is presented in the paper to demonstrate the advantages of the proposed optimization approach.

Keywords: project scheduling; time-cost trade-off problem; non-convex time-cost relationships; nonlinear programming; global optimization

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1. Introduction

The time-cost trade-off problem (TCTP) represents a well-known project scheduling optimization task that was originally presented by Kelley and Walker (1959). The TCTP is associated with crashing and scheduling project activities for the purpose of minimizing the total cost of project execution. The optimal solution of the TCTP has received considerable attention in research community on account of its practical relevance in project management. Namely, the duration of a typical production activity in industrial project tightly depends on the selected technological process to be used as well as the assigned resources, such as crew, machinery, equipment, etc. Realization of each project activity, in normal duration, requires engagement of certain resources and direct cost. Executing the project activity in its reduced duration usually demands additional resources at higher direct cost.

On the contrary, the crashing of project activities leads to reduced project duration and indirect cost. Therefore, the best combination between the duration and the direct cost has to be determined for each project activity, which in turn establishes the optimal project duration and the minimum total project cost. As soon as the total project cost becomes nonlinearly time-dependent, the TCTP turns into the nonlinear optimization problem.

Numerous different approximate heuristic and exact mathematical programming optimization methods have been proposed to solve the nonlinear TCTP. As regards the approximate heuristic methods, the nonlinear TCTPs were solved using the genetic algorithms (Feng et al., 1997; Li et al., 1999; Hegazy, 1999; Leu et al., 2001; Zheng et al., 2004; Eshtehardian et al., 2009), simulated annealing (Azaron et al., 2007; He et al., 2009), tabu search (He et al., 2009; Hazir et al., 2011), neural networks (Adeli and Karim, 1997), ant colony optimization (Ng and Zhang, 2008; Xiong and Kuang, 2008; Afshar et al., 2009; Kalhor et al., 2011), particle swarm optimization (Yang, 2007), differential evolution (Nearchou, 2010), harmony search (Geem, 2010), and different hybrid techniques, such as genetic algorithm and dynamic programming (Ezeldin and Soliman, 2009), cutting plane method and Monte Carlo simulation (Mokhtari et al., 2010), genetic algorithm and simulated annealing (Sonmez and Bettemir, 2012) among others.

Beside heuristic approaches, deterministic methods own a great fraction of the stake. Between those, the nonlinear programming (NLP) has been recognized as a suitable tool for finding the exact optimal solution of the TCTP with continuous nonlinear cost functions (Kapur, 1973; Deckro et al., 1995; Deckro and Hebert, 2003; Turnquist and Nozick, 2004; Klanšek and Pšunder, 2010a). According to the continuous representation of time-cost relationships, the existing solution techniques were focused on the project scheduling problems with linear, concave, convex and hybrid concave-convex functions.

On the other hand, the non-convex time-cost relationships can appear in production activities of the industrial project, see e.g. reference (Klanšek and Kravanja, 2006). Thus, the aim of the paper is to present the optimization of project schedules with non-convex time-cost trade-off relationships by global NLP approach. An example from the literature is presented in the paper to demonstrate advantages of the proposed optimization approach.

2. Time-cost trade-off relationships

In the optimization of project schedules with time-cost trade-off relationships, the direct cost of an activity was frequently expressed as constrained and non-increasing function of its duration. Early studies on the TCTPs, such as research works presented by Kelley (1961) and Fulkerson (1961), assumed that the time-cost trade-off relationship of project activity was linear, see Figure 1a.

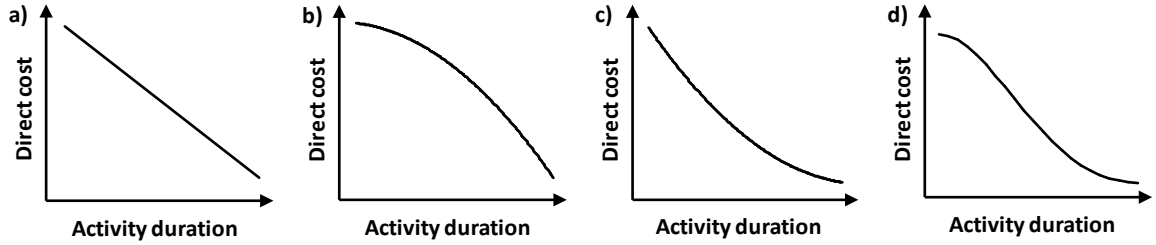

Fig. 1. Activity time-cost functions

Using linearity assumption, the TCTP can be formulated as linear optimization problem and efficiently solved using a suitable linear programming (LP) technique. Nevertheless, even the earliest research works in this field recognized that the linearity assumption for the time-cost trade-off relationship, in many cases, does not reflect a natural dependence between the duration and direct cost of project activity. In subsequently published studies, the linearity assumption has been relaxed by enabling the time-cost function of project activity to take a different shape, e.g. concave (Falk and Horowitz, 1972), convex (Foldes and Soumis, 1993) or hybrid concave-convex (Moder et al., 1995), see Figures 1b-d respectively.

In industrial projects, the shape of direct cost function of a typical production activity is closely related to the resources allocated to it. Activity time-cost function can be oftentimes obtained as an outcome of a nonlinear regression (Li et al., 1999) and the time-cost trade-off relationship can be, in many cases, suitably approximated with linear, concave, convex or hybrid concave-convex function. Though, the non-convex time-cost relationships may occur in industrial projects, especially in cases when various different duration options are available for project activities on account of optional technological processes for their execution or wide accessibility of production resources.

The importance of non-convex time-cost (TC) relationships is visible in cases, where there are more options available to accelerate construction schedule. More precisely, the non-convex TC relationships may occur, when fourth or any subsequent option is available, in order to meet specific deadline, with the least cost. To ensure the latter, there are several options available, for instance, increasing the number of workers, working longer hours or creating an additional shift of workers. Many studies indicate (Hanna et al., 2008), that the above mentioned options do not provide the desired effect due to reduced work efficiency and increased direct costs, furthermore they may cause loss of convexity, see Figure 2, where marked dots denote four different TC options and represent the non-convex function.

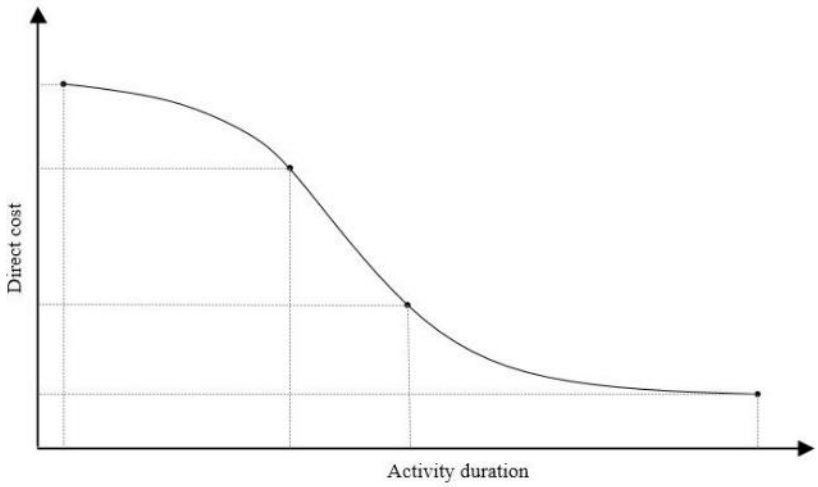

Fig. 2. Non-convex function with four time-cost trade-off options

In such cases, the approximation of project activity time-cost trade-off relationships may not be suitably achieved using linear, concave, convex or even hybrid concave-convex functions. Moreover, the differences between the values of parameters for real time-cost functions, obtained from the project analysis, and the approximated ones, used in optimization

model for project scheduling problem, may cause the search algorithm to find the sub-optimal solution. However, for several different project activity duration options, the polynomial approximation functions can be suitably applied for the time-cost trade-off relationships within the optimization model of the project-scheduling problem.

3. Optimization problem formulation

The optimization problem of project scheduling with nonlinear time-cost relationships can be solved by the NLP approach. The NLP optimization problem may be generally formulated using the following expressions:

$$\text{Minimize } z = f(\boldsymbol{x})$$

$$\text{subject to:}$$

$$\boldsymbol{h}(\boldsymbol{x}) = \boldsymbol{0} \qquad \text{(NLP)}$$

$$\boldsymbol{g}(\boldsymbol{x}) \leq \boldsymbol{0}$$

$$\boldsymbol{x} \in \boldsymbol{X} = \{\boldsymbol{x} \mid \boldsymbol{x} \in \boldsymbol{R}^{\boldsymbol{n}}, \boldsymbol{x}^{\mathrm{LO}} \leq \boldsymbol{x} \leq \boldsymbol{x}^{\mathrm{UP}}\}$$

where $\boldsymbol{x}$ is the vector of continuous decision variables, determined in the compact set $\boldsymbol{X}$. Functions $f(\boldsymbol{x})$, $\boldsymbol{h}(\boldsymbol{x})$ and $\boldsymbol{g}(\boldsymbol{x})$ are the (non)linear functions contained within the objective function z, the equality and inequality constraints, respectively. All defined functions $f(\boldsymbol{x})$, $\boldsymbol{h}(\boldsymbol{x})$ and $\boldsymbol{g}(\boldsymbol{x})$ have to be continuous and differentiable.

From the viewpoint of the TCTP, the vector of continuous decision variables contains the scheduling parameters, such as activity start times, durations, direct costs, etc. The objective function defines the total project cost. The equality and inequality constraints as well as the bounds on variables compose a rigorous system of the precedence relationship constraints, the activity duration constraints and the project duration constraints. More details about the NLP optimization model formulation of the TCTP can be found in reference (Klanšek and Pšunder, 2010a).

4. Solution techniques

The nonlinear TCTPs can, in principle, be solved by several classical local search NLP algorithms and their improved versions such as the reduced gradient method (Wolfe, 1963), the generalized reduced gradient method (Abadie and Carpentier, 1969), the augmented Lagrangian (Powell, 1969), the sequential quadratic programming (Powell, 1978) and the nonlinear extensions of the interior point method (Karmarkar, 1984). However, the presence of non-convex functions within the model of the TCTP may cause difficulties for classical NLP algorithms to find high quality solution.

Nevertheless, recent research findings (Klanšek and Pšunder, 2010b) show that global NLP methods can find high quality results even for difficult non-convex optimization problems. Thus, the non-convex TCTP can be suitably solved by global optimization techniques such as the branch and reduce method (Ryoo and Sahinidis, 1996), the combination of global and local search strategies (Pintér, 2007), the branch and cut method (Lin and Scharge, 2009), and the multi-start stochastic search algorithm (Ugray et al., 2009).

5. Example from the literature

In order to show the advantages of global optimization techniques, an example project, originally presented in reference (Burns et al., 1996), is considered in this section. The example project consists of 18 activities. The precedence relationships between the activities

and the alternative cost-duration options are given in Table 1, while the activity-on-node precedence network of the example project is demonstrated in Figure 3.

Table 1. Precedence relationships and alternative cost-duration options

Act. No.	Preceding Act. No.	Option 1		Option 2		Option 3		Option 4		Option 5	
		Duration [days]	Cost [$]	Duration [days]	Cost [$]	Duration [days]	Cost [$]	Duration [days]	Cost [$]	Duration [days]	Cost [$]
1		14	2400	15	2150	16	1900	21	1500	24	1200
2		15	3000	18	2400	20	1800	23	1500	25	1000
3		15	4500	22	4000	33	3200	–	–	–	–
4		12	45000	16	35000	20	30000	–	–	–	–
5	1	22	20000	24	17500	28	15000	30	10000	–	–
6	1	14	40000	18	32000	24	18000	–	–	–	–
7	5	9	30000	15	24000	18	22000	–	–	–	–
8	6	14	220	15	215	16	200	21	208	24	120
9	6	15	300	18	240	20	180	23	150	25	100
10	2, 6	15	450	22	400	33	320	–	–	–	–
11	7, 8	12	450	16	350	20	300	–	–	–	–
12	5, 9, 10	22	2000	24	1750	28	1500	30	1000	–	–
13	3	14	4000	18	3200	24	1800	–	–	–	–
14	4, 10	9	3000	15	2400	18	2200	–	–	–	–
15	12	12	4500	16	3500	–	–	–	–	–	–
16	13, 14	20	3000	22	2000	24	1750	28	1500	30	1000
17	11, 14, 15	14	4000	18	3200	24	1800	–	–	–	–
18	16, 17	9	3000	15	2400	18	2200	–	–	–	–

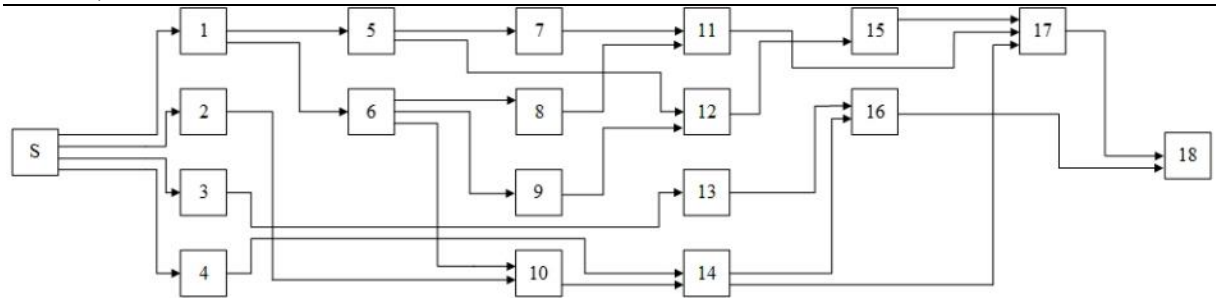

Fig. 3. Activity-on-node precedence network of the example project

The first option refers to the crashed activity duration and direct cost, while the last option represents the normal activity duration and direct cost. Furthermore, the first option for project activity duration denotes its lower bound, while the last option defines its upper bound. Taking the input value for indirect project cost into account, the two separate cases from the literature were considered in this paper.

In the first case, the optimization of project schedule was performed under indirect project cost of $200 per day as proposed in references (Hegazy, 1999; Afshar et al., 2009; Kalhor et al., 2011; Sonmez and Bettemir, 2012; Bettemir, 2009). In the second case, the optimization of project schedule was executed under daily indirect project cost of $1500 as suggested in references (Ng and Zhang, 2008; Afshar et al., 2009; Sonmez and Bettemir, 2012; Zheng et al., 2005).The objective of optimization, in both cases, was to find the project time schedule with optimal start times and durations of activities with respect to the minimum total project cost, subjected to the precedence relationship constraints, the activity duration constraints and the project duration constraints.

Considering the general NLP optimization problem formulation given in the third chapter and the NLP optimization model formulation for the TCTP presented in reference (Klanšek and Pšunder, 2010a), the cost objective function, for the considered example project TCTP, was formulated using the following equation:

$$\text{Minimize } Cost = \sum_{i \in I} \sum_{k \in K} a_{i,k} D_i^k + b\,Dp \tag{1}$$

The objective variable *Cost* represents the total project cost and includes the direct cost of 18 activities i, $i \in I$, as well as the indirect project cost. The direct costs of activities are included within the cost objective function using the polynomial approximations $\sum_k a_{i,k} D_i^k$ where k denotes the degree of polynomial variable, $a_{i,k}$ represents the k-th coefficient of polynomial direct cost-duration function for the i-th activity, and D_i defines the durations of activities. The polynomial direct cost-duration functions were developed using the curve-fitting calculations for each activity on the basis of alternative cost-duration options given in Table 1.

The indirect project cost was determined within the objective function by the term $b\ Dp$, where b represents daily indirect cost and Dp denotes the project duration. The cost objective function was subjected to the rigorous system of the precedence relationship constraints, the project duration constraints and the bounds on decision variables. Considering the input data presented in Table 1, the precedence relationship constraints were expressed as follows:

$$S_i + D_i \leq S_j \qquad i \in I,\ j \in J(i) \tag{2}$$

where S_i and D_i are the start time and the duration of activity i, $i \in I$, and S_j is the start time of its succeeding activity j, $j \in J(i)$. Since the activities must be executed between the project start and finishing times, the following project duration constrains were set to limit their completion times:

$$S_{i\omega} + D_{i\omega} - S_{i\alpha} \leq Dp \qquad i\alpha,\ i\omega \in I \tag{3}$$

where $S_{i\omega}$ and $D_{i\omega}$ represent the start times and the durations of final project activities $i\omega$, $i\omega \in I$, while $S_{i\alpha}$ denotes the start times of initial project activities $i\alpha$, $i\alpha \in I$. Table 1 and Figure 3 demonstrate that the example project includes four initial activities $i\alpha$, i.e. activities 1, 2, 3 and 4, and one final activity $i\omega$, i.e. activity 18.

The developed NLP model formulation for the example project scheduling optimization problem represents the non-convex TCTP. A high-level language GAMS (General Algebraic Modelling System) (Brooke et al., 2012) was used for modelling and for data inputs/outputs. The NLP optimization model contained 27 constraints (23 precedence relationship constraints and 4 project duration constraints), 37 decision variables (18 activity start times S_i, 18 activity durations D_i and a project duration Dp) and an objective variable (variable *Cost*).

Four different global optimization methods were used to solve the non-convex TCTP of the example project, i.e. the branch and reduce method implemented in a computational system BARON (Branch And Reduce Optimization Navigator) (Sahinidis, 1996), the combination of global and local search strategies incorporated in an optimization program LGO (Lipschitz Global Optimizer) (Pintér, 2007), the branch and cut method included in a computational software LINDOGlobal (Lin and Scharge, 2009), and the multi-start stochastic search algorithm contained in a computer package MSNLP (Multi-Start NLP) (Urgray et al., 2009).

As regards the feasible starting point for the optimization, the project activities were initially set to their normal direct cost option, see Figure 4.

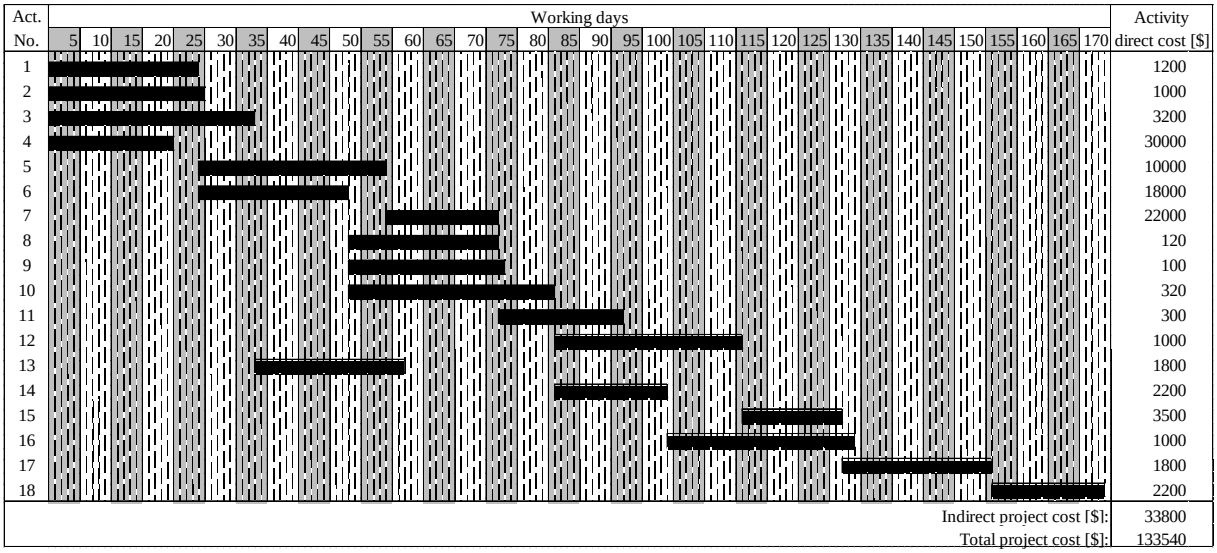

Fig. 4. Initial solution for the cost optimization of project time schedule (indirect project cost of $200 per day)

The defined initial solution, in the case of indirect project cost of $200 per day, shows the total project cost of $133540 (as presented in Figure 4). The same initial solution, used also in the case of daily indirect cost of $1500, demonstrates the total project cost of $353240.

The optimization procedure was performed on a 64-bit operating system using a personal computer with the following characteristics: Intel Core i7, 2.93 GHz, 8 GB RAM and 1 TB hard disc. Since the global NLP represents the continuous technique, the optimization process was executed in two consecutive steps. In the first step, the global NLP optimization was performed to obtain the optimal continuous values for decision variables (e.g. activity start times, activity durations, etc.) inside their upper and lower bounds. The optimal continuous solutions for the example project time schedule, found by global NLP methods in the first case (indirect project cost of $200 per day), are presented in Table 2.

Table 2. Precedence relationships and alternative cost-duration options

Act.	BARON		LGO		LINDOGlobal		MSNLP	
No.	Start time [day]	Duration [days]	Start time [day]	Duration [days]	Start time [day]	Duration [days]	Start time [day]	Duration [days]
1	0.000	16.647	0.000	16.647	0.000	16.647	0.000	16.647
2	0.000	25.000	0.000	25.000	0.000	25.000	0.000	25.000
3	0.000	33.000	0.000	33.000	0.000	33.000	0.000	33.000
4	0.000	20.000	0.000	20.000	0.000	20.000	0.000	20.000
5	16.647	30.000	16.647	30.000	24.000	30.000	16.647	30.000
6	16.647	24.000	16.647	24.000	16.647	24.000	16.647	24.000
7	46.647	18.000	46.647	18.000	54.000	18.000	46.647	18.000
8	40.647	24.000	40.647	24.000	48.000	24.000	40.647	24.000
9	40.647	15.000	40.647	15.000	40.647	15.000	40.647	15.000
10	40.647	15.000	40.647	15.000	40.647	15.000	40.647	15.000
11	64.647	20.000	64.647	20.000	72.000	20.000	64.647	20.000
12	55.647	22.081	55.647	22.081	55.647	22.081	55.647	22.081
13	33.000	24.000	33.000	24.000	33.000	24.000	33.000	24.000
14	55.647	18.000	55.647	18.000	69.728	18.000	69.652	18.000
15	77.728	16.000	77.728	16.000	77.728	16.000	77.728	16.000
16	74.582	30.000	73.647	30.000	87.728	30.000	87.652	30.000
17	93.728	24.000	93.728	24.000	93.728	24.000	93.728	24.000
18	117.728	9.000	117.728	9.000	117.728	9.000	117.728	9.000
							Project duration [days]:	126.73
							Direct project cost [$]:	102412.31
							Indirect project cost [$]:	25345.60
							Total project cost [$]:	127757.91

Table 2 demonstrates that the considered global optimization methods found, in the first case, different continuous solutions for the example project time schedule with the same minimum objective function value of $127757.91 and project duration value of 126.73 days. The obtained minimum total project cost contained a $102412.31 of direct cost for execution of project activities and a $25345.60 of indirect project cost. While the gained values for activity durations were the same in all four solutions, the calculated values for start times were different for some project activities, see underlined values in Table 2.

In the second step, the calculation procedure was repeated/checked for fixed and rounded decision variables (from in the first stage obtained continuous values to their nearest alternative discrete values). The cost optimal time schedule for the example project was achieved after rounding the continuous values of project activity durations to their nearest alternative discrete values presented in Table 1. The cost optimal time schedule for the example project, gained in the first case (indirect project cost of $200 per day), is shown in Figure 5. The calculated objective function value for the obtained cost optimal project time schedule was $127770, while the attained value for project duration was 126 days. The total project cost included a $102570 of direct cost and a $25200 of indirect project cost.

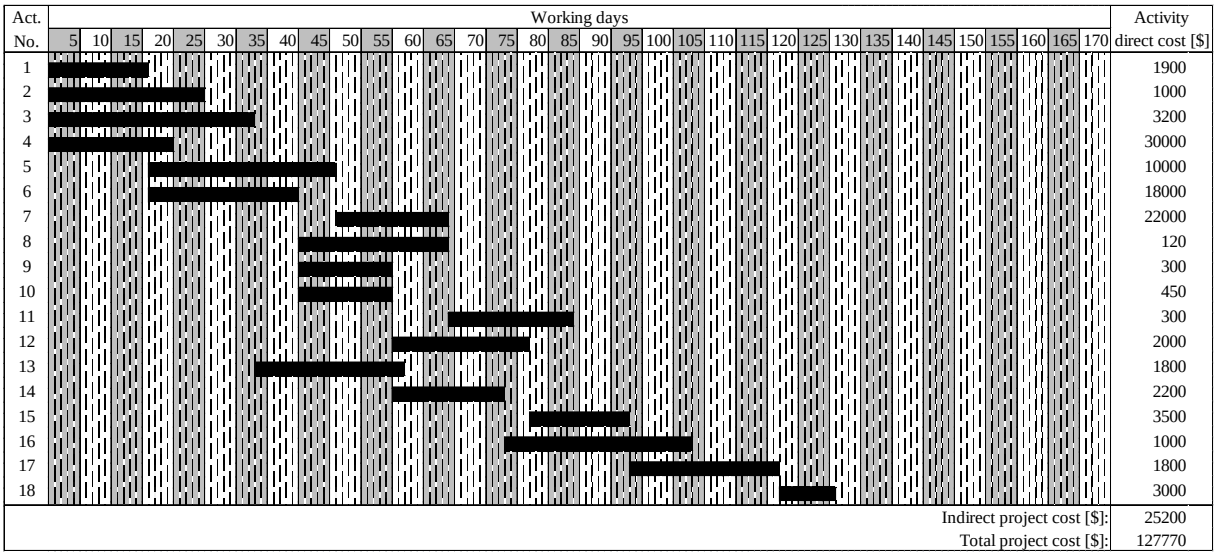

Fig. 5. Cost optimal time schedule of the project gained in the first case (indirect project cost of $200 per day)

The objective function value of the cost optimal project time schedule, achieved in the first case, was compared with those reported in published literature for the same application example, see references (Hegazy, 1999; Afshar et al., 2009; Kalhor et al., 2011; Sonmez and Bettemir, 2012; Bettemir, 2009). The value of $127770 was found to be the best known minimum objective function value for this particular project scheduling optimization problem.

The time-cost curve was also obtained for the example project after running repetitively the optimization model of the TCTP for various different discrete values of project durations. This repetitive calculation procedure achieved the continuous optimal solutions for 70 different discrete values between normal (169-day) and crashed (100-day) project durations. The time-cost curve of the project, found in the first case, is shown in Figure 6.

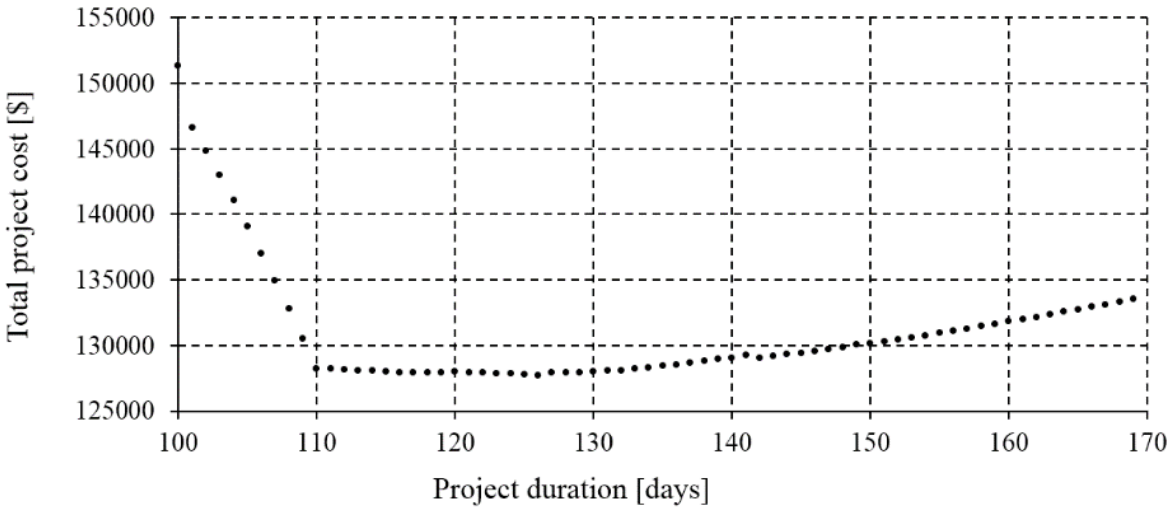

Fig. 6. Time-cost curve of the project gained in the first case (indirect project cost of $200 per day)

The time-cost curve of the example project was drawn by the minimum total project cost values found for feasible discrete project durations. The project time-cost curve presented in Figure 6 shows that the obtained cost optimal solution for the project time schedule was determined in a shallow minimum. The same optimization procedure and the execution of the time-cost curve were also performed for the example project in the second case (indirect project cost of $1500 per day). The cost optimal time schedule and the time-cost curve of the example project, gained in the second case, are presented in Figures 7 and 8, respectively.

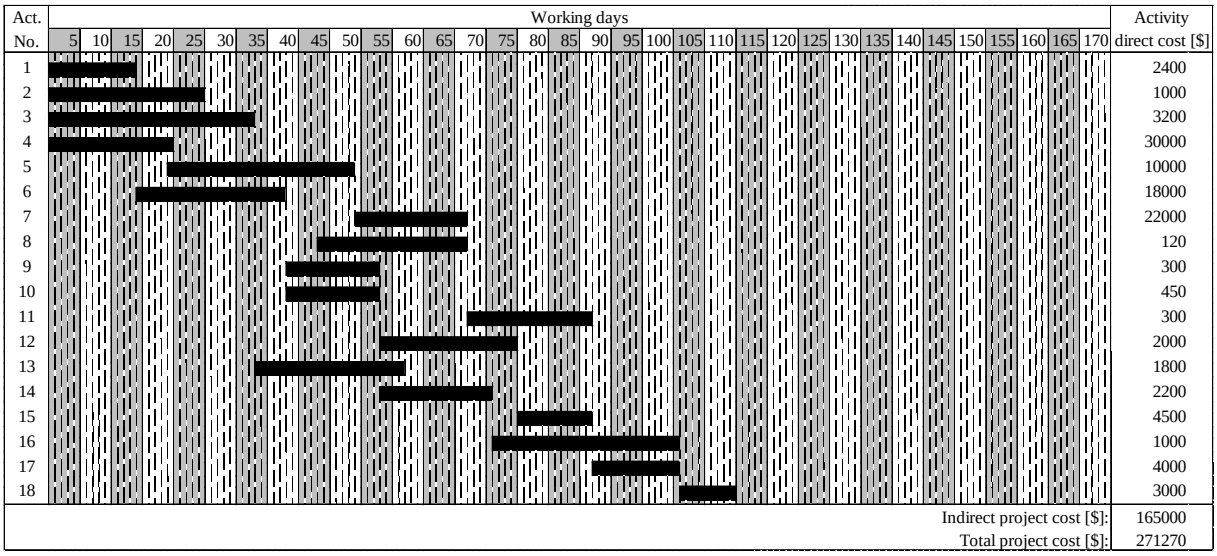

Fig. 7. Cost optimal time schedule of the project found in the second case (indirect project cost of $1500 per day)

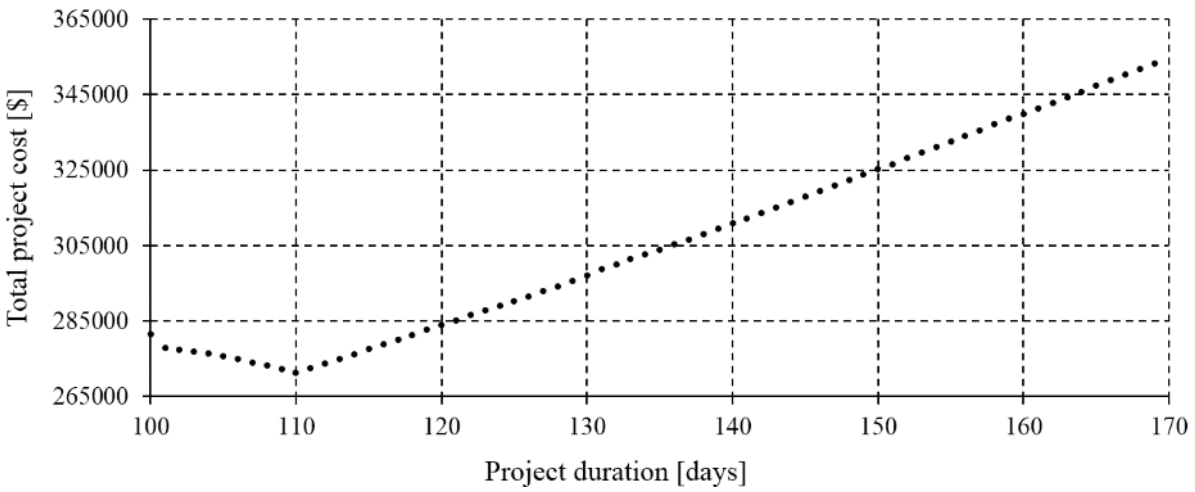

Fig. 8. Time-cost curve of the project achieved in the second case (indirect project cost of $1500 per day)

Also in the second case, the objective function value of the attained cost optimal project time schedule was compared with those presented in existent literature for the same optimization problem, see references (Ng and Zhang, 2008; Afshar et al., 2009; Sonmez and Bettemir, 2012; Zheng et al., 2005). The value of $271270 was ascertained to be the best known minimum objective function value for this specific TCTP. In contrast to the optimal solution obtained in the first case, the cost optimal solution for the project schedule, gained in the second case, was found in a peak minimum, see Figure 8. A close examination of the second case results shows that the high value of the indirect project costs, in comparison with the direct ones, had a significant influence on the peak shape of the time-cost curve.

6. Conclusion

In industrial projects, the shape of time-cost trade-off relationship tightly depends on the resources allocated to a project activity. The non-convex shapes of time-cost relationships may occur in TCTP when various different duration options are available for project activities on account of optional technological processes for their execution or wide accessibility of production resources. Since the existing solution techniques have been focused on the TCTPs with linear, concave, convex and hybrid concave-convex time-cost functions, the aim of this paper was to present the optimization of project schedules, which include the non-convex time-cost trade-off relationships.

The polynomial functions were proposed to approximate the non-convex time-cost trade-off relationships of the project activities in the TCTP for two reasons. The first one was to reduce differences between the values of parameters for real time-cost trade-off relationships, obtained from the project analysis, and the approximated ones, applied in the optimization model for project scheduling problem. The second reason was to increase the possibilities for the search algorithm, to find the actual optimal solution instead of the sub-optimal one, using more precise approximations of the project time-cost trade-off relationships.

Since the presence of non-convexities within the optimization model may cause difficulties for classical search algorithms to find the high quality solutions, the global NLP optimization was proposed to solve the non-convex TCTP. The example demonstrated that state-of-the-art global NLP optimization methods can efficiently solve the non-convex TCTP and found competitive results in comparison with other optimization techniques. In addition, the applicability of the proposed approach is not limited to weakly nonlinear TCTPs.

The application simplicity of the non-convex TCTP model formulation and the solution efficiency of the global NLP optimization can be identified as the main advantages of the proposed approach. In this way, the present study intends to provide new valuable information for project management experts as well as it will serve as the basis for further research in the field of cost optimal project scheduling.

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Empirical Analysis of Delays in Construction Projects

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Abstract

Although they are highly undesirable, delays are encountered in many construction projects. In addition to late completion of the project, the appearance of delays is connected to additional cost generation and appearance of conflicts between the client and the contractor. Delays and their causes are systematically examined and structured in the paper. The responsibilities are allocated to the individual causes in the next step. An empirical study carried out among a group of clients and contractors in Slovenia was carried out. The content of the questionnaire used in this study was carefully designed in order to obtain appropriate results. The survey identified the most common causes of delays as perceived by the interviewed clients and contractors. The results show that the most often cited cause of delay are legal barriers when the building permit is being acquired, followed by the lack of detailed design drawings.

Keywords: construction project, delay, project participants, allocation of responsibility, survey

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1. Introduction

Typically, construction projects are time and cost consuming, involve several complex activities and tasks of different nature. In addition, these tasks are carried out by different project participants. Within construction projects, it is not unusual that schedule delays occur. Activity delays that can appear in all project parts can negatively affect the project performance in several ways. They can lengthen schedules, increase project costs and jeopardize quality and safety (González, González, Molenaar, & Orozco, 2014); (Majid & McCaffer, 1998). As such, they represent serious threat to the competitiveness of the construction industry and to the interests of all construction project stakeholders – owners, design engineers, contractors and subcontractors, users and others (Faridi & El - Sayegh, 2006). The projects suffer from the delays due to a variety of reasons.

Many studies have focused to analyzing delay values systematically, taking as the baseline the comparison between the as-planned and as-built schedule, since this information form the basis for resolving claims and disputes among the stakeholders involved (Yang & Kao, 2009), or using window analysis, where the critical path is split into timeframes and only partial as-built critical paths are modelled.

Often, delays appear already in the initial stages of the construction projects, such as the stage of the preparation of the general plans, or conceptual design, obtaining the building permit etc. As a consequence, the construction process itself is frequently delayed already at its start, due to the occurrence of delays in previous phases. Special attention should be therefore placed to the preparation stage, and ensure that adequately detailed documentation is available at the start of the project.

When dealing with the delays, it is not only important to identify delays and quantify the delay impacts on project performance but also to identify and quantify the impacts of delays already occurred upon further project development. In order to determine responsibility and enable to learning from these undesirable events, the primary causes of delays should be identified as well.

1.1. Classification of delays in construction process

The classification of delays that can be found in the relevant professional and scientific literature is most often based on identification of the delay origin (i.e. responsibility).

Further, they can be classified with respect to their timing, compensability and impact, as presented in Fig.1 (Kartam, 1999). A delay is compensable to the contractor when it is caused by the owner, e.g. incomplete drawing and specification, changes in scope or late possession of site. The conditions of contract should allow the contractor to be entitled to a time extension and to monetary recompense for extra costs caused by the delay. Excusable delays are occurrences over which neither the owner nor the contractor have any control, e.g. extreme weather conditions, acts of God and other unforeseen future events. In this case, the contractor should declare an excusable delay and can thus be entitled to time extension. Non-excusable delays are caused by the general contractor, therefore he is not entitled neither to time extension nor to monetary recompense from the owner. In addition, the contractor may pay liquidated damages according to the contract.

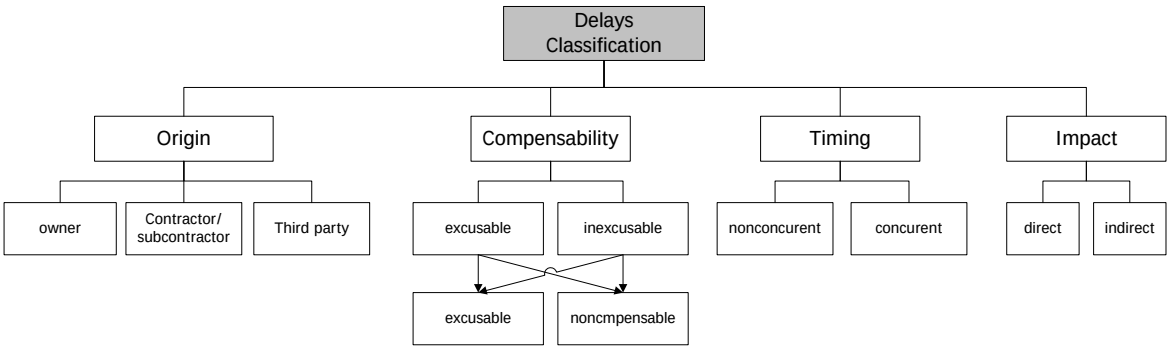

Fig. 1. Classification of delays (Kartam, 1999)

1.2. Identification of delays

In order to study delays and their causes, existing methods used for the identification and study of delays have to be surveyed first. Sun and Meng (Sun & Meng, 2009) conducted a comprehensive survey of literature. The obtained results show that the identification of delays is predominantly carried out on the basis of existing documentation of the completed projects; more precisely, this method was used in 49 papers out of 101 surveyed articles. In 36 papers, the delays were studied by obtaining the response through the use of standardized questionnaires that included questions of ranking the importance of individual causes. Case study approach and interviews were used in 28 and 13 articles, respectively.

1.3. Research objectives and methodology

The purpose of the research presented in this paper was to study the attitudes of different construction project stakeholders regarding the occurrence, type and allocation of responsibility for the delays. An on-line survey among the stakeholders was selected to be used as the research tool, and an extensive literature survey was used to formulate the content of the questionnaire used in the survey.

2. Fundamentals of Delay Analysis

Determination of delay causes has to be based on objective delay analysis; therefore, analysing construction delays has become an integral part of a project's construction life. Even with today's technology and understanding of project management techniques, construction projects continue to suffer delays, and project completion dates still get pushed back. A number of solution methods and delay analysis techniques were developed and their usefulness and selection of proper method are based on available project date and its quality.

The most comprehensive taxonomy and classification is presented in *Recommended practice* published by the Association AACE International (AACE-International, 2011). Schematically, it is presented in Fig.2.

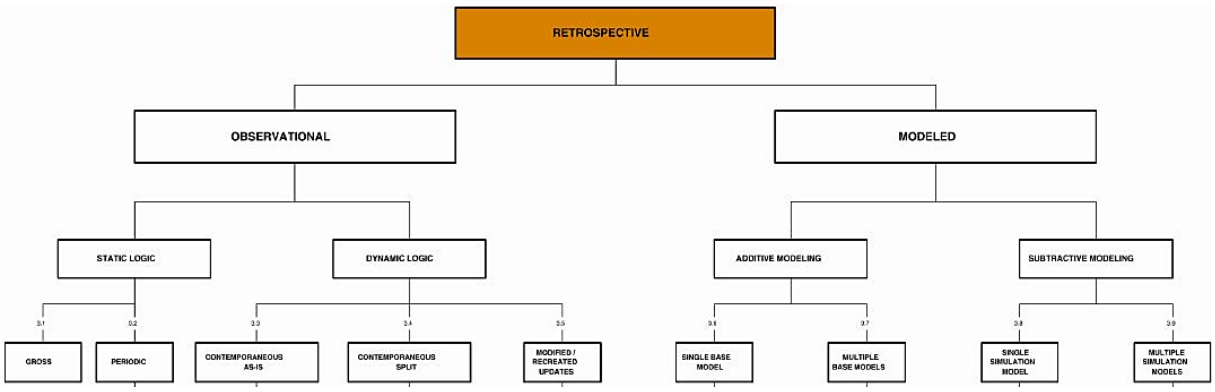

Fig.2: Taxonomy of Forensic Schedule Analysis (AACE-International, 2011)

Regardless to the selected method, the delay analysis procedure should be carried out as a sequence of the following activities (Al-Saggaf, 1998):

- data gathering and collection relevant information
- data analysis, where use of different schedules (as planned, as built, immediate schedules) can be employed
- identification of root causes
- classification of the delays and their impact, and
- assigning responsibility and determination of compensation.

2.1 Classification of delay causes

Within research presented in this paper, the framework of the classification of delay causes was adopted from the pioneer work of (Kumaraswamy & Chan, 1998).

Three categories of the delay causes were identified as relevant in Slovenian construction practice, and as such, they were added to the list of delays. The first category relates to complicated and lengthy procedure of obtaining the building permit. Spatial planning legislature demands that the spatial plans identify, for each plot, special regimes such as cultural, or biodiversity preservation. Relevant institutions provide conditions that need to be respected during construction and use of the structure. Al illustrative example is construction of the new ski jump facility in Planica valley that is located in protected area. In order to ensure uninterrupted nesting of the local (protected) birds, the building permit specifically stated that the contractor was not allowed to execute works during their nesting period (spring). Sometimes, additional stakeholders are identified, after submitting the permit request, e.g. renovation of an old building where elements that have cultural heritage value are found only after the onset of works. This category can be named »legal issues«.

The second cause of delays that became extremely important with the onset of the crisis is the financial structure of the project, especially when there is a long chain of subcontracting organisations. Slovenian legislature demands that the payment of works is carried out after the works are completed, with due date specified in the construction contract. This means that the subcontractors are paid even later than the contractor, which, in some cases, may lead to the insolvency or even to bankruptcy.

The third additionally identified delay cause is related to the project participants who are contractually bound to the general contractor or to the client, such as the Engineer (who is, on one hand, the representative of the client, and on the other hand, required by the legislature), or the subcontractors.

The resulting list of delay causes in presented in Table 1.

Table 1. Causes of delays in construction projects

	Delay causes
1	Project causes
2	Client
3	Incomplete design documentation
4	Execution of works
5	Material
6	Rework
7	Equipment and tools
8	Acts of God (Force Majeure)
9	Legal issues
10	Project financing
11	Auxiliary project participants

3. Execution of the survey

The content of the questionnaire to be used in the survey was systematically prepared. In the first part, general data, such as the role of the company answering the survey in the construction process, type and extent of experience, number of performed projects within the last year, and professional background and experience of the respondent were collected.

In the second part, the questions were focused to the construction activities carried out in the responding company. In particular, we assume that the type of the facility to be constructed, i.e. buildings vs engineering works, has an influence upon the occurrence, extent and causes of delay. We also wanted to obtain information regarding the level of use of scheduling methods and associated software within project planning and monitoring

The core part of the survey is focused to the delay analysis. The classification used in the survey was adopted according to (Kumaraswamy & Chan, 1998). Frequency of the following causes of delays was investigated:

- general causes (e.g. slow process of relevant spatial act acceptance; administrative causes; land ownership consolidation; acquirement of relevant consents, e.g. from the neighbours, or various other stakeholders)
- project financing (delayed payments, financing difficulties)
- poor project management (e.g. inadequate communication among project participants, poor scheduling, project manager is appointed too late etc.)
- client (e.g. orders changes after the project is initiated; making decisions too late; conflicts among co-owners)
- various causes taking place during execution of works (e.g. poor management of the contractor, inadequate operational planning, poor management of conflicts with subcontractors, executed works are not compliant to the project documentation, ...)
- inadequate Engineering (late checks and approvals of the executed works, conflicts between Engineer and the contractor, rigidity of the Engineer, ...)
- project documentation (e.g. incompatibility of drawings, lack of details, poor drawings, late incorporation of changes that were executed, into the drawings; late incorporation of changes into the project documents etc.
- construction products (e.g. lack of certain materials and products on the market, damaged materials, late supply of construction products, …)
- construction machinery and equipment (e.g. lack of machinery and equipment on contractor's side; non-skilled operators, unavailability of up-to-date machinery etc)

- workforce (poorly skilled workers, low productivity, conflicts among foremen and workers, injuries, ...)
- Force Majeure (e.g. different ground conditions as anticipated, unfavourable weather, fire, strikes ....)

An on-line survey containing the questions above was prepared. The target group of respondents was professionals who are either representatives of clients, or contractors. The survey was sent to different stakeholders in construction process who were then asked to answer the questions, and to forward the survey to competent individuals who participated in the construction projects ("rolling snowball principle").

4. Results

62 responses were obtained; however, some of them were only partially completed. The majority of respondents were representatives of clients (14,5%), contractors (22,6%) and professional engineers (project managers, design engineers and surveying engineers) (35,5%). Overall, the results show that they are well experienced, as the reported work experience of 47% respondents ranges from 5 to 15 years, while the work experience of 32% respondents ranges from 15 to 25 years. All respondents have completed secondary education, and the majority (61,3%) has the B.Sc. degree.

Table 2. Scheduling tools used by the respondents

	No. of resp.	No.of resp. (%)
No scheduling is used	16	25,8
MS Project, Primavera	25	40,3
MS Excel, Word	18	29,0
Other	3	4,8
TOTAL	62	100,0

We assume that companies that use contemporary tools for project scheduling are more efficient in time management; therefore, one question addressed the issue of schedule preparation. The obtained results are presented in Table 2. The majority of respondents is monitoring the project progress on weekly (43%), or monthly (27%) basis. Further, the received responses show that a quarter of respondents do not use scheduling tools at all, while MS Project and Primavera are used by 40% of the respondents.

Respondents were asked to provide observed frequency of delay causes identified by literature search. The causes stem form legal issues, design, owner and management (Table 2). The obtained answers show that legal obstacles (building permit issues) are on top of the list of the obstacles; 53,2% respondents find this issue relevant (they answered that legal obstacles were an issue often, or always). Another important cause for the occurrence of delays is lack of design details and specifications; 50% of the respondents think that documentation received from the client is never detailed enough. Slow decision-making on the side of the owner, and delayed design documentation are also two issues that could be improved. Surprisingly, the respondents perceive that project management and lack of risk analysis for the project are not crucial when delays occur; only 3,2% feel that project management is always a source of delay occurrence.

Table 2. Observed frequency of various delay causes

	Causes of delay	Always	Always + often	Category of delay
1	Legal obstacles with building permit issues	9,70%	53,20%	legal
2	Lack of design details and specifications	14,50%	50,00%	design
3	Slow decision making process issued by owner	6,50%	46,80%	owner
4	Design documentation delays	8,10%	45,20%	design
5	Change orders and additional request issued by owner	4,80%	45,10%	Owner
d	Design documentation error and discrepancy	6,50%	43,60%	design
7	Inappropriate design solution	3,20%	35,50%	design
8	Lack of information gathered before design stage	3,20%	35,50%	design
9	Delay with spatial planning documentation	8,10%	32,30%	legal
10	Unqualified workforce	6,50%	30,70%	client
11	No project risk analysis	4,80%	30,60%	management
12	Inappropriate project management	3,20%	30,60%	management

5. Conclusion

Delays are a part of the construction projects. In this paper, we wanted to identify the current state in this field within the Slovenian construction industry by carrying out a survey among various construction project stakeholders. Results show that delays are a part of the daily routine during construction project execution. It can be concluded that more attention should be paid to the processes that are taking place prior to site work, such as producing adequate design drawings and documents.

The results of the presented research identify the needs of the construction industry from the viewpoint of time management and delays that occur in projects, and could be used as the baseline for the preparation of guidelines for all construction stakeholders.

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Understanding Social Influence on Construction Worker's Safety Behavior

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Abstract

Recently, a number of researchers have found that individuals' psychological processes and group-level informal influence have much to do with construction workers' unsafe behavior. In addition, from the perspective of social psychology, social identity—an individual's sense of self as defined by the social groups to which he/she belongs—plays an important role in this normative influence process. However, despite their importance, we have limited knowledge about the effect of group norms and social identities on workers' safety behavior. Adding to these complications are the ways in which workers' temporary and multiple membership nature impact group norms and social identities on workers' safety behavior. Given this background, we aim to investigate: (1) current status of workers' social identities, (2) influence of group norms on worker's personal standard, and (3) impact of social identities on the normative influence process. To fulfill these objectives, a survey questionnaire was developed to measure workers' social identification level, and a novel technique called norm elicitation technique developed by Burks and Krupka (2012) was applied to measure workers' perceived group norms and their personal standard. The results of this study show that workers identify themselves most saliently with their trade, and least saliently with their project. Additionally, our research found that worker's personal standards regarding safety behavior is affected by their perceived workgroup norms. This study also found that workers who possessed a higher level of social identification with their crew had personal standards more aligned with their perceived crew norm.

Keywords: social influence; group norm; social identity; safety management; safety behavior; construction; organizational behavior

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1. Background

Construction is one of the largest and most dangerous industries (Zhang and Li 2015). Although many technologies and practices for improving construction safety have been developed and implemented, the improvement of construction safety is still unsatisfactory (Chen and Jin 2013; Shin et al. 2014). The construction industry still shows the highest number of fatalities among all industries, accounting for 18.3% of all fatal occupational injuries in the United Sates (BLS 2014). There have been significant efforts to reduce accidents in construction, but most efforts have tended to focus on controlling physical work environment and work procedure (Shin et al. 2014). These efforts are based on the view that accidents are caused by unsafe work conditions (e.g., hazard or unsafe physical work environment) and unsafe behaviors (e.g., behavior that deviates from desirable safety rules, regulations, and procedures) (Heinrich et al. 1980). However, because unsafe actions and behaviors cause 80% to 90% of accidents in construction, recent attention has been paid to how to reduce or eliminate workers' unsafe behaviors (HSE 2002).

To reduce workers' unsafe behaviors, construction managers have mainly used individual-oriented formal control, such as penalties on safety violations. However, recent research papers on workers' safety behavior have found that individuals' psychological processes and social influence have much to do with workers' safety behavior (Zohar 1980; Brondino et al. 2012; Fugas et al. 2012). Despite the increasing attention paid to the social aspect of workers' safety behavior, there is a lack of research addressing the mechanism underlying the link between social norms and safety behavior. More specifically, previous studies do not provide an explanation for how workers change their safety behavior in a social context. In this vein, social identity theory (SIT) provides a plausible explanation for the mechanism underlying between social norms and individuals' behavior. Tajfel and Turner (1979) defined social identity as "individual's self-image derived from the social categories to which he/she perceives himself/herself as belonging". According to SIT, effects of group norms depend on whether or not the person identifies him/herself with the group (Terry et al. 1999). In other words, group norms should have a significant impact on individuals' behaviors, particularly for those who identify strongly with the group (Ashforth and Mael 1989).

What makes the effects of group norms and social identities on construction workers' safety behavior more confounding is the complexity of the construction workforce. Generally, a construction worker holds multiple identity-defining memberships while working on a project. Examples of groups to which a construction worker belong are workgroups (crew), companies, unions (in case of United States), trades, and projects. In addition, construction workers cannot maintain these memberships permanently, because they are hired for a specific project and thus move to different projects after completing current project. With this background, the objectives of this study are to investigate: (1) current status of workers' social identities, (2) influence of group norms on workers' personal standards regarding safety behaviors, and (3) impact of social identities on the group norms influence. To fulfill these objectives, a survey questionnaire was developed to measure construction workers' level of social identification with each group in their jobsite. In addition, a novel technique called as norm elicitation technique developed by Burks and Krupka (2012) was applied to measure workers' perceived group norms and their personal standard regarding safety behavior.

2. Research Method

2.1. Participants and procedure

In order to collect data, subjects were employed in three construction sites in Ann Arbor, Michigan, United States. The first site was a large-sized university research facility building construction project, and 26 workers participated in the survey. The second site was a large-sized library retrofit project and 45 workers were participated in the survey. The third project was a large-sized research facility renovation project, and 35 workers were participated in the survey. A total of 106 workers participated in the survey. All workers are male and unionized.

One week before the survey, we explained the purposes and processes of the survey to the foremen in a weekly meeting at the site. The foremen advertised the survey to their crew members, and thus workers participated on a volunteer basis. At the beginning of the survey,

we introduced the purposes and procedure of the survey including information about the incentives. Then, participants provided their responses in each section, and approximately 25 – 30 minutes were taken to complete the survey. After completing the survey, subjects received $10 participation fee.

2.2. Social identity measure

Construction workers hold multiple group memberships, and the salience of each group may vary. In an effort to address this issue, this study repeatedly asked each question about the salience of social identity for the five groups at a construction project (i.e., crew, company, project, trade, union). According to SIT literature, one's social identity consists of cognitive, affective, and evaluative components (Tsai and Bagozzi 2014). The cognitive component is defined as knowing that one belongs to a group and categorizing the self as a part of group (Turner et al. 1987). The affective component reflects the emotions and feelings one has about the group (Ellemers et al. 1999). The evaluative component involves value connotations that are attached to a group (Ellemers et al. 1999). This study focuses on these three components to measure construction workers' level of social identification with each group by using a 7-point Likert scale. Table 1 represents survey instruments for each component of social identities.

Table 1. Survey instruments for social identity measure

Component of Social identity	Survey Instrument (e.g., crew)
Cognitive component	When someone criticizes my crew, it feels like I am being criticized.
	When I talk about my crew, I usually say "we" rather than "they".
Affective component	I am happy to be a member of my crew.
	I am attached to my crew.
Evaluative component	I have respect for my crew.
	I am proud to be a member of my crew.

2.3. Norm elicitation technique

In order to measure workers' perceived group norms and personal standards regarding safety behavior, a novel method called as norm elicitation technique developed by Burks and Krupka (2012) was employed in this study. In this method, hypothetical vignettes and coordination game structures are used to measure workers' perception of group norms and personal standard. A hypothetical vignette describes the situation with which subjects will be familiar, because subjects can observe or experience in their workplace on a daily basis. In this study, a dilemma between safety procedures (i.e., connecting snap hooks to a safety anchor point) versus work efficiency is applied as the hypothetical situation. Then, subjects are asked to evaluate a range of actions a subject might choose in the given situation. A 4-point Likert scale, which range from 'Very inappropriate' to 'Very appropriate', is used. Table 2 depicts the situation and range of actions applied this study.

Table 2. Hypothetical situation and a range of behaviors in norm elicitation protocol

Behaviors (Situation; Please imagine that Robert is another member of your crew. He works at a workspace where a fall protection is required by the OSHA regulation.)	
Behavior 1	Robert does not connect his snap hooks to an anchor point even if he works on a dangerous task and the fall protection system does not bother his work.
Behavior 2	Robert connects his snap hooks to an anchor point only when he perceives a danger of falling and the fall protection system does not bother his work.
Behavior 3	Robert connects his snap hooks to an anchor point only when he perceives a danger of falling.

Behavior 4	Robert always connects his snap hooks to an anchor point whenever a fall protection is required. However, he continues to work even if he cannot find an object he can securely connect his snap hooks to.
Behavior 5	Robert always connects his snap hooks to an anchor point. If he cannot find an object he can securely connect his snap hooks to, he does not continue to work.

In this method, subjects are asked to repeat the rating task twice for each vignette. Subjects are asked to match their ratings with those of a typical member of their crew on the first pass. Therefore, responses from the first pass can be interpreted as workers' perception of shared norms among the crew members (perceived workgroup norm). On the second pass, they are asked to provide their own opinion about the behaviors, and responses from this round are interpreted as workers' personal standard regarding safety behaviors. A coordination game structure and monetary incentives are applied in order to facilitate the elicitation of group norms in this study. The subjects were told that 10% of all subjects are randomly selected. They are also told their response on the first pass will be compared with the response of randomly selected subjects among their crew members, and they will receive $10 for each of matched response. By doing so, the subjects more focused on their crew members' evaluations on the first pass, and thus we can successfully elicit shared group norms among the participants.

3. Results and discussions

3.1. Current status of construction workers' social identity

Before performing the statistical analysis, 14 responses which include any missing data were excluded from the data set. In addition, 10 responses from the respondents who are the only member of their crew were also excluded, because these respondents' perceived workgroup norm is the same with personal standard. After excluding unreliable responses, a total of 82 responses were used for the statistical analysis.

In order to quantify the social identity, the responses in the questionnaire were converted into numerical scores: -3 = 'strongly disagree', -2 = 'disagree', -1 = 'somewhat disagree', 0 = 'neither disagree nor agree', 1 = 'somewhat agree', 2 = 'agree', 3 = 'strongly agree'. Table 3 presents means and standard deviations of construction workers' level of social identity with each organizational entity in their jobsite. In addition, Fig. 1 represents average score of responses for all social identity measures. Each hexagon in the Fig. 1 refers to each organizational entity in the survey questionnaire (i.e., crew, company, project, trade, and union), and each vertex of the hexagon represent each question in social identity measures. Therefore, the size of each hexagon refers to the salience of corresponding social identity.

Table 3. Mean and standard deviation of workers' social identity (N = 82)

	Crew	Company	Project	Trade	Union
Mean	1.92	1.47	1.20	2.27	1.89
SD	0.68	1.11	1.06	0.82	1.25

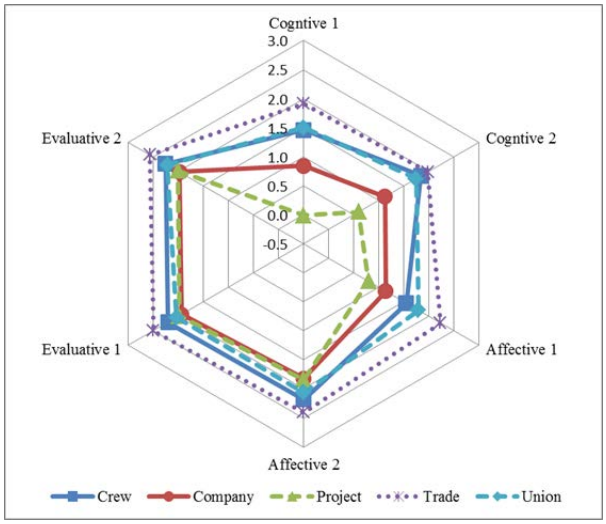

Fig. 1. Current status of construction workers' social identities

Then, paired t-tests among all pairs of groups in the survey were performed to compare workers' level of social identification in their jobsite. Table 4 represents the result of the paired t-test. Bonferroni correction was applied to *p* value because ten mean comparisons were performed simultaneously. The result of paired t-test reveals that construction workers most saliently identify with their trade (M = 2.27, SD = 0.82), and least salient with current project (M = 1.20, SD = 1.06). Crew (M = 1.92, SD = 0.68) and union (M = 1.89, SD = 1.25) followed trade, but differences between crew and union was not statistically significant. Company (M = 1.47, SD = 1.11) was fourth salient social identity, and mean differences between company and project was not statistically significant. In summary, trade, crew, and union showed relatively high level of social identification, but company and project showed relatively low level of social identification. In addition, Fig. 1 shows that cognitive components of project identity were relatively weak than other components of project identity.

Table 4. Result of paired t-test

Pair	Mean Difference	SD	t	df
Crew – Company	0.445	0.998	4.040**	81
Crew – Project	0.713	0.964	6.701**	81
Crew – Trade	-0.350	0.807	-3.923**	81
Crew – Union	0.024	1.276	0.173	81
Company – Project	0.268	1.041	2.334	81
Company – Trade	-0.795	1.221	-5.894**	81
Company – Union	-0.421	1.512	-2.519	81
Project – Trade	-1.063	1.041	-9.245**	81
Project – Union	-0.689	1.446	-4.315**	81
Trade – Union	0.374	1.018	3.328*	81

Note: p-values were corrected by Bonferroni correction.
* p < .05
** p < .01

3.2. Effect of group norms

A 4 point Likert scale in the norm elicitation technique was converted into numerical score for the quantification: -1 = 'Very inappropriate', -1/3 = 'Somewhat inappropriate', 1/3 = 'Somewhat appropriate', 1 = 'Very appropriate'. Table 5 presents a summary of the appropriateness evaluation of the participants in the norm elicitation technique. Each row in Table 5 refers to a safety behavior that subjects evaluated, and summaries of the evaluations

on the first and second pass were separately presented in the table. The columns in the table present mean (M), standard deviation (SD) of the responses, and percentage of the response for each option for each behavior in the list.

Table 5. Summary of response in norm elicitation technique

	Worker's personal standard (N=82)						Worker's perceived group norm (N=82)					
	Mean	-1 (%)	-1/3 (%)	1/3 (%)	1 (%)	SD	Mean	-1 (%)	-1/3 (%)	1/3 (%)	1 (%)	SD
Behavior 1	-0.89	**87.8**	9.8	1.2	1.2	0.32	-0.87	**84.2**	6.1	4.9	1.2	0.38
Behavior 2	-0.37	**43.9**	25.6	23.2	7.3	0.66	-0.33	**41.5**	25.6	18.3	11.0	0.69
Behavior 3	-0.36	**45.1**	23.2	22.0	9.8	0.69	-0.36	**41.5**	23.2	25.6	6.1	0.65
Behavior 4	-0.46	**47.6**	25.6	22.0	3.7	0.61	-0.45	**46.3**	26.8	15.6	7.3	0.64
Behavior 5	0.76	2.4	2.4	24.4	**69.5**	0.44	0.78	1.2	3.7	20.7	**70.7**	0.41

Note: The bold types are mode response for each behavior

As shown in the table, Behavior 1 was evaluated as the most inappropriate, and Behavior 5 was the most desirable behavior in both personal standard and perceived group norm. In addition, the fact that the modal response for any behavior always receives over 40% of the response in the perceived group norm shows that there is a general consensus in the belief about the evaluation made by their crew members. In addition, extreme behaviors (Behavior 1 and Behavior 5) showed relatively small standard deviation. It implies that the subjects have greater consensus in the appropriateness of these behaviors.

Then, correlation analysis between workers' perceived group norm and personal standards for five behaviors were performed to identify the effect of group norms on workers' personal standards regarding safety behaviors. The result of correlation analysis is presented in Table 6. As shown in the table, personal standards for each behavior and perceived workgroup norms for corresponding behavior are significantly correlated except for Behavior 1, $r(82) = .446 \sim .673$, $p < .01$. It implies that construction workers' personal standards regarding specific safety behavior are affected by their perception of coworkers' evaluation on the behavior. In the case of Behavior 1, there is no significant correlation between workers' personal standards and their perceived workgroup norm. As shown in the Table 5, Behavior 1 has the least value of standard deviation in personal standard. It suggests that workers will not rely on their workgroup norm if the appropriateness of the behavior is obvious to them. Therefore, construction workers' personal standard regarding safety behavior is influenced by their perceived workgroup norm when they do not have subjective certainty on the behavior.

Table 6. Correlation analysis between workers' personal standard and perceived workgroup norm (N = 82)

		Worker's personal standard				
		Behavior 1	Behavior 2	Behavior 3	Behavior 4	Behavior 5
Perceived Workgroup Norm	Behavior 1	-.068	.130	.169	.192	.028
	Behavior 2	.098	.673**	.270*	.235*	.018
	Behavior 3	.117	.460**	.637**	.452**	-.117
	Behavior 4	.059	.357**	.335**	.446**	-.140
	Behavior 5	-.072	-.034	-.033	-.207	.589**

* p < .05
** p < .01

3.3. Effect of social identity

A misalignment measure is constructed to assess the effect of social identity on group norms influence. As shown in the equation (1), the misalignment measure is defined as sum of the differences between individual's personal standards and perceived workgroup norms for five behaviors in the norm elicitation technique.

$$M_i^{PS,PN} = \sum_{j=1}^{5} \left| PS_{ij} - PN_{ij} \right| \tag{1}$$

where PS_{ij} is person i's personal standard for behavior j, PN_{ij} is person i's perceived workgroup norms for behavior j. The small value of the measure means that workers' personal standards and their perceived workgroup norm is close to each other. Therefore, the measure reflects strength of group norms influence, and the smaller value of the measure means stronger group norms influence.

Then, correlation analysis between the misalignment measure and each component of crew-based identity was performed to identify the effect of social identity on group norms influence. Table 7 represents the result of the correlation analysis. As shown in the Table 7, affective (r = -0.29, $p < 0.01$), and evaluative component (r = -0.24, $p < 0.05$) of crew-based identity are significantly associated with the misalignment measure. However, cognitive component of crew-based identity is not associated with the misalignment measure. The negative correlation coefficient means that increases in affective and evaluative component of crew-based identity are associated with decrease in the misalignment measure. This suggests that a worker who has a high level of emotional attachment to their crew and a high level of crew-based self-esteem tends to have a personal standard more aligned with perceived group norms. In other words, affective and evaluative components of crew identity motivate workers to follow workgroup norms. Therefore, the result of the correlation analysis shows that affective and evaluative dimension of crew identity can moderate the effect of workgroup norms on personal standard regarding safety behavior.

Table 7. Correlation analysis between misalignment measure and crew-based identity (N = 82)

	Crew-based identity			
	Cognitive	Affective	Evaluative	Overall
Misalignment measure	-.059	-.242*	-.292**	-.238*

* p < .05
** p < .01

4. Conclusions

To address a lack of understanding of the mechanism of social influence on workers' safety behavior, this study aimed to investigate current status of construction workers' social identity and the effect of group norms on workers' personal standard regarding safety behavior, as well as the effect of social identity on group norms influence. To accomplish these objectives, a survey questionnaire for the social identity was developed and a novel approach called as norm elicitation technique developed by Burks and Krupka (2012) was applied to measure workers' perceived group norms and their personal standard regarding five specific safety behaviors.

The result of this study revealed that trade is the most salient social identity in workers' mind and project is the lease salient social identity. In addition, it is found that there is a significant correlation between workers' perceived group norms and their personal standards regarding safety behavior. However, the correlation was not statistically significant when

workers have strong subjective certainty on the behavior. Additionally, from the result of correlation analysis between workers' level of crew-based social identity and misalignment measurement, it was also found that affective and evaluative dimension of crew-based social identity moderate the group norms influence.

The research findings of this study suggest a new way of thinking of safety management. Rather than focusing on formal rule, construction managers need to pay more attention to social norms regarding safety behaviors. The result of this study suggests that managerial efforts to create positive group norms of the salient group can be an effective means of improving the construction safety. In addition, the moderating effect of social identity on group norms influence implies that stimulating project-based identity can foster a positive social norm at a construction site. If positive social norms are fostered in work groups, control of safety behaviors would be less costly and more durable. Further, it is expected that the results of this study help to better understanding of social aspect of workers' safety behavior. This extended understanding will help to set a firm foundation of a new way of safety management emphasizing social aspects of safety behavior.

Although this paper demonstrates the mechanism of social influence on workers safety behavior, two limitations of this study should be noted. First, there is a lack of consideration of diverse factors affecting workers' safety behaviors. For example, workers' safety behaviors would be affected by personal factors (e.g., personal attitude) and environmental factors (e.g., time pressure and site conditions). The second limitation of this study is a lack of consideration of managers' effect on workers' safety behaviors. Since managers' safety feedback is one of the main sources to change workers' safety behavior, the managers' effect on workers safety behavior should be considered in the safety behavior context. Therefore, in order to have comprehensive understanding of a socio-psychological aspect of workers' safety behaviors, personal and environmental factors of the safety behavior and managers' influence should be considered in the future research. Future research will address these limitations.

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AHP Based Contractor Selection Procedure for Highway Infrastructure Projects in Serbia

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Abstract

The recently published papers reveal that the cost and time overrun on highway construction projects are global problems. The need to assess and control projects in terms of the iron-triangle goals of management (cost, time, and quality/performance) is emphasised, especially for the projects financed from international funds. Among other efforts, it is necessary to minimize the risks of contractor's failure. Therefore, the assessment of the potential contractor's competencies within the bidding process is one of the key check points prior to the construction phase. Instead of the prevailing practice of contractor selection using mainly the lowest bid, different types of criteria should be considered, all of them subjected to the specific project's goals. The relative importance of these criteria is difficult to determine and quantify. Various mathematical models that rely on multi-attribute ranking are available for solving the problem. In this paper Analytic Hierarchy Process (AHP) is suggested and the approach that determines criteria weights and contractors selection during bidding process is proposed. Based on this approach a baseline framework for selection of contractors for future use on highway infrastructure projects in Serbia is proposed. The preliminary results show that there is a potential to facilitate the objectives and rationalize the decisions during bidding process in open procedures on highway infrastructure projects.

Keywords: bidding procedure, contractor selection, highway infrastructure, AHP method

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1. Introduction and background

Procurement of infrastructure projects is rightfully labeled as highly risky, meaning that delays and budget overruns on these projects happen very often. Even though in the past decades there has been an outburst of methods used for improving procurement, there has been no improvement in the success rate of these projects. Many authors described current bidding procedures and emphasized contractor selection as one of the important critical points for reaching the projects goals in terms of time, cost and quality (Hatush and Skitmore, 1997; Watt et al., 2010). In this respect an appropriate model was sought by them to help decision makers and to increase the chance of reaching the project goals (Hatush and Skitmore, 1998; Cheng and Heng, 2004; Watt et al., 2010, Plebankiewicz, 2009; Jaskowski et al., 2010).

In an effort to help the borrowers with the procurement and to ensure the success of projects financed by them, international financing institutions such as the World Bank (WB), the European Investment Bank (EIB), the European Bank for Reconstruction and Development (EBRD) and the EU Commission, issued their own procurement guidelines. WB guidelines are more elaborated in this paper as they have been frequently used on projects in Serbia. The main award criterion for the contractor selection throughout these guidelines is the lowest bid price.

Public procurement law in Serbia is in line with the EU directives. According to Serbian public procurement law, the lowest price or the most economically advantageous bid are the two possible award criteria. Nowadays, the criteria most economically advantageous bid has been recognized by the EU Commission and the Europian Investment Bank and incorporated as an award criterion in their guidelines (EU Commission PRAG, 2014; EIB Guide, 2011).

Even though repeatedly criticized both by researchers and practitioners (Bower 1989; Holt et al., 1994; Hatush and Skitmore, 1998; Wong et al., 2000), lowest price continues to be the prevailing criteria for ranking of bidders when it comes to procurement of construction works. Since, infrastructure projects are mainly connected with the public sector, reason for using lowest price as the criteria may be found in difficulties of public justification of selection using "best value for money" bid rather than the lowest price bid. On the other hand, Contractors when faced with shortage of works are more likely to enter low price bids to stay in business in the short term hoping that they will raise additional income through claims or by cutting costs (Hatush and Skitmore, 1998).

The need for the development a highway infrastructure in Serbia, as a developing country heading towards EU, is indisputable. In 2009, Government of Serbia founded a company “Koridor 10” Ltd (which later grew and changed its name into “Koridori Srbije” Ltd) for the purpose of tendering and management of construction works. The company is responsible for construction and finalization of the remaining motorway sections on the pan European Corridor X, (E75 and E80) through Serbia, and construction of motorways on E763 and M 21 road.

There are currently 30 construction projects and 200 km of highways under the supervision of Koridori Srbije Ltd. The works are financed from the loans provided by the WB, EIB and EBRD. Although financed by different institutions, procurement of all projects was in accordance with the International Competitive Bidding (ICB) procedures recommended by WB for borrowers operating in the public sector where the lowest price was the only award criteria (WB Guidelines, 2011). According to the construction execution review for 2014 issued by Koridori Srbije, in the period from 2009, only a minority of projects were completed or will be completed in next two or three months, while the rest suffer from serious time delays and, low rate of progress (Koridori Srbije, business and financial plan, 2015).

Authors of this paper were active participants in the bidding process where the contracts were awarded on the lowest bid price basis. They also witnessed the execution of these projects. Since 2009, on some projects contractors have bankruptcy and contracts were terminated, on others final warnings (notice to correct) before contract termination were issued. Non of the contracts have been completed within the contractual deadlines. The authors propose a modification of the current bidding procedures by introducing two phases, the eliminating and the ranking phase. Eliminating phase comprises questioning of whether the criteria which are currently used to demonstrate the adequacy of the bidder's proposal meet the minimum of the requirements set in bidding documents. Ranking phase compares the bids proposals in order to determine most economically advantageous bid or "best value

for many bid" by considering other criteria (financial issues, general and specific experience, technical proposal and expertise) besides the bid price criterion.

The current evaluation procedure involves preliminary examination, ranking and post qualification of bids. Preliminary examination of bids needs to determine its eligibility and responsiveness to the bidding documents, where the bids that are not responsive are not being considered further. Ranking is comparing of bids in order to determine the bid with the lowest price, while post qualification analyzes whether the bidder whose bid has been determined to offer the lowest evaluated cost has the capability and resources to effectively carry out the contract as offered in the bid. This is determined by a set of criteria and sub criteria displayed in the bidding documents. If the bidder does not meet the criteria, the lowest price bid is rejected and the similar examination is done for the next lowest evaluated bidder. The bidder who meets all the criteria requirements and offers the lowest price is awarded with the contract.

The criteria serve to demonstrate the overall financial position and profitability of bidder, bidder's participation on previous projects, especially if they are similar to the project that will be executed, its capability of planning, organizing and controlling a project and consistency of his offer with requirements stipulated in bidding documents. The criteria which is being used for post qualification with the minimum of requirements as recommended by the WB are shown in Table 1 in columns 1 to 4 (WB Standard Bidding Documents (SBD), Procurement of Works & User's Guide, 2015).

Table 1. List of criteria used for post qualification on a Serbian infrastructure project (financed by WB)

1) Criteria	2) Sub-criteria	3) Description and minimum requirements	4) Type of criteria
Eligibility	Nationality	Borrower's country not having prohibited commercial relations with Bidder's country .	Eliminating
	Conflict of interest	Bidder shall not have conflict of interest.	Eliminating
	Bank ineligibility	Not having declared ineligible by the Bank.	Eliminating
	Government owned entity	Legally and financially autonomous and operate under commercial law .	Eliminating
	Ineligibility based on UN resolution or Borrower's country law	Not having declared ineligible by UN or Borrower's country law .	Eliminating
Historical contract non-performance	History of non-performing contracts	Non-performance of a contract did not occur within the last five years prior to the deadline for application submission.	Eliminating
	Pending litigation	a) Pending litigation in total are less than 20 % of the Bidder’s net worth and shall be treated as resolved against the Bidder. b) All claims are less than 20 % of the accepted contract amount of the contract c) No pending litigation with the Employer.	Eliminating
Financial issues (C1)	Historical financial performance	Submission of audited balance sheets for the last three years. A Bidder’s net worth needs to be positive.	Eliminating & Ranking
	Average annual turnover	The Bidder's average annual turnover within the last three years shall be equal or more than the expected annual turnover if this contract is awarded to Bidder.	
	Financial resources	The Bidder must demonstrate access to, or availability of, financial resources other than any contractual advance payments to meet the overall cash flow requirements for this contract and its current commitments.	
Experience	General experience (C2)	Experience under contracts in the role of contractor, subcontractor, or management	Eliminating & Ranking

		Contractor for at least the last five years.	
	Specific experience on project of similar value (C3)	Participation as contractor, management contractor, or subcontractor, in at least one contract within the last five years, with a value which corresponds to 70-80% of this contract value, that have been successfully and substantially completed and that are similar to the proposed Works.	Eliminating & Ranking
	Specific experience – key activities (C4)	For the above or other contracts executed, a minimum experience within the last five years in the following key activities that reflects the majority (70-80%) of Works' scope (i.e. earthworks and rock excavation, asphalt and concrete production and placement, construction of bridges.	Eliminating & Ranking
Technical expertise	Key personnel (C5)	The Bidder must demonstrate that it has the personnel for the following key positions: project manager 15 years (7 on similar projects), site managers and engineers 10 years (5 on similar projects).	Eliminating & Ranking
Technical proposal (AHP C6)	Site organization Method statement Programme of works Equipment Subcontracting Traffic management plan Environmental management plan Quality assurance plan Sources of material procurement Cash flow Personnel	The Bidder's technical proposals must be made on the basis of a conceptual design or performance specifications set out in the bidding documents. It needs to describe the organization, work methods and processes, scheduling, ability to ensure the requested quality and to mobilize enough personnel and equipment to execute the project, plan of material procurement, traffic and environmental management plan. All of this needs to be provided in sufficient detail and fully in accordance with the requirements stipulated in bidding documents.	Eliminating & Ranking
Financial proposal (C6)	Bid price	Value of bid	Ranking

The proposed method considers these criteria through the bidding process. The first, eliminating phase in majority corresponds with the preliminary examination phase. The proposed addition is to use the criteria in the eliminating phase alongside with the eligibility and bid responsiveness requirements. Minimum of requirements set for each of the criteria would be used as a threshold. All the bids that exceed the threshold are being considered and compared further in the ranking phase but now instead of using the lowest price as the only criteria the elimination criteria are also used for ranking candidates. Considering that these criteria have both the qualitative and quantitative indices, this makes the selection of contractor's a multi-criteria problem.

Many techniques are proposed and applied as a solution (Hatush and Skitmore, 1998; Cheng and Heng, 2004; Plebankiewicz, 2009; Jaskowski et al., 2010). Because of its wide application in construction project management Analytical Hierarchy Process AHP is, as decision making method, widely used for multiple criteria decision-making (MCDM) in construction project management. (Saaty, 1990; Kamal et al., 2001; Chun-Chang Lin et al., 2008; Jaskowski et al., 2010). Some areas of construction project management where AHP method is used are contractor selection (Kamal et al., 2001; Jaskowski et al., 2010; Abudayyeh et al., 2007), technology selection (Skibniewski and Chao, 1992), equipment

selection (Shapiraand Goldenberg, 2005), analysis of causes of disputes in the construction industry (Cakmak and Cakmak, 2013).

2. General description of AHP Method

AHP is MCDM method where the process factors are hierarchy organized. Vertically, objective is on the highest level, with criteria, subcriteria and alternatives on lover levels, respectively, as it is showed on the hierarchical structure on Figure.1.

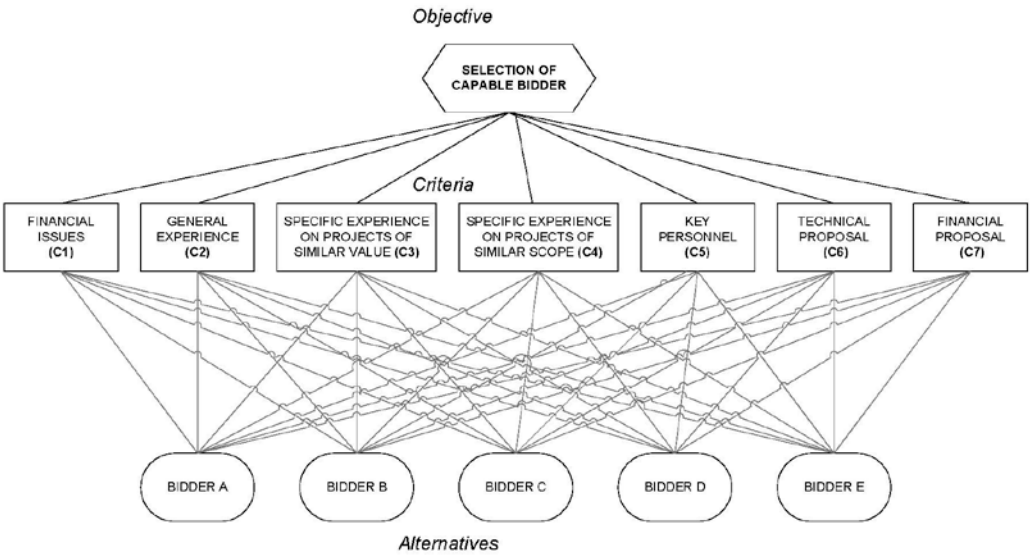

Fig.1. Hierarchical decomposition of an example

For each level − the criteria, subcriteria and alternatives, elements are compared in pairs. It means that one unfamiliar with the methodology of AHP can compare two elements from the same level according to verbal description scale. Fundamental scale used to compare the elements consists of verbal judgments ranging from equal to extreme (equal, moderately more, strongly more, very strongly more, extremely more). Corresponding to the verbal judgments are the numerical values (1, 3, 5, 7, 9) and intermediate values (2, 6, 8). (Saaty, 1990) Saaty's scale is given in Table 2.

Table 2. Saaty's fundamental scale

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	Any activity is strongly favored and its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring on activity over another is of the highest possible order of affirmation

2, 4, 6, 8	Intermediate values between two adjacent judgments	When compromise is needed
Reciprocals	If activity *i* has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	
Rationales	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to the span matrix

Comparison results of n elements belonging to Saaty's scale and AHP hierarchical structure levels are comparison matrices. These matrices ensue vectors priority or $\omega = (\omega_1, \omega_2, \dots \omega_n)^T$, ω is the eigenvector of corresponding matrix. Vector priority involves normalized values which determine importance of the elements – weights of the elements which are compared. This is the method for determination of the priority vector of criteria, the priority vector of alternatives, and as the final result the priority vector of the objective. The priority vector of objective ranks alternatives respect to the importance of the criteria. (Saaty, 1990)

3. Example with results and discussions or research plan

The numerical example is conducted through AHP model in this paper. The main purpose of AHP model is to support ranking which is proposed in this paper as the second phase in the process of selection of contractor in bidding procedures. Here AHP is used in the procurement of an infrastructure project − construction of nearly 6 km of highway with 6 bridges and an overpass. This project is financed by the Government of Serbia and managed by the company Koridori Srbije Ltd.

The AHP model consists of five alternatives and seven criteria. The alternatives represent a contractors which passed the eliminating phase in the open procedure. The criteria are proposed by the authors in the following way: C1 −financial situation, C2 − general experience, C3 − specific experience, C4 − key activities, C5 − key personnel, C6 − technical proposal, C7 – bid price. Some criteria from Table 1 are eliminating (Yes/No), and here are proposed those which can be assessed.

C1 − financial situation involves contractor's sound financial position and profitability, here is considered minimum average annual construction turnover within the last three years;

C2 − general experience under construction contracts for the last five years;

C3 − specific experience − under this criterion minimum value of contracts which are similar to the proposed works and which were successfully completed within the last five years is required;

C4 − key activities − under this criterion minimum construction experience for the key activities in the last five years is required;

C5 − key personnel – for key positions minimum years of work experience and minimum number of years on similar positions are required;

C6 − technical proposal – equipment of certain type and characteristics and minimum number of pieces are required;

C7 – total bid price.

Judgments of the elements and comparasion were provided by the independent experts. This example includes group of three experts which have a great number of years experience in tender procedures.

Each expert compares and assigns pairs of elements belonging to AHP hierarchical structure levels. Comparison results of the criteria are comparison matrices. In the Table 3 comparison matrix for the experts has been showed. The priority vectors of criteria follow as it is explained in general description of AHP. Considering the experts' equal participation, the final priority vector of criteria (criteria weights) are solved by the arithmetic mean method in Table 4 (Cho and Cho, 2008). In criteria ranking bid price has the main priority with 56%, and the second is key activities with 18,9 %, while general experience has the lowest priority.

Table 3. Experts criteria judgments

Criterion number		Expert 1	Expert 2	Expert 3
1	2	1/3	1	1
1	3	5	1	2
1	4	7	9	9
1	5	5	3	3
1	6	3	2	2
1	7	9	9	9
2	3	3	1	3
2	4	5	9	9
2	5	3	3	3
2	6	3	2	3
2	7	9	9	9
3	4	2	9	5
3	5	1/3	3	2
3	6	1/3	2	1
3	7	8	8	8
4	5	1/3	1/3	1/3
4	6	1/3	1/5	1/5
4	7	7	8	8
5	6	1/3	1/3	1/3
5	7	9	9	9
6	7	9	9	9

Table 4. Criteria weights

ω_1	ω_2	ω_3	ω_4	ω_5	ω_6	ω_7
0,0273	0,0253	0,0651	0,1894	0,0821	0,0467	0,5641

Further, the experts assign the alternatives for each criterion respecting the goal. Judgments for all pairs of alternatives considering the criterion are elements in the comparison matrix. Eigenvectors of all these matrices (for all criteria) rank importance of alternatives in accordance with the corresponding criterion and they are given per columns in result matrix in Table 5. This matrix ensue the final priority vector of alternatives, that is showed in Table 6.

Table 5. Ranking matrix alternatives per criteria

	C1	C2	C3	C4	C5	C6	C7
A1	0,309	0,146	0,401	0,511	0,468	0,306	0,23
A2	0,046	0,49	0,059	0,054	0,067	0,09	0,235
A3	0,461	0,154	0,218	0,277	0,261	0,185	0,193
A4	0,138	0,154	0,206	0,103	0,138	0,233	0,147
A5	0,046	0,058	0,116	0,054	0,067	0,185	0,195

Table 6. Ranking alternatives list

A_1	A_3	A_2	A_4	A_5
0,318	0,222	0,170	0,145	0,144

In this example contractor – A2 is the first on the ranking list considering criterion with highest importance C7 – bid price. Also, considering the criteria which follow the price on the criteria weights list, the contractor named alternative A1 has better characteristics than contractor – A2. Finally, Table 6 ranks alternatives where contractor – A1 has the first position. In the considered example of decision making, contractor A1 is the best solution, although his price was not the lowest.

4. Conclusion

The model presented in this paper takes into consideration other criteria besides the widely used lowest bid criterion for the contractor selection, thus making it a multi-criteria problem. AHP method as a decision support system was proposed and used for assessing the contractors in the ranking phase of the bidding procedures. In this paper, evaluation on the base of experts judgments using procurement of one infrastructure project financed by the Government of Serbia was conducted. Except bid price, criteria related to the contractor's financial situation, experience, key personnel and technical proposal was taken into account in the numerical example. It was estimated that the bid price participates with over 50% in the selection, but solution with much better other characteristics meaning contractor's specific experience and key personnel could have high importance. Result of the conducted numerical example is the contractor with a little higher bid price than the lowest, but with significantly better other proposed criteria. This result is proposed having in mind the project goals: cost, time, and quality.

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Investigating Position of Low and Un-Skilled Labor - A Construction Industry's Perspective

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Abstract

Construction sector is highly driven by its labor. The sector has also been considered as an entry point for the labor market and also serves as a substitute to farm labor for those who do not have any particular skill. In construction, a large number of workers are always needed partly due to the dependence of many sectors on the construction industry and secondly, a relative low degree of automation in the construction industry. The costs saving and lack of skilled labor are among the majors reasons that are being called upon in the construction sector in utilizing low and un-skilled craftsmen. On the other hand, the jobs that require low and un-skilled labor are continually examined to decrease due to technological and societal advances.

The study looked for a detailed literature review to investigate the position of labor in the construction sector around the globe with emphasis mainly on low and un-skilled labor. At first, the social position of construction labor has been examined along with the exploration of different challenges faced by them. Moreover, social and technical aspects of their employment are also examined from the perspective of both workers and their employers. The study identifies that the economic contribution made by such labor remains largely unnoticed with their rights often suppressed. The study also supports the fact that shortage of skilled labor and increasing number of low-skilled labor are serious problems needed to be tackled in the construction sector.

Keywords: construction, construction industry, construction labor, low and unskilled labor, social position, employment.

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1. Introduction

The construction industry plays an important role in the developing economies in addition to its continuous contribution to the developed ones. The sector is of high importance as it enhances the GDP of growing economies by acting as a major investment component (Wells, 2001), whereas it also plays a key role by proving employment opportunities to many. With the provision of employment opportunities, the sector ranks among the top employers providing more than 7% employment to the workforce of Europe (Ward and Coughtrie, 2009; Proverbs et al, 1999). By satisfying the social needs, the construction sector is continuously acting as an employment opportunity for the world's poorest possessing low or no skills. The sector provides opportunities to low-skilled or entry-level workers and to those migrating from the countryside in addition to absorbing those with few academic qualifications (Wells, 2001). It provides opportunities to long term unemployed force as well as those out of labor force (Dougherty, 1996). With the cost per job created in construction being lower than any other sector of the economy, construction is seen as an "employment-spinning" sector (Vaid, 1997).

With growing mismatches in the construction sector, one of the main issues is skills shortages. The issue is not new since its effects have been felt for decades. Despite the tremendous growth which the construction industry had, it is still struggling with significant workforce challenges with competent skills. Actually it is not only construction; every industry which depends on skilled craft workers is feeling its shortage (McConnel, 2007). The Institute of Management and Administration (IOMA) does not define the skilled craft shortage as a shortage of worker but as 'a shortage of adequately trained, skilled, and productive workers available for certain jobs'.

If the study by Dobbs and his colleagues (2012) is considered in the context of construction industry, the end of this decade would be distressing. The report came up with 45 million high skills shortages and 95 million surplus low and un-skilled worker around the globe by 2020. If these finding are transformed to the construction sector which also represents a high global workforce within, the situation would be alarming as well with an increased shortage of skilled workers by the end of this decade and an additional surplus amount of low and un-skilled labor.

In regard to these forecasts, the authors of this study felt a great need to come up with a study to explore the position of low and un-skilled labors in construction sector. The study would enable the construction stakeholder to get a clear picture about these labors. The idea is to make them understand the position of low and unskilled labor in the construction labor market for coming up with required solutions to these complications before it is too late. The study objectives have three main parts as follows:

- Examining the social position of low and un-skilled construction labor by finding their magnitude, earnings and working hours;
- Looking into different challenges faced by them in different parts of the globe;
- Observing the social and technical aspects of their employment from the perspective of both workers and employers.

In order to come up with a significant data, meaningful countries have been selected. The idea is to come up with countries having construction sector as one of the main source of

investment and growth. Though limited, the study covers a radius of eleven (11) countries in which China, Pakistan, India, Kingdom of Saudi Arabia (KSA) and United Arab Emirates (UAE) represented the Asian region. For European part, Germany is covered along with United Kingdom (UK) and Spain. Egypt and South-Africa were considered for the African region whereas American region is covered mainly through the statistics and information obtained through construction industry of United States of America (USA). The secondary information from past researches and various national statistics accessible through online sources have been used to perform a detailed content analysis. At first, a big picture is analyzed by looking at the proportion of low and un-skilled labors in construction sectors of targeted countries. Furthermore, their hourly income and working hours per day have been realized in addition to the challenges faced by them in these targeted countries. Pluses and minuses of their employment have also been discussed in the perspective of both these workers and their employers. A summarized discussion on the overall picture is then followed before the concluding statements.

2. Low and un-skilled labor in construction- A position overview

2.1. China

China is home to 1.37 billion people with more than one fifth of the total world's population. The Chinese construction sector is controlled by large state-owned or state-dominated constructions where mostly the building projects play a significant role. According to a national statistics, construction workforce in China by the year 2014 amounted to 44.9 million (NBSC, 2014). If we look into the quantity of construction workforce belonging to the low and un-skilled category in accordance with the level of education attained, the figure comes out to be approximately 80% (as in Fig. 1) with a highest education level being the junior secondary level (CDPR, 2014).

According to a study, China has significant differences in pay. For example, salaries in eastern regions are 40 to 100 percent higher than in the west (CICI, 2012). For working hours in the construction sector, labors tend to work long, ranging between 8 and 12 hours per day, with the average being 9.50 hours for a day (Fig. 1) thus making an exhausting time of around 57 hours per week (CDPR, 2014). Regarding the income of the workforce in the construction labor market, the average hourly wage of 1.45 Euros (1USD = 0.88€) is recorded for the unskilled category as shown in Fig. 1 (CICI, 2012).

Figure 1: Low & un-skilled labor in Chinese construction industry

After the restructuring of the Chinese construction sector was almost complete by the late 1990s, dramatic changes like the efficiency and productivity had increased implementation of construction projects. However, on the other hand a direct consequence was the emergence of the subcontract system which now holds the top spot as the employment method used to hire construction labor force (Li and Peng, 2006).

The study (CDPR, 2014) conducted thorough a survey from construction workers concluded that 'no written labor contract', 'lack of social insurance' and 'late payment of wages' are particular concerns for workers. It is common that construction workers do not know the name of the construction company, on which they are hired. This situation causes serious problems, for example, in the case of withholding salaries when the respective construction workers are not able to prove their employment. Late payment of wages or even withholding of wages remain a significant problem in the industry, which will continue to be difficult to solve in future if the current practice does not change (Li and Peng, 2006). Regarding the deficiencies in social insurance, insurance related to occupational safety and health is a particular concern. For example, about 60% of workers have had to buy their own safety equipment. And over 18% of workers have experienced work-related injuries or occupational diseases (CDPR, 2014).

2.2. Pakistan

Pakistan is the sixth most populous country in the world with an estimated total population of 185.35 million. Apart from the fact that construction sector is one of the major contributor to the economic development, the construction industry is also the second largest sector in the provision of employment opportunities for the socially or financially challenged people especially from rural areas. Out of around 56 million workforces, approximately 4.1 million belong to the construction sector (GoP, 2014). With a total of 7.4 percent employment which the construction sector provides, the activities in the construction sector have a direct impact on the employment, in particular on low to medium skill segments. The reliance on low and un-skilled workers (40% of total construction work force) in the construction is related to the issues of cost constraint and low adoption of technology (Fig .2).

The remuneration of the labors in the construction industry of Pakistan is also among

below average level where an average hourly wages for low and un-skilled workers in the last quarter of 2013 amounted to 0.40 Euros (1USD = 0.88€) as shown in Fig. 2 (GoP, 2015). Like China, subcontracting system is also the main source of employment for these low and un-skilled construction labors. For the working hours, as shown in Fig. 2 the construction workers typically work around 48 hour per week making an average of 08 working hours per day (Choudhry and Hinze, 2011).

Figure 2: Low & un-skilled labor in Pakistan construction industry

Among the challenges faced by the construction labors, there are no specific health and safety law present in the construction industry of Pakistan (Hassan, 2012). Differences in language often lead to communication problems where the labors do not properly understand the information provided to them. A few numbers of companies concern for the safety and thus have established themselves few safety procedures. Among other things, they provide training for workers, and strive to the training of security at construction sites. However, profit maximization is at the forefront for the majority of entrepreneurs and thus work safety is often hidden on building sites and workers are exposed to numerous life-threatening hazards (Farooqui et al., 2008).

2.3. India

The construction sector continues to be the second largest employment provider in India after the agriculture sector. With more than 31 million people employed in the construction industry (Chen *et al*., 2014), approximately 83% are unskilled craftsmen as shown in Fig. 3 (Hajela, 2012). The Planning Commission (2013) also states that the major impediments faced by the construction industry in raising the levels of productivity are the acute shortage of skilled manpower, both at worker and supervisory levels.

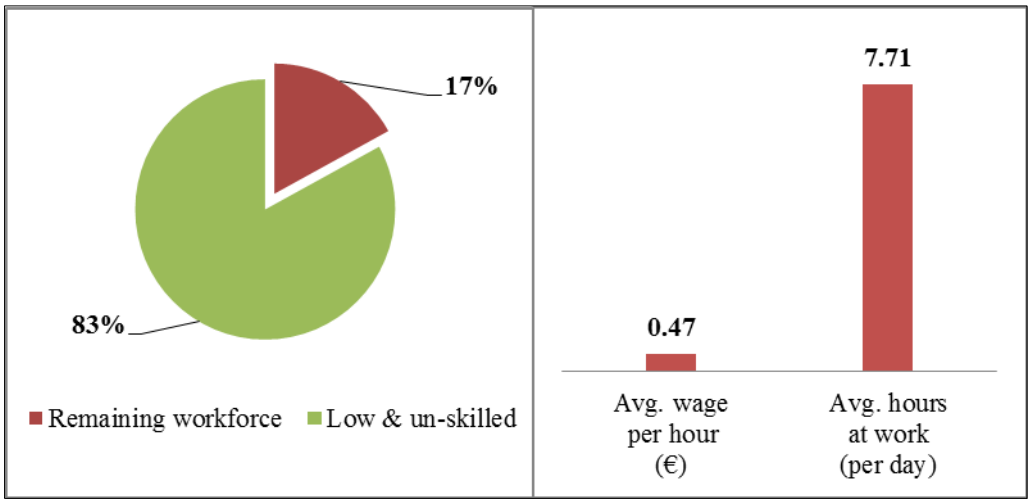

Figure 3: Low & un-skilled labor in Indian construction industry

The remuneration which is intended for unskilled or low-skilled workers is below a realistic average hourly wage of 0.47 Euros (1USD = 0.88€) as shown in Fig. 3 (The Indian Express, 2014). The payment arrangements are opaque where the workers often do not get regular pay (Kumar, 2013). As highlighted in Fig. 3, India construction workers typically work between 45.0 and 47.5 hour per week forming 7.71 hours of avegarge work per day (CICI, 2012). Long working hours, poor housing facilities, lack of health and safety measures, inadequate compensation factors and poor wage and salary structures invites more attention of the care takers to intervene. The construction workers are constantly exposed to accidents, ill-health, extreme level of harassment and poor quality of work life (Kumar, 2013).

2.4. KSA & UAE

The construction boom has attracted hundreds of thousands of migrant workers since the mid-1970s in the sparsely populated but oil-rich Middle Eastern countries (ILO, 1996). Through the oil wealth, GCC countries have become one of the largest employers. However, the construction boom in the region is primarily due to the cheap labor from abroad. The poor working and living conditions of the workers in the construction sector are largely ignored and hidden from the public consciousness (Al Shaibany, 2010). A job change is very difficult and requires a great deal of bureaucracy. In most Gulf States, trade unions and strikes are illegal and the workers have no way to call attention to existing shortcomings (Ghaemi, 2006).

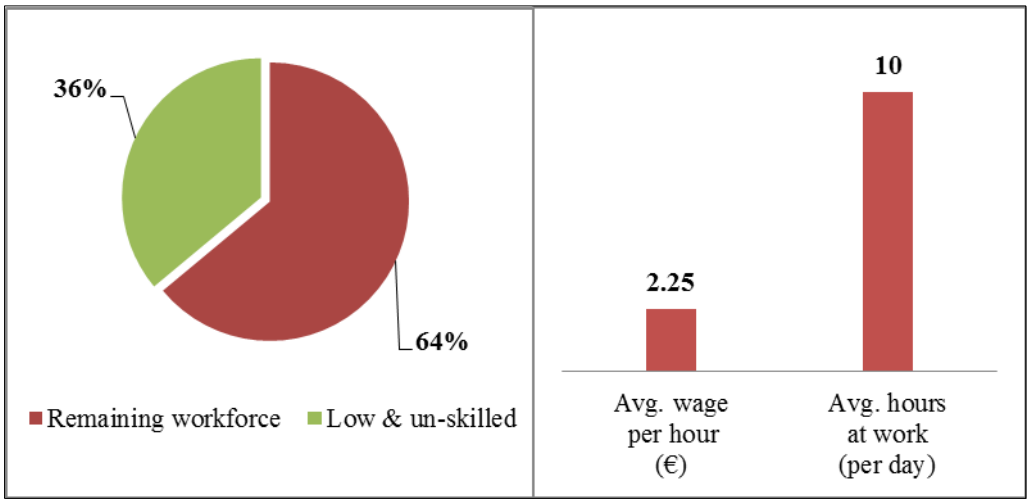

Figure 4: Low & un-skilled labor in KSA construction industry

The total number of employed workers in the construction sector of KSA by the end of 2014 was 1.4 million while workers under the category of low and un-skilled were 510,608 in total covering 36% of the whole construction sector as shown in Fig. 4 (CDSI, 2014). For UAE, the figure for the total construction workforce came out to be 1.38 million with 17.5% in the low and unskilled category as also shown in Fig. 5 (Ministry of labor, 2013). The average wages which these workers earn in Saudi Arabia is 2.25 Euros (1USD = 0.88€) as shown in Fig. 4 (Naffee, 2013) while in UAE it was recorded as 1.60 Euros as given in Fig. 5 (1€ = 4.2AED; Tong, 2010).

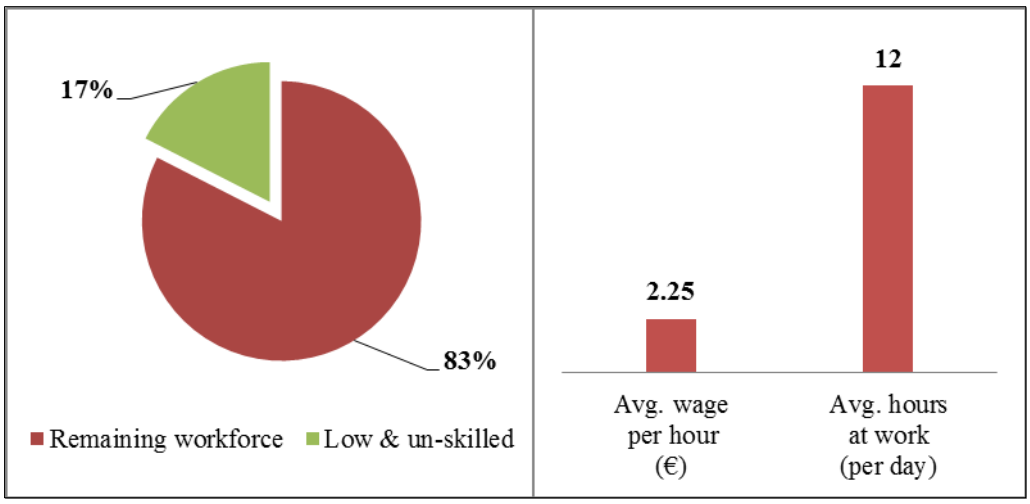

Figure 5: Low & un-skilled labor in UAE construction industry

According to the labor laws in KSA, workers generally must not work more than eight hours per day/48 hours per week. However, Muslim workers, during the month of Ramadan must not be required to work more than six hours per day or 36 hours per week. Nevertheless, the laws also provide exceptions to these limits where labors be required to work up to ten hours per day or 60 hours per week which is usually the case. The overtime in that case will then be made according to his regular wage plus 50% (Husein, 2014). Whereas the construction workers in UAE usually spend up to 12 hours per day on their worksites and in

summer are often exposed to extreme conditions of heat and humidity with high hot temperatures (Esveld, 2009).

The construction workers live in these Gulf States in appalling and inhumane conditions. The employer does not grant them the least fundamental rights. The workers are housed in wooden barracks, where hygienic conditions can often be described as non-existent. Heat stroke, food poisoning or injuries caused by the work on the site are common complaints of the workers (Al Shaibany, 2010).

2.5. USA

The construction industry accounts for about 7% of the total work force in both the US and Canada, as well as in Latin America (CPRW, 2013; Statistics Canada, 2012). The sector is of great importance, especially for low and un-skilled workers as it provides an employment opportunity to most of them. Out of the total 8.5 million construction workforce, around 22% belong to the low and un-skilled category (Fig. 6).

The amount of the salary depends on many factors. These include employment in the construction sector, age, sex, education level and ethnicity. As shown in Fig. 6, the US federal minimum wage is 7.25 US dollars (6.38 Euros; 1USD = 0.88€) per hour (USDL, 2008). Wages in Latin America in the construction sector are significantly lower than in the US. For south American country like Brazil, the hourly wage in 2012 was between 4.10 and 5.30 US dollars for low-skilled workers. Similarly, hourly wage in Mexico for a low-skilled workers ranges from 4.30 to 5.80 (CICI, 2012).

Figure 6: Low & un-skilled Labor in USA Construction Industry

The workers in the US construction industry get an overtime wage once the quota of 40 hours per week is exhausted, leading to an average of 6.67 hours per day as shown in Fig. 6 (USDL, 2008). The number of hours per week for the producing workers followed a similar trend. This decrease was caused and associated to the crisis in 2007 and the economic downturn (CPRW, 2013).

In the US in 2010, 83% of all wage and salary workers were a member of a health insurance policy. However, the share of health insurance in sectors with a high rate of self-

employed workers is generally lower. This also applies to the construction industry where in 2010, 68% of workers were covered by insurance (CPRW, 2013).

2.6. Germany

The German construction industry takes fourth place in the Top 15 on the world construction market after the US, China and Japan (CICI, 2012). In construction sector, about 820,000 are employed by the start of 2014 (Schulten and Schulze-Buschoff, 2015). In construction, there are just ¼ of employees with age over 50 years, out which 98% belong to male sex. This low percentage of older workers can be attributed to the difficult and physically demanding working conditions that prevail at the construction sites (Brussig and Schwarzkopf, 2013). Almost one-fifth of the total workers belonging to the construction sector belong to the low and unskilled category of construction workers (Fig. 7).

Cooperation between employers and employees are governed by collective agreements that have been compiled by the federation of the German construction industry. In paragraph five of the federal framework, collective agreement for grouping of wages was made in regard to the education, skills and knowledge as well as the performance activities for the classification of the construction workers. The average wage per hour for lowest category was recorded to be around 10.50 Euros as shown in Fig. 7 (Soka-Bau, 2013).

Figure 7: Low & un-skilled labor in German construction industry

In federal framework collective agreement of 2012, the average working time of 40 hours per week is set for the construction labor. During the winter months i.e. from March to December, the daily working time is 08 hours from Monday to Thursday with only 06 working hours on Friday. The summer work time is in turn 41 hours, with a division of 8.5 hours from Monday to Thursday and 07 hours on Friday (BRTV, 2014). Wage supplements are there for construction workers for overtime, night work, Sundays and public holidays (BRTV, 2014).

According to a study, the working life of construction workers in reality is characterized by seasonal work, redundancies and fixed-term contracts and unemployment (Brussig and Schwarzkopf, 2013). There is a significant problem with the compliance and enforcement of collectively agreed wages and working conditions. Various studies like (Bosch *et al.*, 2011; Schulten *et al.*, 2014) have also come up with a wide range of illegal employment practices

followed in the construction industry.

2.7. United Kingdom

With the construction companies like M/s. Amec, Atkis, Costain, Laing O'Rourke and Taylor Woodrow, the United Kingdom ranked at number five on the top 15 construction markets and hence also plays an important role as a construction employer (CICI, 2012). In Britain, about 2.37 million workers are employed in the construction sector representing 8% of the total UK employment (Gambin *et al.*, 2012). Out of those, around 15% belong to the category of low and unskilled construction workers as shown in Fig. 8 (Ward and Coughtrie, 2009).

Wages are often paid weekly at low qualifying activities to unskilled construction workers in the UK where an hourly wage of about 11.00 Euros as shown in Fig. 8 (12.5 US dollars; 1USD = 0.88€) was recorded (CICI, 2012). The typical workweek in the construction industry is 39 hours, Monday through Fridays. Overtime is allowed, and usually is paid for at time and one-half (EFBWW, 2009).

Figure 8: Low & un-skilled labor in UK construction industry

According to a study by the health and safety executive, it came in the year 2009-10 where UK recorded 50 fatal accidents and 2,585 major injuries (Maxey, 2011).

2.8. Spain

Spain is among the 15 largest construction markets. From 2000 to 2006, the share of added national value in construction increased by 8 to 12.1%. Thus, about 18 percent of gross fixed capital was invested in the construction industry. After the recession and economic crisis of 2007-08, the economy and competitiveness of the industry decreased dramatically (Kreiss, 2009).

Compared to a figure of 2012 where about 2.3 million people were employed in the construction industry, currently 20 to 35 percent are in unemployment (CICI, 2012). Out of this figure, 15% ordinary workers belong to low levels of education as given in Fig. 9 (Farber and Allard, 2012).

The average hourly wage for a low skilled worker was 8.27 Euros (Fig.9). The weekly working time is 40 hours (6.5 hours/day) and a maximum of 80 additional hours are allowed in a year. Annual leave is covered by 30 calendar days (EFPWW, 2009).

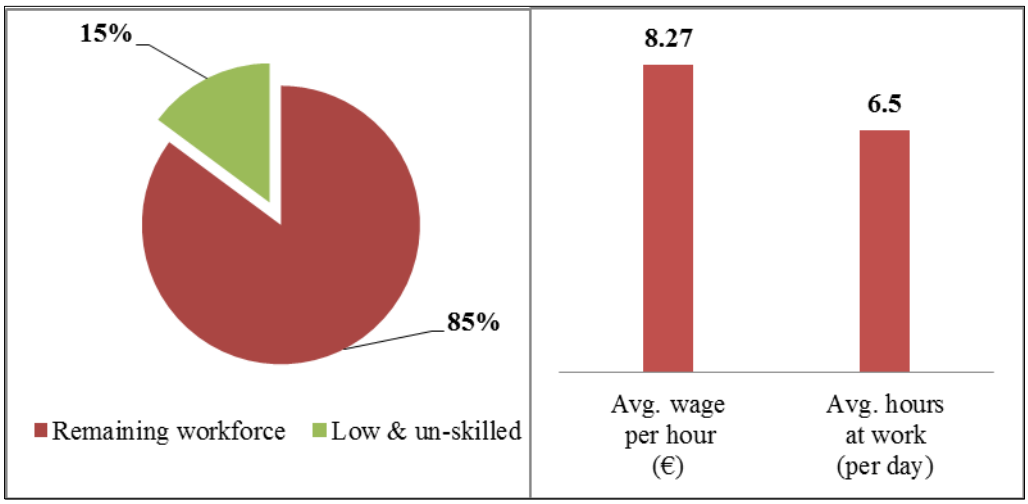

Figure 9: Low & un-skilled labor in Spanish construction industry

A study by the University of Burgos confirmed that the construction industry provides insufficient training to deal with a higher level of accidents. This lack of education and training is also directly related to the employment relationship. Temporary workers receive a lower level of education and training, as the investment from the client is not of their benefits (Arquillos *et al.*, 2012).

The overall accident rate is at 45.3% for skilled workers and 36.4% for low and un-skilled workers. Added overtime is among the reasons that put the health and safety of workers at risk (López *et al.*, 2008).

2.9. Egypt

The Egyptian construction industry is one of the largest employers in the country and is largely in private hands. There were just over one million people employed in the construction industry in 2002, which nearly doubled in 2012 nearing around 2 million due to the boom in the Egyptian construction industry. On the other hand, the unemployment rate in the construction industry is moving between 15-25%, where many of these unemployed people make a living as day laborers on construction sites which is often not covered by the statistics (CICI, 2012). The poor people processing no education with less expectation from other sectors usually work as daily wage construction workers, making up at least 70% percent of casual workforce in most of the urban parts as shown in Fig. 10 (El-Ehwany *et al.*, 2000).

The general unemployment rate in Egypt is 10-20%, with the numbers growing every year for available labor force by three to four percent. This large number consist mostly young workers, since their entry to the work is difficult and the risk of becoming long-term unemployed is more. Moreover, the remuneration in the construction industry largely falls at low category where the hourly wage obtained by low skill category workers was 1.37 Euros (1USD = 0.88€) in 2012 (Fig. 10). As also shown in Fig. 10, they work as a rule from 45 to

47.5 hours per week forming an average of 5.75 hours per day. On average, they receive ten to 14 days of vacation and 8-12 holidays are granted (CICI, 2012).

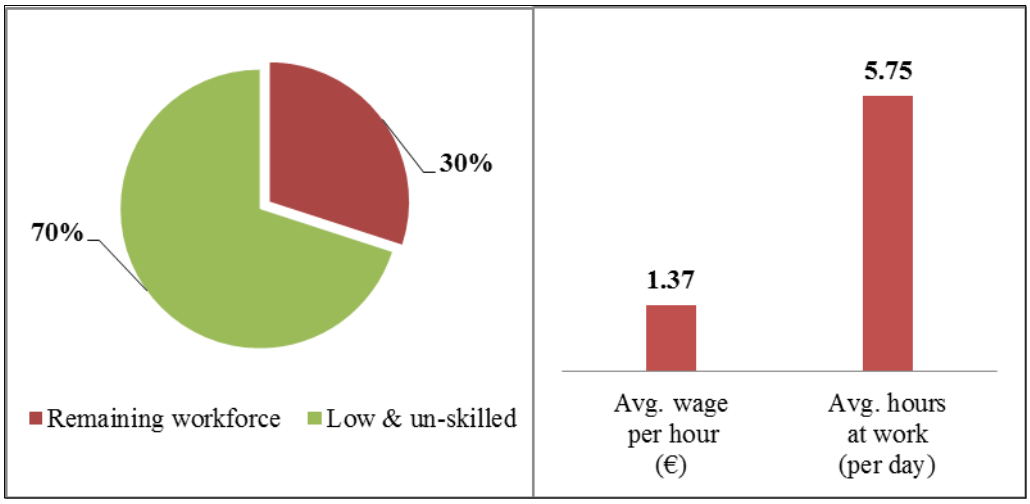

Figure 10: Low & un-skilled labor in Egyptian construction industry

In the Egyptian construction industry, there is little direct employment. The major construction companies use subcontractors and employment agencies in order to draw flexible labor. An estimated 90% of unskilled construction workers are either only occasionally hired as wage laborers or they work on a freelance basis (ILO, 2001).

2.10. South Africa

South Africa is the one of the largest economy from the African continent. South Africa's location advantages over its neighbors is its relatively good infrastructure, a financial sector at world level, large reserves of raw materials and a reliable and independent legal system. There are almost unlimited amount of unskilled construction workers in South Africa, which illustrate the five million unemployed. However, there is a great shortage of low-skilled and skilled workers as well. The government has started to recently promote mainly the training of unskilled workers in the private sector through the expansion of training facilities for the black youth in skilled trades (CICI, 2012*)*.

The South African labor market is flooded with a large number of unskilled laborers, offering their services on the principle of supply and demand in the informal labor market in various industries. A majority of these workers have worked in the construction industry, which is another indication of the high turnover in the South African construction industry (Blaauw, 2005). South African construction sector employs over 1.11 million people, or eight percent of all employees in the country where 604,000 among those belong to low and un-unskilled category (Statistics South Africa, 2008).

Following the section 9 of the basic conditions of employment Act, maximum working time for an employee in normal condition is 45 hours per week. This leads to a maximum of nine hours per day for five or less days a week, whereas eight hours per day in case of more than 5 working days in a week (South Africa, 2009). However, figures regarding working hours are difficult to control in the informal construction sector and are therefore hardly enforced resulting in long working hours for the construction labor. The average hourly wage for a construction worker belonging to low and un-skilled category came out to be 1.16 Euros

(15.68 Rands; 1Euro = 0.074 Rand) from the labor department's document as shown in Fig. 11 (South Africa, 2010)

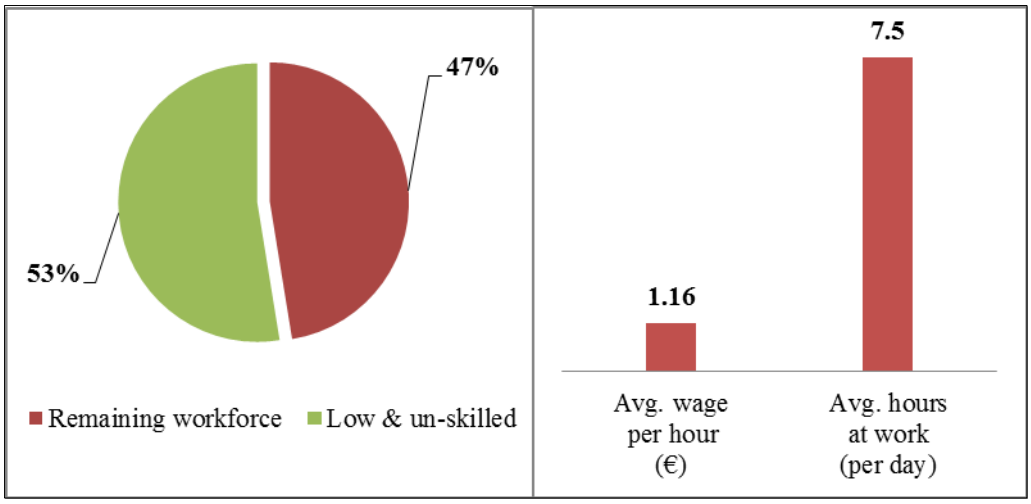

Figure 11: Low & un-skilled labor in South African construction industry

The construction workers in South Africa tend to change many professionals. In the first half of 2008 alone, 446,000 have lost their jobs in the construction industry out of which 67,000 left on its own. Informal construction workers are engaged at short notice, but lose their jobs after the completion of construction projects just as quickly. The unskilled South African construction workers that match 53% of the labor force usually do not have claims to health care or retirement, nor do they have a written employment contract (Statistics South Africa, 2008). General social security for workers in the South African construction industry is low. Only 10% of all construction workers have health insurance. Only 28% are entitled to paid vacation and 52% of construction workers do not have a written employment contract. Moreover, only around 10% of all construction workers are unionized, which is far below the national level (SAH, 2009).

3. Social and technical aspects of labor employability

3.1. Favorability for construction employers

The biggest advantage which the construction contractors get by employing low and un-skilled labor is actually the low wages to be paid. The resultant savings are extremely profitable because the labor costs are generally associated with a high financial resource expense (Bilginsoy, 2003). This in turn has a positive effect on the inclination to invest by which entrepreneurs can expect higher output.

The savings which a contractor makes owing to the employment of low and un-skilled workers could then be invested in the creation of new jobs (Peri, 2012). By the lack of binding agreements and employment contracts, the wages for the labor are set nearly freely by the contractors, especially in case of Asian and African regions. Since insurance and social security are almost uncommon, the employers also do not worry about any additional costs (Gërxhani, 1999; Mitullah and Njeri Wachira, 2003).

Another big advantage for the contractor is through the flexibility of these low and un-skilled workers. They are mobile, adjust quickly and easily and could then be fired again without a pertinent reason (Gërxhani, 1999; Mitullah and Njeri Wachira, 2003). This is more

advantageous, particularly in the construction sector since the work places change more frequently than in other industries. On average, one in three construction workers in the US has more than one client per year (Construction Users Roundtable, 2009).

3.2. Favorability for workers

One main advantage for the workers in the construction industry is that they work without special requirements for education or work experience. The employers are placing greater emphasis on flexibility, motivation and a positive attitude to work rather than on their educational qualifications (Green *et al.*, 2013). With low demands of professional qualifications, low and un-skilled workers find opportunity to pursue an activity to satisfy basic needs of their families (Lingard *et al.*, 2007).

The increasing competition in markets and the development of new competence-based technologies have led to a rising complexity in professions. This has resultantly decreased the demand for low-skilled labor continuously in recent past years (Maxwell, 2008; Dobbs *et al.*, 2012). The construction sector, still in comparison to other industries has more capability to accommodate these low and unskilled workers due to less adoption of automation and technology in developing parts of the world. According to study conducted by ILO in 2002, 70% employment of the construction labors are existing in the developing parts of the world.

Job availability simultaneously averts social tensions. This is mainly true for migrant workers in the Gulf region where many of them send large portions of their income to their families back to their home countries (Pongsapich, 1989).

3.3. Drawbacks for construction employers

Often illegal migrants are employed in the unskilled labor category and due to this fact they are mostly not registered in the domestic sector, a real GDP or the government performance are hardly determined (Gerxhani, 1999).

Often the workers due to their lack of training are not able to comply with the required quality standards in construction sites which lead to significant delay factor in the construction process (Kalhöfer, 2013). These workers often change jobs due to no fixed-term contracts are not immediately on the same performance level as those of skilled (Green et al., 2013).

A broken communication link is also witnessed on construction sites where the information mainly generated by contractors regarding instructions related to tasks/activities, are not completely understood by these low and unskilled labors (Lim and Alum, 1995). The main reason could be the less education level of these workers along with their inability to visualize the construction process and understand what is needed and how it is executed. The communication barriers particularly related to inability of workers to speak language spoken on construction sites besides reading is also categorized as a key project failure factor in many researches (Han et al, 2008). Statistical studies conducted in North America where a large proportion of low-skilled workers are from Latin America, revealed that many of these immigrants do not speak English. When questioned by the American Community Survey in 2010, 25% of Hispanic construction workers are not able to speak English, whereas another 46% had only basic knowledge of English language (CPRW, 2013).

Retention of labor is also a critical issue for contractors in parts of the world with high agricultural activities/growth. The construction workers belonging to low and un-skilled

category often tend to leave the working sites at the harvesting time of the crops (Bargstädt *et al*, 2014).

3.4. Drawbacks for workers

The disadvantages for low-skilled workers outweigh their benefits. For these workers are the first to be fired in critical economic conditions of the company. Through their mostly temporary employment contracts, this effect is further amplified as it sets the working under strong pressure and fear of dismissal (Ward and Coughtrie, 2009). Since the economic changes have a greater effect on men than on women, it affects their social conditions as the construction industry is largely dominated by men (Parent-Thirion *et al*., 2008).

These low and un-skilled construction workers are often in a constant change between work and unemployment due to seasonal fluctuations in the construction industry. Through the continuous exchange of jobs, development of skills and progress in long-term employment are generally prevented (Green et al., 2013; Lingard *et al.*, 2007). To make matters worse, the situation exacerbated in the labor market where in recent years, a shrinking demand for low and un-skilled workers was recognizable due to technological changes, international competition and organizational changes in the developed parts of the globe (Schlitte, 2012; Green et al., 2013).

The construction sector in 2010 was in the US, the industry with the most work-related deaths. The number of deaths among construction labors was significantly higher than in all other occupations in construction (CPRW, 2013). In particular the large numbers of immigrants, especially Hispanics are busy in this area. Hispanic workers in construction have on average a higher rate of deaths in the construction industry besides non-fatal injuries (CPRW, 2013).

The resulting disadvantages for low and un-skilled workers in the African construction industry are mostly from the fact that the workers are not registered, thus make no contributions on paper. These labors also cannot assume any social benefits. A pension, unemployment and health care is often nonexistent, so the workers on which their families are dependent carry out activities even at their old ages (Banerjee *et al*., 2008).

Besides low wages recorded for these labors, irregular payment or total payment defaults are also recorded at various instances. Since most of these workers pursue informal employment, they have little opportunity to take action against the suppression by employers (Banerjee *et al*., 2008).

4. Discussion

The study in regard to low and un-skilled labor in the construction sectors of meaningful countries supported the notion of a huge proportion of workforce belong to the low and un-skilled category as envisaged by various researches of the past (Dobbs *et al*., 2012; Özmucur and Pamuk, 2002). The total construction workforce in the targeted nations came out be approximately 104.5 million where Asian region takes a lead. This makes logic as these regions are comparably highly populated from other parts of the globe. The total workforce belonging to the low and un-skilled category in the targeted regions came out with an astonishing figure of 72.4 million, representing almost 70% of the construction force (as shown in Fig. 12).

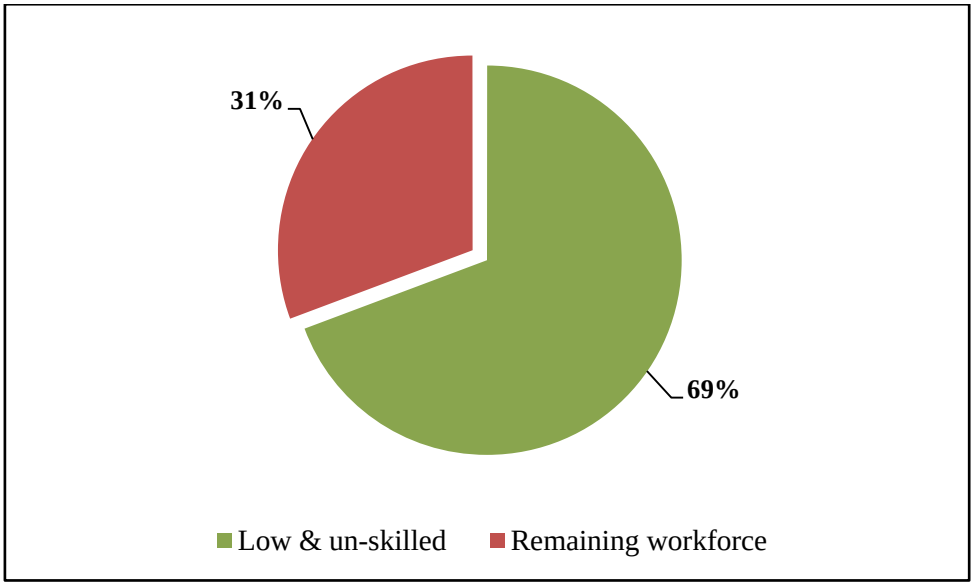

Figure 12: Share for low and un-skilled construction labor in targeted countries

The average wage earn by the labors belonging to low and unskilled categories also came up in the below average area (as shown in Fig. 13), particularly in the developing parts of the globe. There is a clear disparity when comparing the hourly wages in different continents. For example the average wage came out be 1.27 Euros per hour for a labor belonging to targeted Asian and African parts. This low figure would be non-comparable with those of European and American regions with average hourly wage of 9.92 and 5.29 Euros respectively. Moreover, during the extraction of data for the research it was also observed that these low and unskilled labors mostly earn less than half as compared to that of skilled labors. This polarization of wages has also been highlighted by (David and Dorn, 2013; Manning, 2004). One of the main reasons for this low income of low and un-skilled labors is their abundance in the developing regions as determined by the study. This surplus amount of these labors could be seriously alarming by the end of 2020 as envisaged by Dobbs and colleagues in 2012, which came up with dismaying figure of 95 million surplus low skilled workers. This situation in the future would lead to more long term joblessness and increment of unemployment ratio for those belonging to low and un-skilled categories.

The workings hours for the construction labors and particularly for those in low and no skill possession came out to be on the higher side as showin in Fig. 14. The scenario is worse in the middle-eastern region where the workers are demanded to work in extreme hot conditions. Furthermore, the situation becomes worst when the labors intend to work longer than normal i.e. overtime of their normal working hours in need of extra compensation for their livelihood. The working hours in the European, American and African regions found to be under suitable limits mainly due to the implementation of labor laws which are barely executed in Asian parts (Teicholz, 2001; Goos, Goos *et al.* , 2009).

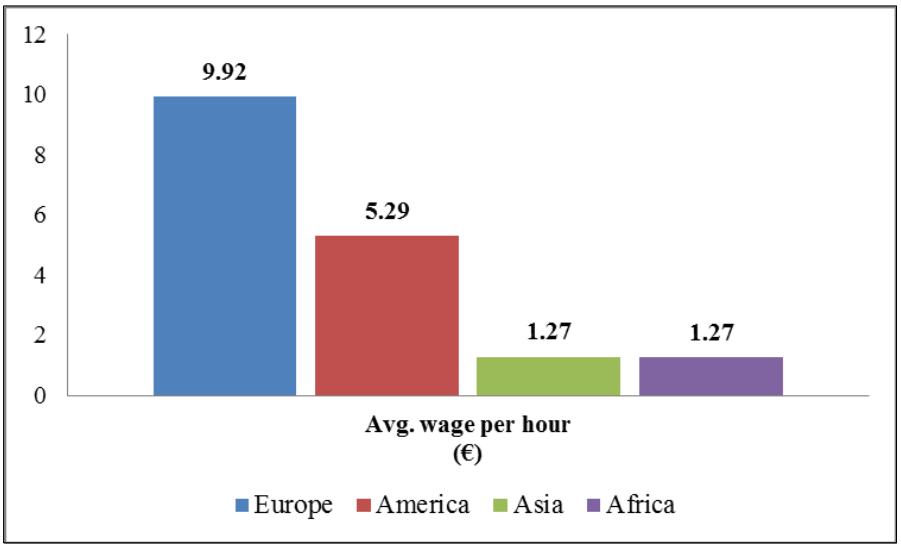

Figure 13: Average hourly wages for low and un-skilled labor in different regions from targeted construction industries

Regarding the challenges faced by these labors in Asian part of the targeted countries, 'no written labor contract', 'lack of social insurance', 'poor wage and salary structures' and 'late disbursement' of those, 'non-implementation of health and safety practices', 'poor housing facilities' are mostly common. Their respective employers fail to grant them the least fundamental rights where instances like living in wooden barracks, with un-hygienic conditions can often lead to heat strokes, food poisoning.

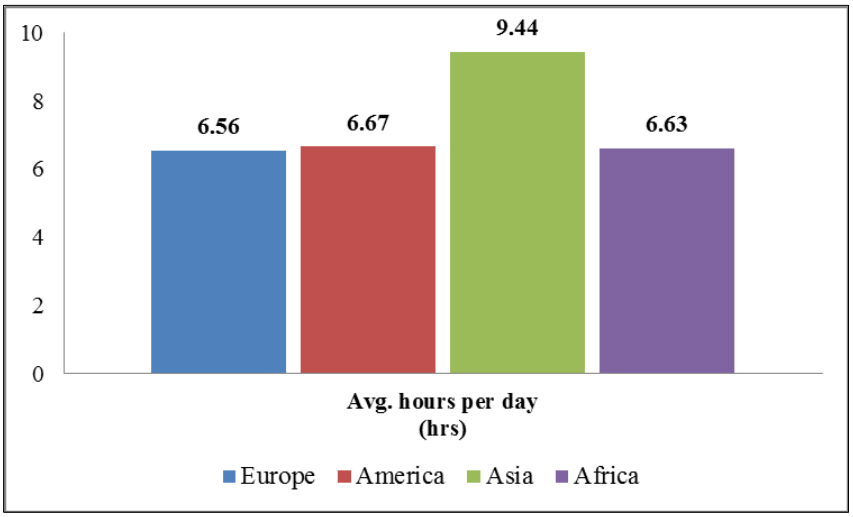

Figure 14: Average daily working hours for low and un-skilled labor in different regions from targeted construction industries

As per some studies, instances like 'illegal employment practices' are followed in some European and American parts. Those illegal employees are thus deprived of their basic rights, where they find themselves in a bad position in case of lodging a complaint or demanding for benefits as compared to their colleagues which are working legally. Other prevalent problems are related to 'health and safety practices' where the workers are exposed to unsafe environment which results in fatal and serious injuries as also highlighted by (Gillen *et al.*,

2002; Brenner and Ahern, 2000). Like Asia, 'social security' is also a problem with workers in Africa where they are unable to seek securities due to unemployment.

In the second part of the research, the social and technical aspects of labor employability have been discussed from the perspective of both the workers and their employers. Low cost used to hire these labors on one hand leads to employers profitability and allowance to create more jobs, while on the other hand it also results in inadequate productivity. The contractors also face the drawbacks of communication barriers while interaction with these labors whereas retaining them also becomes a key issue where they tend to leave the job at times of works related to other sectors (like harvesting season in agriculturally rich Asian region). For these low and un-skilled labors, a big plus is getting an employment in the construction sector without any necessary qualifications. The contractors tend to focus more on workers flexibility and motivation as compare to his qualification. Due to migrations, these labors earn more than double of what they get in their local environment thus resulting into averting their social tensions where accommodating the needs of their families are on top of the list. On the negative side, these labors are fired at the first instance when an employer feels any negative economic conditions. Moreover, these labors are also exposed to unsafe conditions.

5. Conclusion

The study results support the fact that a huge proportion of the manpower in construction sector belongs to the low and un-skilled categories which will further enhance the skills shortage problem if not treated appropriately and timely. The average hourly wage was found less in the developing parts of the globe as compared to that of the developed. Similarly the working hours required from these labors in a day are on the higher sides in Asian region which represents the tough working conditions in the middle-eastern part. The study also identifies that since most of the workers have no fixed terms contracts, they are often not registered with national statistical departments. Thus the economic contributions made by such labor remain largely unnoticed with their rights often suppressed. Problems like no fixed-term contracts, lack of social insurance, poor wage and salary structures and its late disbursement, non-implementation of health and safety practices, and poor housing facilities are prevalent which surely needs to be considered to retain and motivate these workers for further enhancement of skills through necessitated training incentives. Emphasis should also be placed to educate and train these labors within the existing and prevailing communication barriers found on construction sites.

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Innovation Performance of EU Members States and Selected Providers of Building Materials in the Czech Republic

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Abstract

The European Union recognizes the need to integrate innovation into their program. The main reason is the ongoing slowdown in the European economy. The present article analyzes the innovation in manufacturing industry of building materials. The purpose was to establish share and cooperation possibilities of the various operators on the market. Data was used from the Czech Statistical. Methodology related to this statistical survey is distributed in the international manual "Oslo Manual 2005", which was initiated by the OECD. To the data collection it used harmonized questionnaire of the EU member countries to community innovation survey Community Innovation Survey (CIS). The survey was carried out through a combination of selection and surface survey taking into account the regional dimension of the Nomenclature of Territorial Statistic Unit (NUTS2). The selection includes companies with at least 10 employees. The conclusion shows the necessity of integrating productive innovation, process innovation, marketing innovation and organizational innovation, competitiveness reasons and necessary development of the manufacturing industry of building materials in the Czech Republic with an overlap abroad.

Keywords: innovation, process innovation, productive innovation, organizational innovation, marketing innovation, European Union, Summary innovation index, EU Member States

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1. Introduction

In the course of the past decade (Exelová, 2007), with continuing transformation of the worldwide economic system, evaluation of innovation performance has become an integral part of macroeconomic studies of development of national economies. Today a major competitive edge may only be built through innovation, economic appreciation of knowledge and human creativeness.

Union of Innovations as one of the EU initiatives periodically monitors progress achieved in research (Pavelka, 2011), development and innovations. Comparative tables are compiled with key indicators with the help of which progress in this area may be assessed. These indicators are included in the Summary Innovation Index

On the basis of the recommendations formulated in the European document of the Union of Innovations the Czech Republic has prepared its National Innovation Strategy (Rada vlády ČR pro vědu, výzkum a inovace, 2015). Monitoring of research, development and innovations in the Czech Republic has been done by the Czech Statistical Office.

The European Union recognizes the need to integrate innovation into their program. The main reason is the ongoing slowdown in the European economy. The present article analyzes the innovation in manufacturing industry of building materials. The purpose was to establish share and cooperation possibilities of the various operators on the market. Data was used from the Czech Statistical. Methodology related to this statistical survey is distributed in the international manual "Oslo Manual 2005", which was initiated by the OECD. To the data collection it used harmonized questionnaire of the EU member countries to community innovation survey Community Innovation Survey (CIS). The survey was carried out through a combination of selection and surface survey taking into account the regional dimension of the Nomenclature of Territorial Statistic Unit (NUTS2). The selection includes companies with at least 10 employees. The conclusion shows the necessity of integrating productive innovation, process innovation, marketing innovation and organizational innovation, competitiveness reasons and necessary development of the manufacturing industry of building materials in the Czech Republic with an overlap abroad.

2. Research methods

2.1. Measurement framework

Finding the best possible method of measurement of innovation performance in the European Union and its evaluation is a difficult task (Hubbard, 2010). The difficulty follows from the very essence of the subject of the measurement. By definition innovation is a qualitative change. Hence every innovation should be different1. But anything can be measured. If a thing can be observed in any way at all, it lends itself to some type of measurement method. No matter how “fuzzy” the measurement is, it´s still a measurement if it tells you more than you knew before. And those very things most likely to be seen as immeasurable are, virtually always, solved by relatively simple measurement methods

Construction of indicators of innovation performance is inevitably preceded by development of a schematic model of innovation – a conceptual framework. Statistical measurement of the individual indicators within the conceptual framework requires the monitored phenomenon to show similarity of observations in different environments and contexts. Otherwise quantitative comparison and aggregation are not possible. Indicator values are mostly obtained from official statistics. The basic source is represented by EUROSTAT statistics and data obtained from innovation surveys of CIS (survey of Community innovations). Further data used are obtained from international organizations, such as OECD (Organization for Economic Cooperation and Development), UNCTAD (UN Conference for Trade and Development), FIBV (Global Federation of Stock Exchanges). Where official data are not available reliable private statistics are used.

One of the summary indicators allowing for clear and comprehensible comparison of country positions according to a set of selected factors and their development in time is the Summary innovation index – SII. The purpose of this index is to provide an easy-to-interpret tool for evaluation of multiple separate indicators for innovations and thus to obtain an

objective ranking of the evaluated countries (Exelová, 2007). The methodology of creation of this index is updated annually. Processing is based on the input-output analysis. The analysis is based on the assumption that the result will show in the context of examination of relations between sources (inputs) and performance of the innovation system (outputs). The input-output analysis was originally used for interdisciplinary balance on the national level with further applications developed later (Rabbova et. al, 2013). This analysis has for example been beneficial for measurement of economic impact on culture (Jindrová, 2010). The analysis uses matrix count, symmetrical input – output table with the relevant inputs which influence each other. The essence of the method is work with the Leontief inverse matrix.

$$L = (I-A)^{-1} \qquad (1)$$

L – Leontief inverse matrix, I – unit matrix of the same order as matrix A, A – coefficient matrix

The Summary innovation index 2014 summarizes the performance of a range of different indicators. There are 3 distinctive types of peak indicators – Enablers, Firm activities and Outputs and 8 innovation dimensions further divided to 25 detailed indicators (European Commission, 2014). The measurement framework is presented in Fig. 1.

2.2. Measurement of Innovations in the Czech Republic

The first common harmonized innovation research in the EU took place in 1993. The present statistical survey of innovations is governed by EU Commission Regulation no 995/2012 and is performed in all EU countries every 2 years with 3-year reference period. In the Czech Republic the first pilot survey was performed for the reference period 1999–2001.

The found data are used for mapping the innovation environment and innovation potential of enterprises in the individual EU Member States

Innovations of products and processes are crucial for the company and its competitiveness.

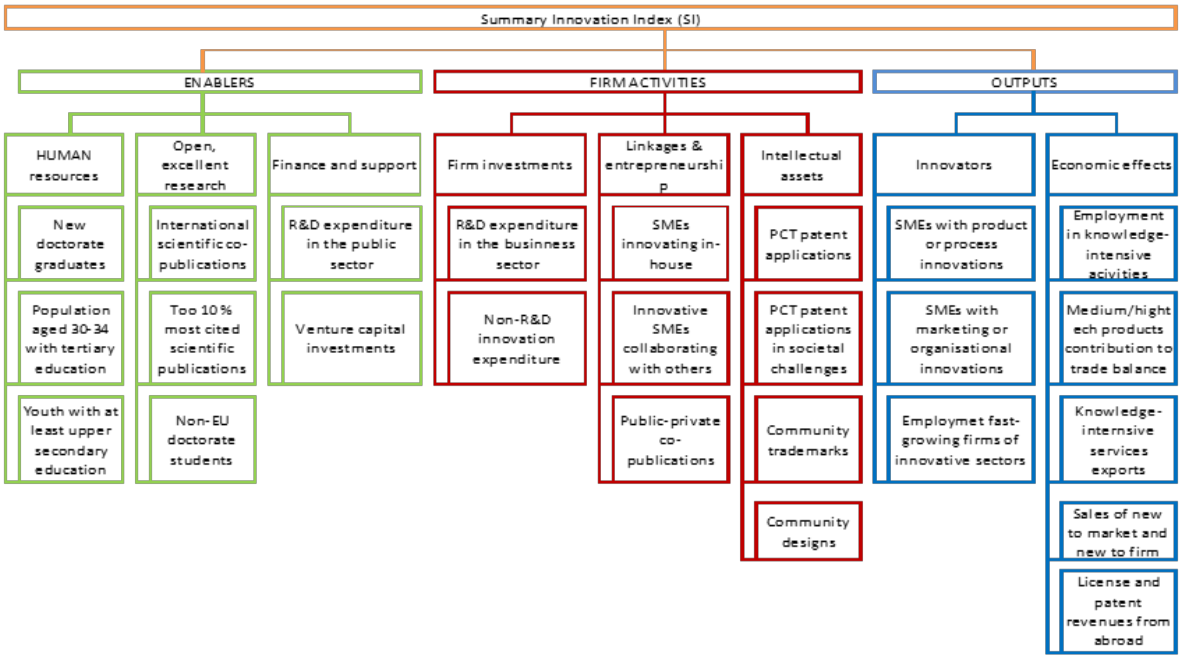

Fig. 1. Summary innovation index 2014 (European Commission, 2014)

Supportive function is performed by marketing and organizational innovations which enable finding new effective ways of promotion of new products and services and introduction of flexible changes in corporate governance in reaction to new market trends and customer requirements (Český statistický úřad, 2015). Statistics of innovation activities of enterprises (innovation statistics) aims at mapping of the area of innovation activities from the decision of an enterprise to innovate, information sources and partners via the innovation itself (type of innovation) and related costs to economic benefits of the innovation deployment (revenues from the innovated production). The basic methodological material for innovation activity measurement is the Oslo Manual (OECD, 2005).

Product innovation means introduction of goods of services which are new or significantly improved with regard to their characteristics or intended use. The term "product" is used for both goods and services. Product innovation mean both introduction of new goods and services and significant improvements in functional or user characteristics of existing goods and services (Český statistický úřad, 2015) Measurements of product innovations in the Czech Republic is based on statistical data of the Czech Statistical Office.

3. Results

3.1. Innovation Performance of EU Member States

Performance of national innovation systems within EU is measured by the Summary Innovation Index. Innovation performance of EU Member States is shown by Fig. 2. The EU mean is around 0,54 and Czech republic around 0,45 (European Commission, 2014).

Member states are divided into four groups by their innovation performance:

- The first group, the Innovation Leaders, includes Member States with very good innovation performance exceeding the EU mean by more than 20%. They are Denmark, Finland, Germany and Sweden
- The second group, the Innovation Followers, includes Member States close to the EU mean, i.e. less than 20% up or more than 90% of the EU mean. Innovation Followers are Austria, Belgium, Cyprus, Estonia, France, Ireland, Luxembourg, the Netherlands, Slovenia and the United Kingdom.
- The third group, the Moderate Innovators, includes Member States with innovation performance lower than the EU mean, ranging between 50% and 90% of the EU mean. This group includes Croatia, the Czech Republic, Greece, Hungary, Italy, Latvia, Malta, Poland, Portugal, Slovakia and Spain.
- The fourth group, the Modest Innovators, includes Member States with innovation performance much lower than the EU mean, i.e. less than 50% of the EU mean. Bulgaria, Lithuania and Rumania are Modest Innovators(European Commission, 2014).

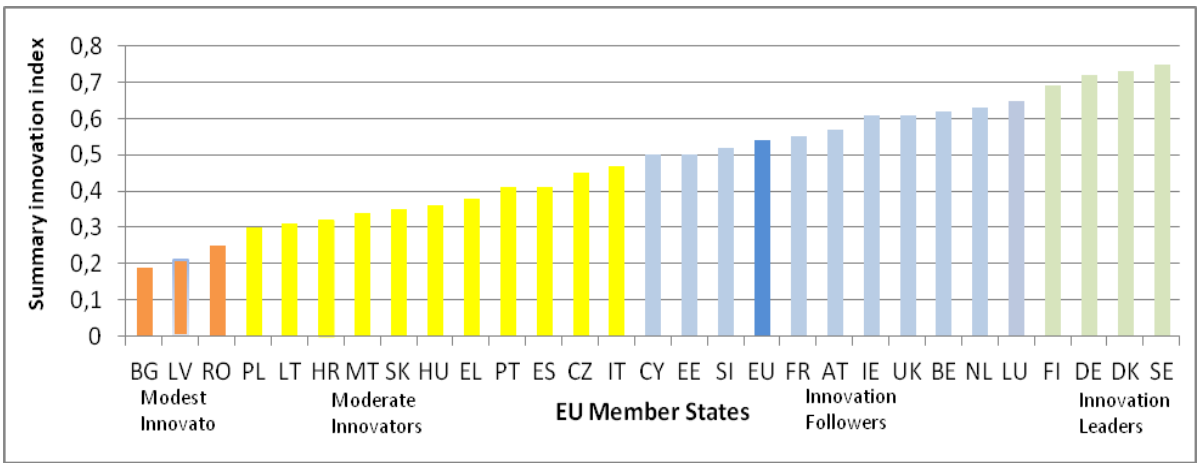

Fig. 2 Innovation performance of EU Member States in 2014 (European Commission, 2014)

3.2. Innovation Performance of Building Material Providers in CR

In the Czech Republic 468 companies processing building materials were addressed by the survey. The results of the survey by the Czech Statistical Office performed in the years 2010-2012 showed that almost half of the addressed enterprises were involved in an active innovation process Fig. 3(a).

Structure of innovation activities was investigated, including non-technological innovation (marketing and organisational) and technological innovation (product and process innovation) Fig. 3(b).

The following survey focused on companies with product innovations. The results of product innovation deployment were monitored.

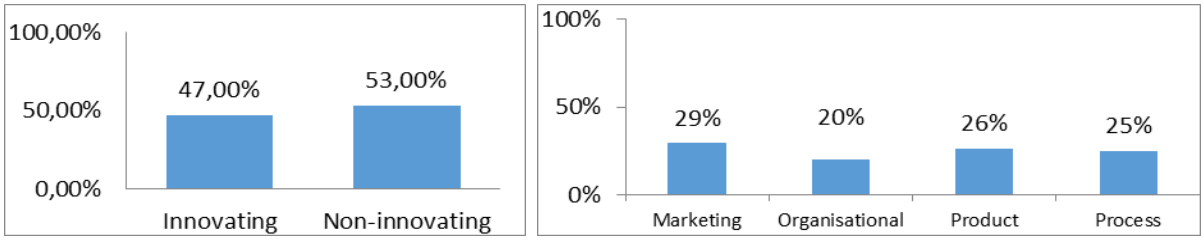

Fig. 3. (a) Classification of enterprises: innovating and non-innovating; (b) Companies by innovation type

Inquiry about types of products introduced showed “Just innovated service” as the lowest category (5%) Fig.4(a).

At the same time revenues from innovated products were investigated in innovating companies. The lowest revenues were found in the category of “Revenues from products new to market” (11%) Fig.4(b).

On the other hand, the revenue category of “Revenues from products unchanged or just slightly modified” showed a surprisingly high percentage, reaching 70%. This point to the fact that most revenues from innovations rather come from rationalisation measures than from higher orders of innovation.

Cooperation of building material providers with partners is shown by Fig. 5. Innovations by in-house sources appears to be most important, closely followed by cooperation with universities or research institutions.

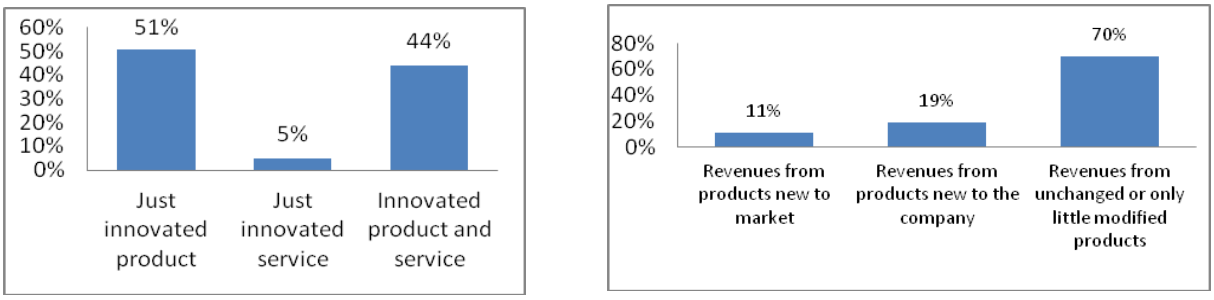

Fig. 4. (a) Introduction of technological/product innovations by innovating companies; (b) Revenues of innovating enterprises – revenue structure by product novelty

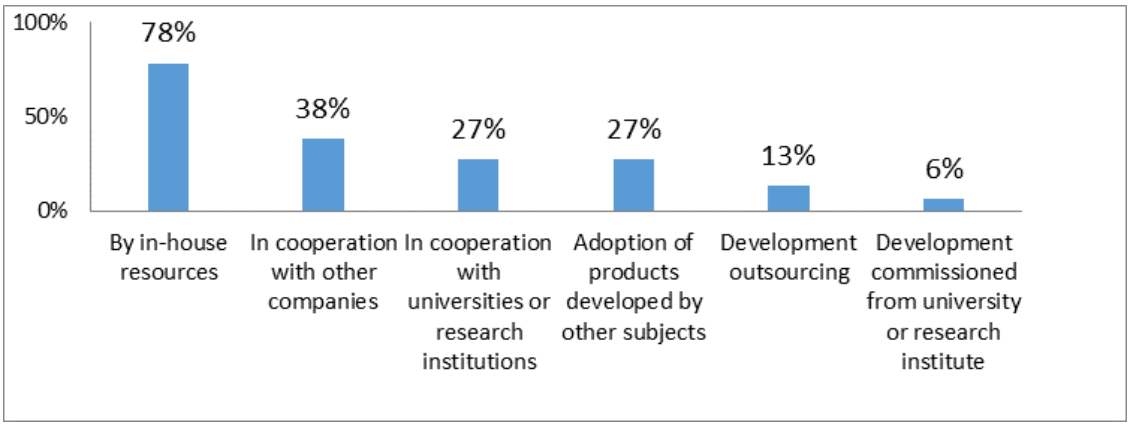

Fig. 5. Cooperation in development of innovated products by innovating companies

3.3. Innovation in cooperation chosen company and university

The selected company performed mapping of the process of product innovation. The following scheme shown in Fig. 6 reveals a relatively complex process from the idea to the product marketing. The diagram also shows possible ways of intellectual property right protection by patent, industrial and utility models. The scheme also shows that part of in-house innovations remain unregistered property right – business secret. The reason is concealing the essence of the innovation from potential competitors. In the case of cooperation with universities or research institutions the resulting innovations are mostly registered as patents or utility models. Publicity through articles published by the university in professional journals and conference presentations is also part of this cooperation. For product establishment on the market product marketing is also important together with activities of the sales department of the building material provider. This area represents another field of cooperation with universities and research institutions.

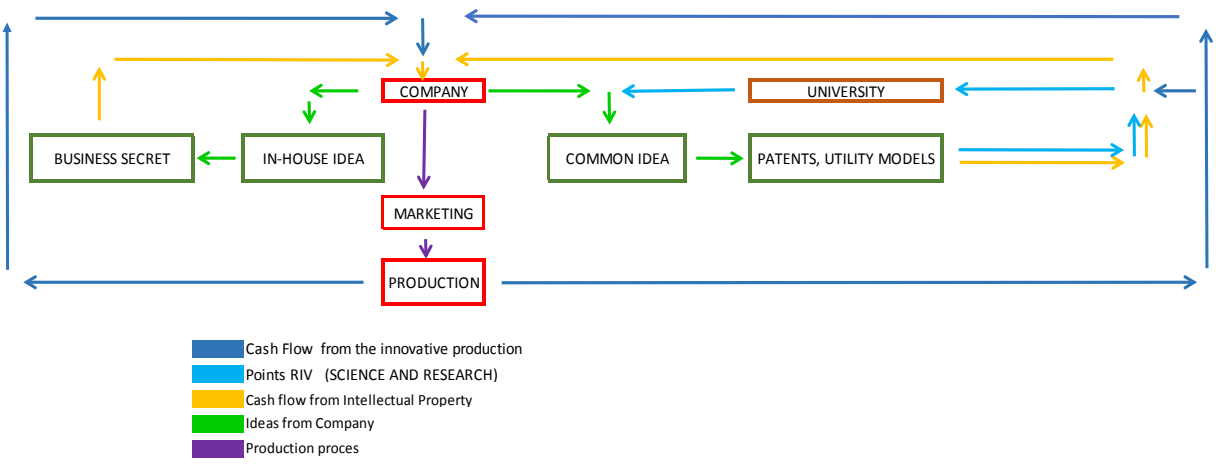

Fig. 6. Process from idea to product marketing

4. Conclusion

As is evident, Czech Republic still has major shortcomings compared with EU Summary Innovation Index. Research results in the previous chapter are evidence. Carried out research it was found that the enterprises surveyed in the chosen field mainly belonging to not innovating. Product innovations are relatively balanced with the other types of innovations in innovating companies. Balance is shown in the area of mere product innovation and product – service innovation mix. The greatest surprise is the fact that the companies generate most revenues from unchanged or just little modified products. Typically for the Czech Republic

building material processing companies mostly use in-house resources for innovation development. Extended cooperation with universities and research institutions is badly needed, to the benefit of both parties. In the Czech Republic came to an end innovation statistics in the construction according to the classification CZ-NACE (section F - Construction). Therefore, in the next period, the authors research and statistics in this area to deal with in their projects. Investigation of innovation potential in processing companies of glass, ceramics, porcelain and building materials is very closely connected with innovation monitoring in building companies. Inclusion of innovated building materials in building production is not specifically monitored by the Czech Statistical Office. The purpose of the project, including this study, is fondling out innovation potential of building companies active in the Czech Republic. A questionnaire-based inquiry will be organised by the Faculty of Civil Engineering of the Brno University of Technology. The results will be used for further orientation of the research and development focused on innovations and their evaluation by means of patents, utility models and other tangible results of intellectual property application.

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Facing the Issues of: Design, Construction and Management of Zagreb Airport Terminal - A Case Study

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Abstract

The project of new Zagreb Airport Terminal is currently the largest civil engineering undertaking in Croatia. Almost 66.000 m^2 of the Terminal will accommodate 5 million passengers per year, 3 times more than the current Terminal. The project started in 2008 when a competition was called upon by Zagreb City. In an international competition the winning design was chosen from a group of authors comprising two architects – Branko Kincl, Velimir Neidhardt, and one civil engineer – Jure Radić. This terminal design distinguished itself among competition in its integral multidimensional approach between the construction, form, urbanism, ecology and functionality. After some pause due to financial shortcomings, the project was again rebooted in 2012, when Croatian government signed a concessionary agreement with French company Bouygues and its local partners. Concessioner agreed to finance the whole project, including design, erection and service, in exchange for 30 years exploitation privileges. The main design started in 2012 according to the winning design. The main identity of the building is an architectural trademark which is achieved with an elegant double curvature fluid form of its roof. Management before and during erection encountered several risk situations that were dealt with without delays in work flow. Project management includes complex and strict flow and review of documentation, controlled on multiple levels. The erection of the Terminal started in late 2013. Until now all concrete structure has been finished, and roof steel truss is being assembled. The opening is scheduled for late 2016.

Keywords: Airport Terminal; concessionary agreement; architecture; steel space truss; prestressed concrete slabs

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1. Realization of the project

1.1. History of the existing Airport

Today's Zagreb Airport was first built during World War II to serve as a military airport and it retained that function until 1959 when it was opened for civil traffic. The fastest growth in traffic was recorded from1960 – to 1980 with an annual traffic increase of more than 70%. To accommodate for this growth, several reconstructions were conducted in 1966, 1974 and 1984. In 1966 new 5.000 m^2 extension to the terminal was built, and in 1974 and 1984 additional extensions were added to increase the total airport area to about 15.000 m^2, which remains unchanged to this day. In addition to the passenger terminal extensions, in 1984 a new cargo terminal with an area of 2.200 m^2 was also built, and the runway was reconstructed and prolonged to 3.250 m, along with the erection of some other supporting facilities. In 1990, when Croatia became independent country, Zagreb Airport consequently became a capital city and national airport.

Use of the existing airport shows that in passenger traffic mostly international flights prevail, of which most passengers are local passengers (80%), followed by transfer passengers (20%). The capacity of the existing passenger terminal of about 1.5 million annual passengers was already reached in 2005, and in 2007 the recorded peak was 1,992 million passengers. It is without a doubt that present situation does not permit further optimum development of traffic capacities. Therefore, it was imperative to take action in order to prevent stagnation in traffic capacities and to increase the level of the airport's technical capability and services.

1.2. New Terminal – from competition to concession

Soon after analysis for the future traffic increase concluded that the most viable solution is to build a new Terminal, a new location was chosen due to shortcomings of the existing one, just northeast from it. The new location allows for longer runaway and better layout plan, so the terminal building and other facilities can comply with all new safety regulations in respect to minimal distances and infrastructure needs. Also, a different location ensures the usage of the existing airport during construction and ultimately its repurposing for either military or recreational/sport/exhibition use (still to be decided).

Following the decision for a new terminal building, an international competition was called upon in summer 2008. Total of 17 respectable authors responded from all over the world. First prize was awarded by international panel of judges to the project by Branko Kincl, Velimir Neidhardt and Jure Radic (Figure 1). Second prize was awarded to the project by Shigeru Ban and Taro Okabe (Figure 2a), and the third prize to the project by Norman Foster (Figure 2b).

Fig. 1. International competition (2008) winning design by Branko Kincl, Velimir Neidhardt and Jure Radic

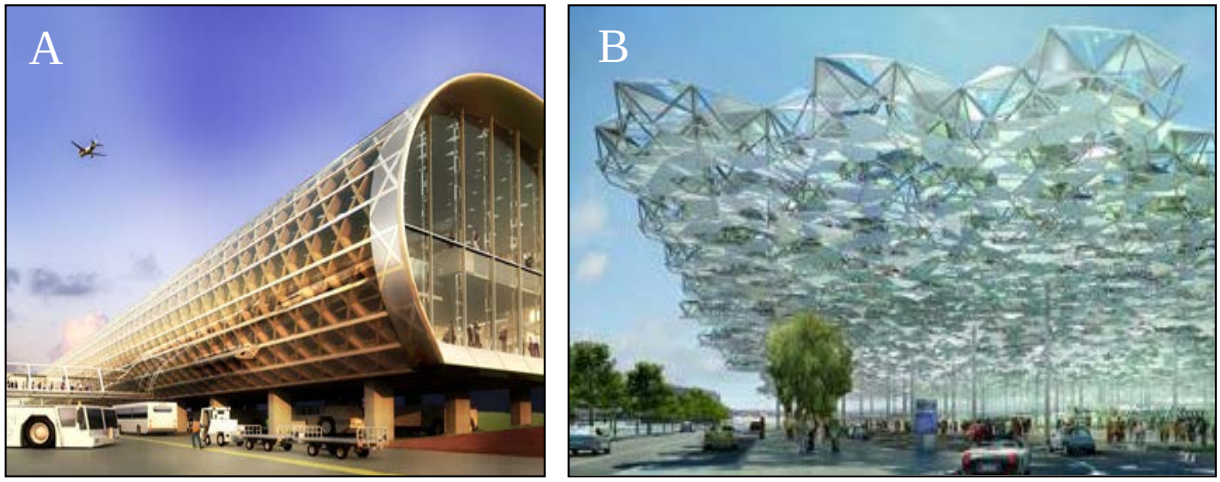

Fig. 2. (a) International competition (2008) second prize won by Shigeru Ban and Taro Okabe (2008);
(b) International competition (2008) third prize won by Norman Foster (2008)

An international competition jury expressly stated that the winning work was distinguished among others, because of the excellent functionality in relation to the handling of baggage and the flow of goods and passengers, but also due to favorable proportions of the central building suitable for future modular expansion and for passenger traffic of up to 10 million passengers per year. It was pointed out that the winning design shows the best balance of spatial and structural terms and is efficient in relation to energy conservation and environment. They were especially impressed that the entire roof structure is reminiscent of the developed flag

enveloping interior and floating above the terminal thus creating the illusion of a floating roof as an expressive location trademark. More than once it was noted that the design shows great architecture which is technologically developed throughout many details, and that the project is capable of becoming a true world terminal airport in the architectural, functional and technological terms, and that architectural expression offers the promise of building of the highest international reputation and to be the entrance to Croatia as a country at the highest cultural and technological level.

Due to economic crisis, funding for the continuation of the project was not found, and further work on the project was postponed. However, in 2010 it was decided that the new airport terminal will be built according to the model of concession. In spring 2011, the Ministry of the Sea, Transport and Infrastructure announced the competition, and offers were opened by the end of the year. Only two bids arrived, one of the consortium that constituted the Airport Zurich and Strabag AG, and the other by the ZAIC (Zagreb Airport International Company) which was constituted by French company Bouygues and some local partners. The first offer was not considered because it was incomplete. ZAIC offered a fee of about 88 million euros for a 30 year concession period, plus part of the concession fee calculated as a percentage of gross air traffic. This offer was accepted by the tender commission and approved by the newly formed Croatian government. In late February 2012 it was decided to entrust concession to ZAIC, founded by Bouygues Batiment International (BBI) and Aéroports de Paris Management. The contract was signed on 11th April 2012.

Concession contract was transferred on September 28th 2012 from ZAIC to the newly founded company International Airport Zagreb (MZLZ – Međunarodna Zračna Luka Zagreb) which was founded by Aéroports de Paris Management (a company owned by Aéroports de Paris), BBI (a company owned by Bouygues Construction), TAV Airports from Istanbul, Viaduct Inc., Marguerite Fund (European Fund for Energy, Climate Change and Infrastructure) based in Luxembourg and the IFC (International Finance Corporation, part of the World Bank). 20,77% of the ownership of the company MZLZ is held by Aéroports de Paris Management, BBI and Marguerite Fund, 17,58% by IFC, 15% by TAV Airports, and 5,11% by Viaduct Inc. MZLZ and the Government on two occasions signed amendments to the concession agreement (30 July and 2 December 2013), and the company has also signed agreements on financing. The investment is financed from two sources – two thirds from the loan, and one third from the shareholders of the consortium in accordance with their ownership percentages. Loan creditors for the project are European Investment Bank (EIB), IFC, Unicredit Bank Austria and Deutsche Bank (Vrančić & Nadilo, 2015).

With the finalization of this financial and legal agreement, MZLZ became the official manager of Zagreb Airport for the next 30 years and the transfer of ownership was conducted on December 5th 2013. The concession contract includes financing, design and erection of a new passenger terminal in the surface of about 66.000 m2, and the management of the existing airport (including the runway and current passenger terminal) during construction, cargo and a new passenger terminal when completed, together with parking and other infrastructure that will be built. Responsible for operation and maintenance of the airport are Aéroports de Paris Management and TAV Airports, which already together manage more than 33 airports in the world (Vrančić & Nadilo, 2015).

Construction works were planned to last for three years and will be performed by company BBI, which already built three new passenger terminal buildings according to same concession model. The construction of a new passenger terminal (NPT) will employ from 700 to 800 workers, and special attention will be devoted to sustainable construction because the project seeks to ensure LEED certification for green building. Completion of works is scheduled for Christmas 2016, when the new passenger terminal will be able to receive the annual traffic of 5 million passengers.

The company Zagreb Airport Ltd. remains active entity and its principal task is to provide expert and technical assistance to the Government in monitoring the implementation of the concession agreement, as well as asset management, which is not the subject of the concession.

It should also be is pointed out that it is very fortunate to have a French construction company Bouygues as the concessioner, since it is one of the largest in the world, and since

they have also been a concessionaire for Istrian Y highway. In the past, cooperation between this concessionaire and the Croatian authorities has proven to be very good, and also excellent experience in cooperation has been reported by Croatian contractor, design and consulting companies (Vrančić & Nadilo, 2015).

2. Multidisciplinary solutions between architecture, location and function

2.1. Location and traffic connections

Location of the new terminal is just north-east of the existing one. Its position has great benefits due to two major traffic routs from Zagreb city being intersected here – one coming from the Zagreb center through Bundek and Buzin area, and the other coming from Radnička road and Homeland bridge. This location is also on a future planned route of Zagreb rapid railway (metro) line. Location is outside of all major urban structures, but very near to city Velika Gorica. By directing traffic towards it, this terminal will facilitate the merger of the capital Zagreb and Velika Gorica, expanding their urban areas and efficiency. Through overall cumulative attraction and the complementary inter-function of the new airport and the city of Velika Gorica, both areas will acquire marks of the highest urban standards and gain national importance, potentially becoming the key performing factors for the urban efficiency of the metropolitan Zagreb.

The landside surroundings of the terminal building is divided in two parts, the east in-bounding side and the west out-bounding side, both with vehicle parking facilities (Figure 3). Spatial organization allows the dominance of the pedestrian area in the middle of the landside complex. It is oriented along its axis towards the entrance facade of the terminal building. Such a pedestrian oasis with the variety of urban amenities functionally connects the front of the terminal with both eastern and western side of vehicle parking area, and finally reaches south towards the potential development of Airport city. Green landscaping is present all around the building and is then further reiterated within the terminal, involving the greenery modular units as elements of the architectural interior. Traffic solution is multidimensional with discrete arriving and departing flows, starting with the aerobridges entrances/exits and leading all the way to nearby approach roads connected by roundabouts on each side.

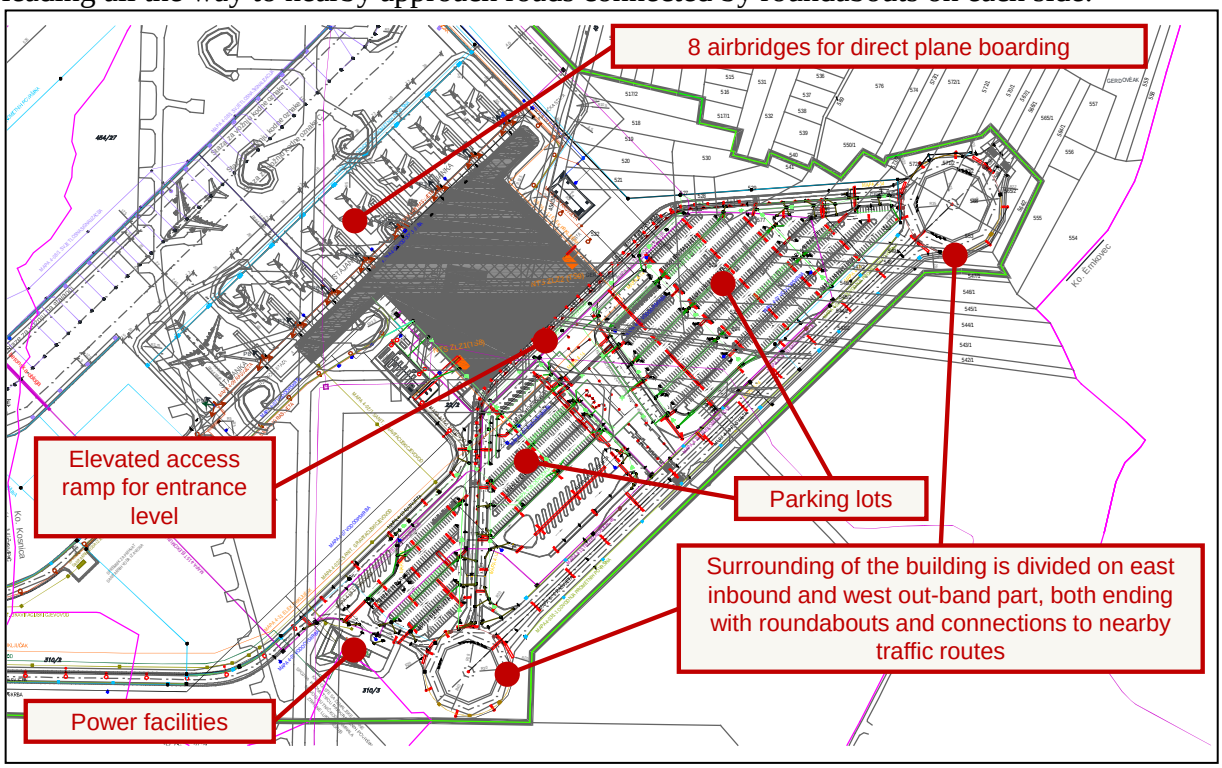

Fig. 3. Surrounding area and traffic connections

2.2. Architectural and structural form

The dominant architectural form of the terminal serves both its functionality and its desired landmark signature. Main structural form is presented by a wavy roof, which levitates in a form of wind carried banner over the main building. This roof calmly transcends in an airside facade which then fluidly continues in two pier structures for aircraft docking purposes. The whole terminal resembles an extended flagpole displaying the combination of the long linear inductive pole structure, softly wrapped in a dynamic envelope, which unwraps itself to levitate above the terminal hall generating the free dynamics of the flying roof – an iconic expression of the landscape. Such spatial harmony is apparent inside the terminal from a series of different, function generated aesthetic attractions. The levitating roof envelope allows for the maximum exposure of the hall interior and the widest possible panoramic orientation towards both Zagreb and its mountain, and the dynamic development on the approach side of the new airport terminal. Main building roof is variable in height ranging from minimum 20 m in the lowest part (near the building entrance) to maximum 34 m at the middle near the airstrip side. It extends as a 10 m console from the floor pan view. This console further emphasizes the waviness and levitation of the roof. Pier roof height is also variable following the descending form of the main building roof. The longer left pier height rises at its middle. Pier roof is a vault with circular cross section, so with the change of its height it also changes horizontally. This causes a variable width of pier upper floor at level +10.2 m and a curvy edge of concrete slab at that level. Therefore, the width of the floors in the pier area varies from 16.2 m to 17.4 m.

2.3. Functional integrity of the terminal

The basic design principles deal with the overall rationality - with unambiguous distribution of functions and with clear, spatial focal points - all designed to fulfil a perfect passenger orientation pattern. It allows the adaptability towards the developing or changeable needs and in the end to the optimal functional performance of the terminal. Main division of space and thus construction is achieved horizontally (plan view – Figure 4) and vertically (cross section – Figure 5). In plan view structure is divided in three dilatations – main building area and two linear pier structures. Main building hosts all main operational facilities and services, while piers provide the necessary area and access for airplane docking and passenger boarding. These functionally different parts are also structurally divided with dilatations in concrete floors and roof steel space truss. Vertically the structure comprises 4 levels: ground level (+0.0), and three floors (+5.4, +10.2, +15.0 m). Each level has a distinct function: arriving level (ground level), transfer level (+5.4 m), departure level (+10.2 m) and departure gallery (+15.0 m). They are connected by stairways and escalators which are enclosed with walls that serve as main seismic shear walls.

The pier design allows for the flexibility that is necessary to sustain the expected increase of air traffic in the future by linear prolongation of piers or through the possible addition of air bridges to the south-west pier to allow double side pier function.

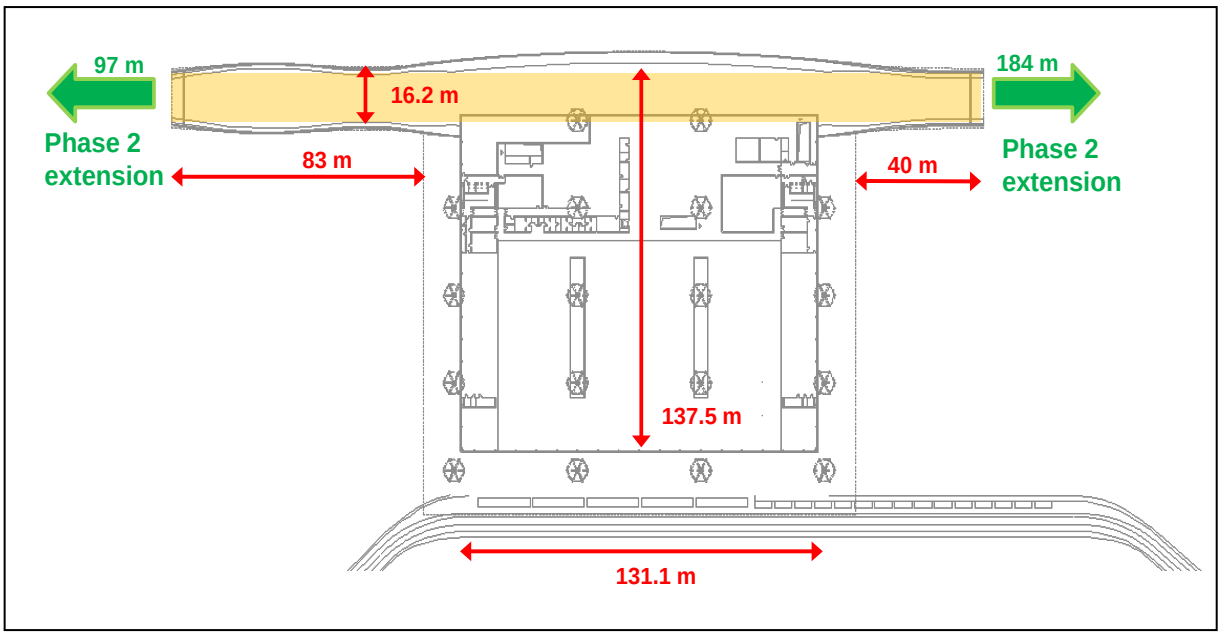

Fig. 4. Plan view of the main building and piers

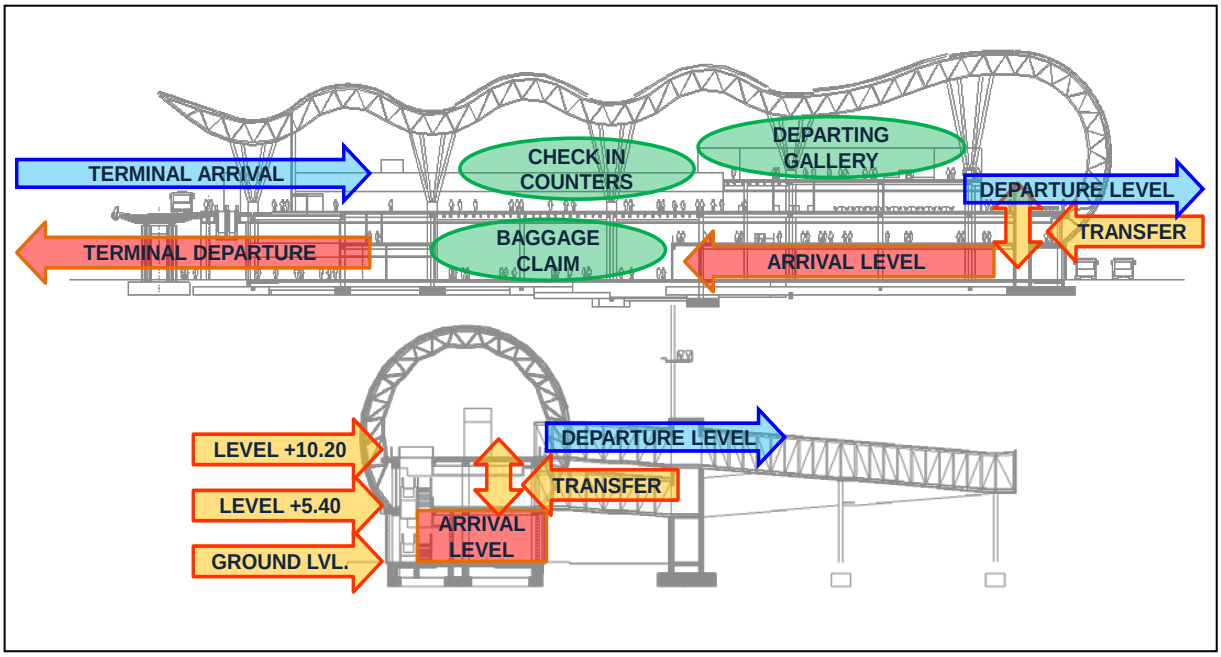

Fig. 5. Functional plan over the terminal cross section

3. Main design

3.1. Changes from the competition design

Construction design from the winning design was somewhat changed (Kincl et al, 2013) at the request from the Concessioner in order to optimize the cost of the project (Table 1). But, the Authors of the winning design had to approve each of these changes. One of the biggest compromises that had to be made was to abandon the basement level of the building. Consequently the total area of the building is smaller, but modular construction is adopted in order to later allow for the extension of the piers with the increase of the traffic. Other more notable change was the adoption of the roof steel space truss instead of the three-directional plane truss, but triangular grid was kept. The form of the roof, which is the main trademark of

this project, was not to be changed, only tweaked in order to comply with roofing allowed radiuses and manufacturing.

Table 1. Differences between competition and main design

	Competition winning design	Main design (as being built)
Passengers / year	**from 5 million (phase 1) up to 8 million (phase 2)**	
Layout area (Main building)	155 x 165 m	**129.6 x 136.8 m**
Pier lenghts	353 m (left), 151 m (right)	**83 m (left), 40 m (right)**
Gross construction area	73.320 m^2	**65.883 m^2**
Number of Levels	Basement, 0, 1-4	**0, 1-3**
Concrete construction	Monolithic RC	**Monolithic RC, Prestressed**
Steel roof construction	Three-directional plane truss	**Triangular grid space truss**
Cost	280 – 300 mil €	**236 mil €**

Terminal will be built in two stages, comprising different length of the side piers for different number of airplane docking bridges. First, shorter piers (Figure 6) will be built to allow an annual capacity of up to 5 million passengers. After this capacity is reached, second phase will be undertaken to lengthen the piers and extend the capacity to 8 million annual passengers. Preliminary design for the terminal was finished in summer 2012 and location permit was issued. In summer 2013 main design was finished and building permit issued. Building preparation and excavation work started late 2013. The terminal will be finished and open for traffic in late 2016.

Fig. 6. New Zagreb airport terminal visualization according to the Main Design (as being built)

3.2. Foundations and concrete construction

Main building foundations comprise 3 different types, depending on their location and the construction above. Main foundation blocks are under 4 seismic concrete cores near the corners of the main building and partly under the seismic shear walls. Strip foundations are laid under 3 facade lines and in-between the concrete cores connecting them. All shear walls are founded on strip foundations. And finally, independent columns are founded on foundation foots which only take vertical load. Pier foundations comprise foundation strips in three main axes distanced 7.2 m and foundation slabs under elevator concrete cores. All fore mentioned foundation types are interconnected by concrete beams and 15 cm (pier) or 20 cm (main building) thick concrete slabs of the ground floor.

Floor structures of level 1 and level 2 of the main building are 18 to 25 cm thick prestressed slabs stiffened by shallow beams 160/55 cm or 300/55 cm. In the front airside of the building the slabs are 55 cm thick to allow instalment of steel anchors for supports of the roof space truss construction.

Vertical concrete structure of the main building is mixed from columns and shear walls. Concrete floors of the main building are supported by columns on 7.2 x 14.4 m grid in the central part of the main hall (that has a height of two floors), and 7.2 x 7.2 m grid in the side parts of the main hall near the core walls. Columns are rectangular (sections 60/60 cm – 70/70 cm) and circular (D = 70 or 80 cm). Supports for steel roof structure are circular concrete pedestals 170 cm in diameter. Elements for horizontal bracing (antiseismic) are shear walls of the four corner cores that are partly continued longitudinally and transversally to the middle of the building. Concrete structure of the pier is a two levels high frame consisting of edge 40 cm high beams and columns spaced at 7.2 m. There are 3 longitudinal frames (edges of the pier and middle of the pier) and cross frames every 7.2 m. Two floor structures of the piers are 22 and 25 cm thick reinforced concrete slabs. On the edges, slabs are continued to 40 cm thick cantilevers overhanging from the side frames for anchorages of the space truss roof vault (Radic & Vlasic, 2014).

Table 2. Concrete construction elements

	Element	Type	Size / thickness	Spans
MAIN BUILDING	Vertical elements	**ANTISEISMIC:** Concrete cores Shear walls Columns	 20, 25, 30, 40 i 50 cm 60/60 - 70/70 cm Φ70, Φ80 cm	
	Floor slabs	Prestressed concrete monolithic slabs with wide and shallow beams	**1st floor slab:** Beam 160/55 cm Slab 18cm **2nd and 3rd floor slab:** Beam 300/55 cm Slab 25cm	7.2 x 14.4 m 14.4 x 14.4 m
PIERS	Frames	**ANTISEISMIC:** 3 RC frames longitudinally Transversal RC frames every 7.2 m Shear walls	Columns Φ70 **1st floor:** Edge Beam 70/80 cm **2nd floor:** Edge Beam 70/70 cm 50 cm	7.2 m
	Floor slabs	RC monolithic slabs	**1st floor slab:** Slab 22cm **2nd floor slab:** Slab 25cm	7.2 x 14.4 m

3.3. Steel space truss roof construction

The roof structure of the main building is a steel space truss structure. The basic plan-view disposition of the main building comprises triangular grid shapes with each triangle having the base of 3.6 m and the height of 3.6 m. These triangles define the axes of the chord truss members. The grid of the bottom chord is displaced 1.8 m longitudinally and 1.2 m transversely in respect to the top chord. The top and bottom chord are joined together with diagonal members. The basic plan layout of the pier space truss is ≈3.6 x 2.4 m. The layout of the roof structure of piers has been harmonized with the layout of the main building roof structure. The axial height of the space structure is 3.0 m in the main building area and 1.4 m

in the pier area. The transition between these heights is achieved gradually in the edge parts of the front truss of the main building.

Steel space truss is made of tubular circular members with connecting elements and spherical nodes with threaded holes. A conical element, with a bolt that is fastened with a sleeve, is welded at the end of each round pipe member. Members are assembled by connecting them with bolts onto spherical nodes. Truss pipe members vary from Ø76.1x2.9 mm to Ø219.1x20 mm depending on the position in the truss, and the compression or tension force. Total number of the truss members is 25.780! The main building roof structure is supported by 18 columns, with the span layout of 43.2 x 28.8 m. Columns are shaped as branched inverted cones and each of them comprises six members. Column members are made of round pipe sections Ø406x16 mm. Columns are supported, via reinforced-concrete pedestals, by the bottom reinforced-concrete structure at the levels +10.20 m and +15.00 m. Near the connection of the building and the pier, columns are omitted and the roof is supported by truss walls which continue into the pier structure. The roof structure of piers is supported on both sides by the bottom reinforced-concrete structure at the levels of +10.20 m (inner chord) and +5.40 m (outer chord). Since the tubular arch sections of the piers and the front of the main building are variable in height, the anchoring line of the inner chord is wavy following the change of arch height. The roofing of the structure is made of the trapezoidal steel sheeting with thermal insulation. The difference between the polygonal approximation of the space truss and the real curved shape of the roofing is bridged by curved roofing beams every 2 m (Radic & Vlasic, 2014).

Fig. 7. Roof steel space truss during assembly

4. Project participants organization structure

Figure 8 shows a hierarchy of all the participants behind the project of new Zagreb terminal. Along them there are also many subcontractors, reviewers and design teams involved. The main designer, prof. Branko Kincl, and his office, are responsible for all coordination between Design teams, Contractor and Client-Concessionaire.

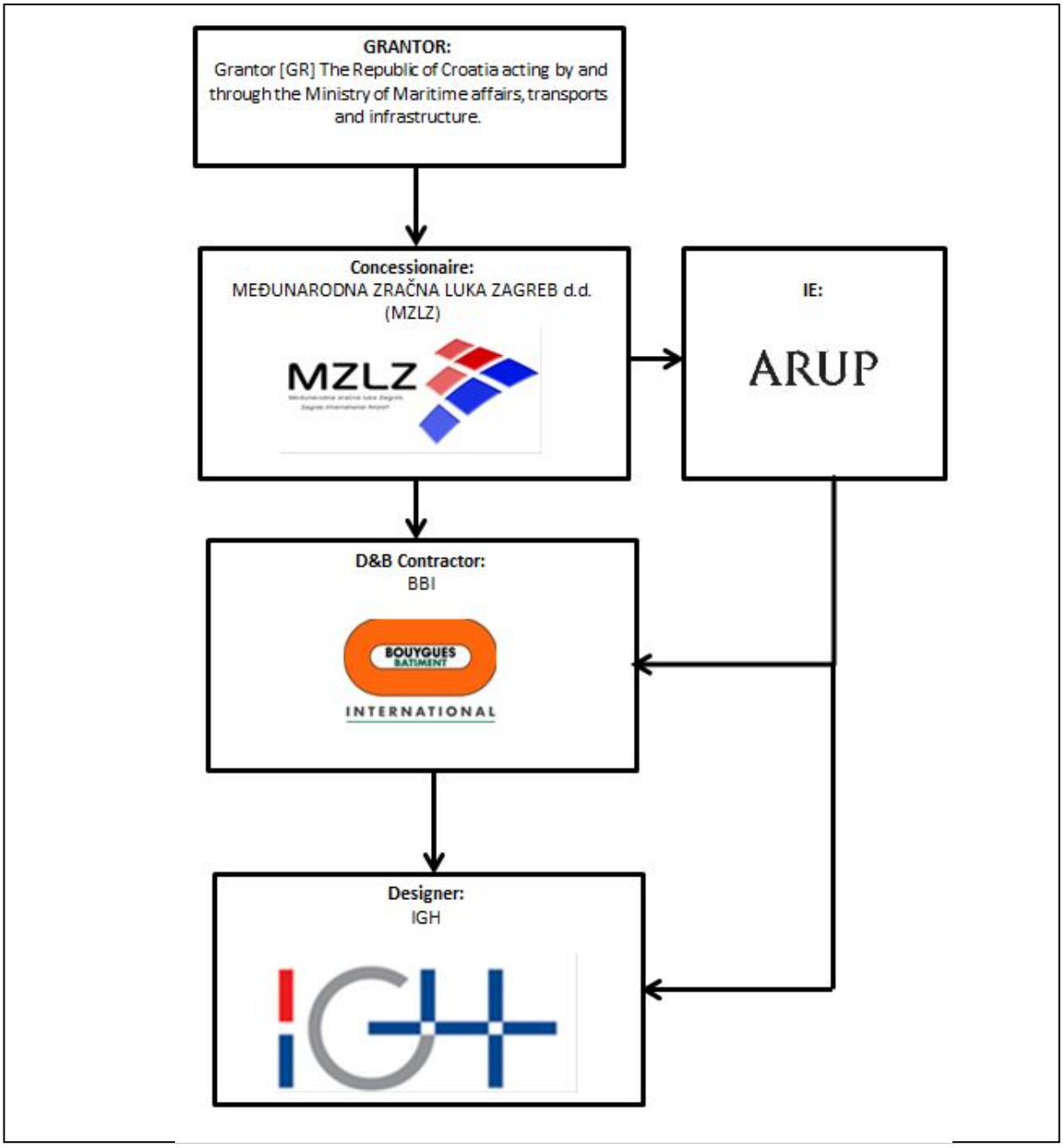

Fig. 8. Design organization structure

5. Risk management

During the design and construction of the new terminal building, three key events can be recognized in the risk management. Two of these events were decisions made by the Concessioner (medium level impact risk), and one was the withdrawal of the major Contractor (high level impact risk).

5.1. Medium level impact risk

First medium level risk event was when the Concessioner decided to alter the main concrete construction design in October 2014. Instead of Precast RC construction, new, monolithic post – tensioned RC construction was chosen. New concrete construction design had to be made,

along with changes in architectural project and obtaining a new positive review for the project. Also, new Building Permit had to be obtained.

Second medium level risk event was when the Concessioners decided to change the beginning of construction works to middle of April instead of July 2014 as it was originally planned. Design plans for RC construction were scheduled to start in January, so the reorganization of workflow and resources was required. Due to shifting deadlines, formwork and reinforcement design plans were created simultaneously, causing additional risks in workflow of construction works on the site. Also, new designs for installations were made after reinforcement plans, causing additional changes in the formwork design. Review of time schedule was proposed by IGH in order to maintain the workflow on construction site. IGH scheduled additional meetings of design team in order to track and monitor delivery of reinforcement plans on construction site. Review of reinforcement designs was made in order to conform to new designs for installation openings. Additional engineers were assigned on the project (14 engineers instead of 6-10 originally planned) during the critical time period from June to August 2014, working hours were prolonged and 6 day week introduced (Figure 9).

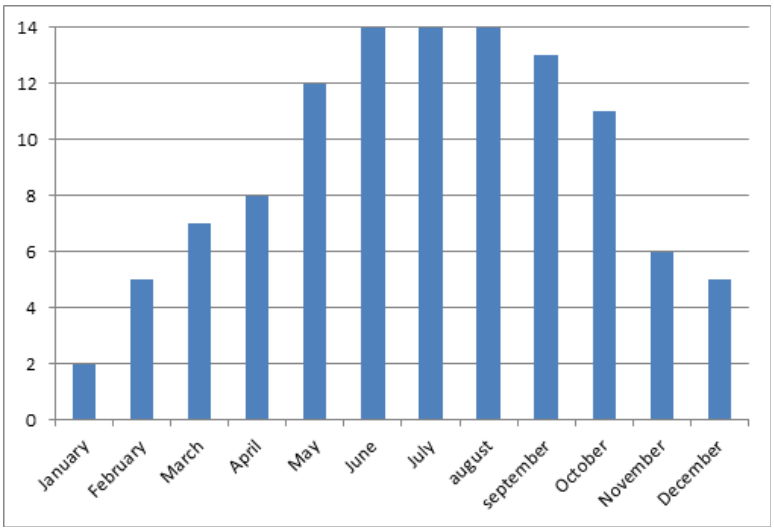

Fig. 9. Number of IGH design team members employed during 2014

5.2. High level impact risk

A major high level impact risk was recognized when the Contractor for roof steel space truss abandoned the project in September 2014, at which time the erection was well under way. As a result, main design for the steel roof had to be completely changed to comply with new construction technology and reviewed by state approved reviewer in order to apply for the change of the building permit.

A reaction to this high level risk input was a quick foundation of a Croatian Contractors Cluster for the new design and manufacturing of steel roof construction. Design was managed by IGH, which made the new design in a record time. Change of building permit was applied for in October 2014 and approved in December 2014. Parallel to this, detailed design and workshop drawings for the roof truss were being made. Therefore, the risk of delay because of the change in the building permit was minimized and the dynamic plan for the construction site was not affected.

6. Flow and control of project documentation

6.1. Documentation management system

Documentation management and exchange of information (drawings, workshop documents, calculations, reports, technical specifications, equipment specifications, material and equipment deliveries, samples, changes in the design, correspondence...) is handled through ACONEX platform. This is a web site set up for this project specifically, whose purpose is to simplify the cooperation between project participants. The system is available for all those involved in the project. Designer IGH is responsible for upload of design documentation in both Croatian and English language, which is then reviewed online and marked with a certain status – "approved", "rejected" or "commented" by the independent engineer (IE), BBI or MZLZ. This system enables access to information, upload of documents and commentaries. All documents are reviewed online before downloading, which allows for corrections before printing and hard-copy distribution on construction site. The total number of revisions is thusly reduced.

6.2. Documentation identification

All design drawings, workshop drawings, calculation notes, method statements, specifications, purchasing technical specifications, samples, project generated quality records and other documents are identified by numerical codes according to Figure 10 throughout the project. Every document is identified as a unique document by this identification number. At least one of the codes on the numbering structure must be different from one another to avoid duplication.

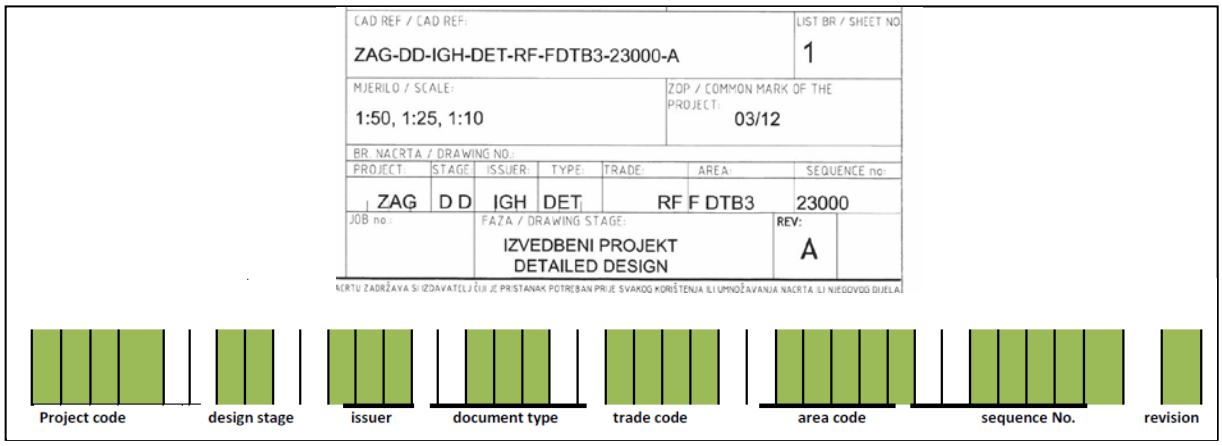

Fig. 10. Code structure for identification of the documentation

6.3. Documentation flow

There are two stages of reviews for design documentation and 7 steps (Figure 11) which must be followed in order for the document to be approved.

Stage one is the internal review of the document between all parties involved in the design (BBI, IGH, VIA, consultants, cooperators). Stage two is external review by Grantor, MZLZ and an independent engineer (IE).

Steps to be followed are:

- Step 1: Review of the project Authors (IGH) and distribution to the Client BBI for review
- Step 2: BBI coordinator reviews the document and approves it as technically correct in accordance with contract demands. At this stage correspondence can be done by email.
- Step 3: After the approval by coordinator, document is formally delivered to BBI's department for documentation management (by invoice mail)

- Step 4: BBI's department for documentation management (DM) reviews the document, issues a dispatch note and instructions for internal documentation control.
- Step 5: Persons responsible for review of the documentation are divided by their professions and structure parts. They review the document and return it with commentary to DM who then decides whether to keep the document or forward it to MZLZ
- Step 6: MZLZ and an independent engineer review the document and return it to BBI with status "approved" (status A), "approved with commentary" (status B) or "rejected" (status C)
- BBI DM analyses the response from MZLZ and decides upon further actions – whether to revise the document or to deal with the comments on construction site.

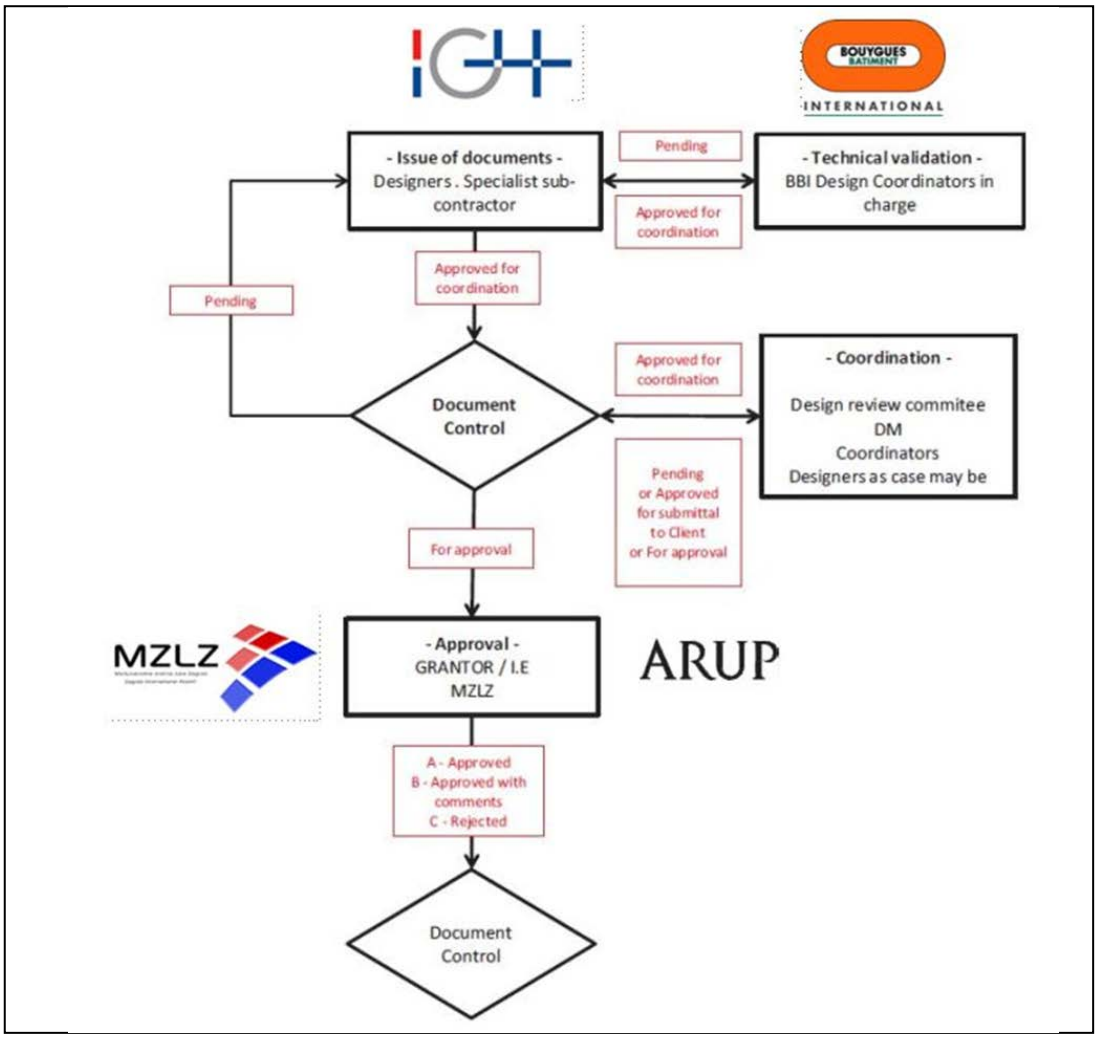

Fig. 11. Control and flow of documentation

7. Conclusion

New Zagreb airport terminal is the most ambitious and important project being built in Croatia in the last decade. It is also the most challenging one – engineering, financial and management wise. A complex structure of almost 66.000 m^2 area is being erected in record time, with very little setbacks, due to intelligent and prompt risk management derived from strict organization hierarchy imposed by Concessionaire/Client. All design and construction work is being done by Croatian engineers and Contractor companies. When finished (Figure 12) in late 2016, new terminal will be able to host 5 million passengers per year and up to 8

million with additional extensions already planned. It will be a perfect example of state-of-the-art architectural and structural design, impeccable management and flawless erection.

Fig. 12. Visualization of the finished terminal (night view of the front main entrance)

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Looking at the Stakeholders in Megaproject Through Sustainability Lens – Zagreb on Sava Case Study

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Abstract

One of the major challenges in their management is the involvement of a lot of stakeholders leading to complex stakeholder interrelationships and conflicting interests. The aim of this paper is to portray the stakeholder analysis on Sava River megaproject case study using the sustainability impact. The paper begins by reviewing the literature concerning stakeholder analysis in projects. It then explains the methodology for stakeholder analysis within COST Action: Megaproject, Working group Managing External Stakeholders aiming to provide the mechanism how stakeholders influence impact megaproject performance. In order to succeed, the framework goes beyond the "iron-triangle" treating it as "side effect", introducing sustainability issues as important aspects of megaproject impact. The paper concludes with presenting results of stakeholder analysis using the proposed framework. The new analysis is proposed based on stakeholder efficiency using difference between interest and impact.

Kewords: megaproject, stakeholders, sustainability, impact

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1. Introduction

Megaprojects are huge project producing profound, widespread and highly impactive changes upon the context, community and environment in which they are placed. (Burcar Dunović et al, 2014) They are characterized by high technical, organizational and managerial complexity involving a huge number of stakeholders with different interests. Pau et al. (2013) adopted as a definition of megaproject "an important critical project", where importance and criticality depend on stakeholders, risk and governance issues.

The huge size and high complexity of mega projects bring about three major challenges in their management:

(1) the involvement of a lot of stakeholders leading to complex stakeholder interrelationships and conflicting interests;

(2) the dynamics and growing capacity leading to high project uncertainty and

(3) their governance by a multi-role administrative structure leading to high public attention and controversies (Mok et al, 2015).

By their very nature, megaprojects have networks of stakeholders that go far beyond those associated with smaller projects. Given the societal imperatives that drive the design and delivery of many megaprojects, the beneficial impact on stakeholders will frequently form part of the assessment of their success. In addition, stakeholders can also have the power to disrupt and even to terminate megaprojects. Stakeholder management, therefore, has a critical role in insuring megaproject success (Burcar Dunović et al, 2014).

This paper will discuss current approaches of stakeholder analysis and present case study using methodology for stakeholder analysis within COST Action: Megaproject, Working group Managing External Stakeholders aiming to provide the mechanism how stakeholders influence impact megaproject performance.

2. Project stakeholder analysis

The importance of identifying and managing key stakeholders has been widely recognized in literature (Olander, 2006), (Mitchell et al, 1997), generating in the last decades a significant amount of unique definitions (Littau et al, 2010). Stakeholders are any individual, group or organization who have a vested interest in the project. (Freeman (1984), Cleland (1985) and Olander (2007)).

Stakeholders are commonly assigned in literature a wide range of attributes including power, legitimacy, urgency (Mitchell et al, 1997), vested interest (Cleland, 1985), attitude, knowledge (McElroy & Mills, 2000) and proximity (Bourne & Walker, 2005). Stakeholders attributes are usually evaluated and analysed in two dimensions matrixes such as Power/Interest and Interest/Attitude.

Power, legitimacy, urgency framework (Mitchell et al, 1997) classify stakeholders in terms of whether or not they possess power to influence (P), legitimacy relative to other stakeholders (L), or an urgent claim on project management's attention (U). Label seven of the eight resulting combinations of attribute possession as a class of stakeholder as follows: 'dormant' (P only), 'discretionary' (L only), 'demanding' (U only), 'dominant' (P and L), 'dangerous' (P and U), 'dependent' (U and L), 'definitive' (P, L and U).

Power/interest matrix is the most common tool for stakeholder analysis. (Johnson et al, 2005) Stakeholders are categorized depending on their power to influence the project (high or low), and their level of interest in impressing their expectations on the organization's purpose and choice of strategies (high or low). The required relationship of project managers with a stakeholder characterized by the four possible combinations: for high interest, low power—'keep informed'; for low interest, low power—'minimal effort'; for high interest, high

power—'a key player'; and for low interest, high power—'keep satisfied'.
For the vested interest-impact index (Viii) (Bourne & Walker, 2005) 'Vested interest' level (V) and 'influence impact' level (i) are qualitatively assessed on a five-point scale between 'very high' (55) and 'very low' (51). A vested interest-impact index for a given stakeholder is then calculated as (v*i/25)K.
Olander (2007) introduced external stakeholder impact index which is a combination of vested interest-impact index Viii, the 'nature of the impact' via an attributes value (A) based on Mitchell et al. 's (1997) seven stakeholder classes (A5[P+L+U] where power P50.4 or 0, legitimacy L50.3 or 0, and urgency U50.3 or 0) and a 'position' value Pos (21.0, 20.5, 0, 0.5 or 1.0). Impact index for each stakeholder is calculated as the product of those three values (Viii*A*Pos) and stakeholder impact index for the overall project is sum of all calculated values for all stakeholders. Stakeholder management should ensure an increasing stakeholder impact index during the projects life-cycle (Olander, 2007).
It is considered here that stakeholders' impacts can be easily forecasted using power, interest and attitude, which are basis of more complete (Murray-Webster & Simon, 2006) Stakeholder Cube Model. The resulting framework consists in three rather than two dimensions and it is shown in Figure 1.

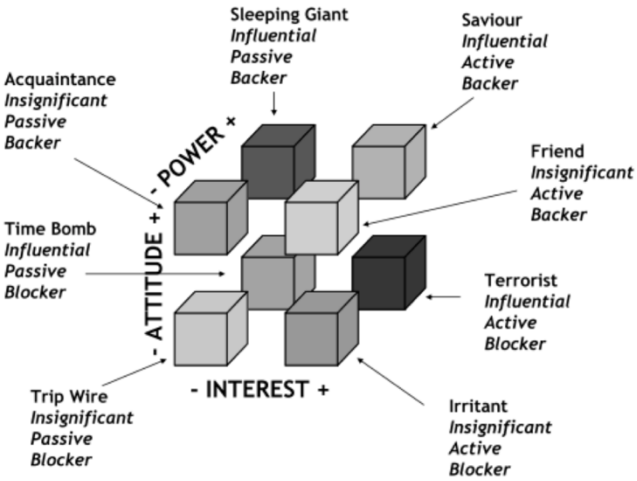

Figure 1: The Stakeholder Cube™ (Murray-Webster & Simon, 2006; Youker, 2014)

Power. This attribute is considered a key driver of stakeholder-management relationships and it is a property of social relations (Nguyen et al, 2009). Mitchell at al. (1997) define power as "*A relationship among social actors in which one social actor, A, can get another social actor, B, to do something that B would not have otherwise done*". Power is the mechanism through which stakeholders influence the direction and decisions for a project (Newcombe, 2003). Power is here simply defined as the ability to influence the project and should not be evaluated in absolute terms, but rather in relative terms depending on the project organization's power (Eesley & Lenox, 2006). Mitchell et al. (1997) identified three bases of power: coercive power using force or threats, utilitarian power based on materials and incentives and normative power based on symbolic influences.
Vested Interest. It may be defined as the willingness to engage to the project. Stakeholders may be interested in the project for many reasons such as mission relevancy, economic interest, legal right, political support, health and safety, lifestyle, opportunism and survival (Nguyen et al, 2009).
Attitude. Stakeholder's attitude refers to weather the stakeholder supports or opposes the

project (McElroy & Mills, 2000). Because each stakeholder may have a positive or a negative impact towards the project it is necessary to determine its attitude (Nguyen et al, 2009). A negative attitude to a project by stakeholders will cause conflicts and controversies that in turn will be reflected in cost and time overruns (Olander & Landin, 2005). According to McElroy and Mills (2000) stakeholder attitudes can be assessed in five levels: active opposition, passive opposition, no commitment, passive support and active support. The assessment of stakeholders' attitudes is particularly critical compared to other attributes because stakeholders may hide it or lie and most of the project managers, on the other side, are reluctant to describe attitudes, especially negative ones, as they are afraid that such an outline may be see by the "wrong" people, not only during the project but even in the long term (Jepsen & Eskerod, 2009).

Stakeholder management's objectives consist in understanding and predicting stakeholders behaviours, actions and devising strategies to be able to effectively deal with them and it consists in answering the following questions (De Lopez, 2001):
Who are project stakeholders?
What is the nature of their stakes in the project?
What type of behaviour can be expected from stakeholders?
What strategies should the project adopt to achieve its goals and deal with stakeholders?
In this paper the new approach to the stakeholders in megaproject is presented on the case study.

3. Description of the methodology

To understand the complete stakeholder behaviour, stakeholders should be evaluated by their characteristics, relationship and their impact on the project. Impact of megaprojects goes further from the "iron triangle", treating it as side effects while looking at sustainability issues of the project.
Stakeholder analysis was done according to the framework developed for research of megaprojects within COST Action: Megaprojects: The effective design and delivery of megaprojects in the European Union. (Figure 2) The framework is based on previously described The Stakeholder Cube^{TM} and 5P model of sustainability. The Stakeholder Cube^{TM} is used for assessing stakeholder's characteristics and impact on project is assessed using 5P model of sustainability.
5P model is derived from PRiSM™ (Projects integrating Sustainable Methods), the sustainability based project delivery method, which incorporates tangible tools and methods to manage the balance between finite resources, social responsibility, and delivering "green" project outcomes (Carboni et al, 2013). It was developed for organizations to integrate project processes with sustainability initiatives to achieve business objectives while decreasing negative environmental impact.
PRiSM is a structured project management methodology that highlights areas of sustainability and integrates them into the traditional core project phases which, when understood and effectively addressed, can reduce negative environmental impacts in all types of projects while maximizing opportunities to manage sustainability and finite resources. (Carboni et al, 2013) This concept takes further than 'triple bottom line" by adding two more aspects of sustainability: process and product. Product aspect is covering product sustainability, lifespan of product and servicing of product and process is about process sustainability, maturity of process and efficiency and fairness of process. These two elements are integrating internal and external sustainability in projects.
There is very strong support for stakeholders being involved in the development and appraisal of projects from an early stage. Engaging stakeholders does not mean that all their aspirations

can be met. (Centre, 2010) Project stakeholders, depending on how powerful they are and how interested they are will affect the project delivery. To understand stakeholders and their behaviour we need to observe their interest and impact on project.

Leaning on Green project management concept, this framework for stakeholder assessment aims to include all aspects of sustainability in stakeholder analysis. The 5P model enables to capture interest and impact together. Stakeholders by definition have interest in project. It is our proposition that their interest in megaproject must be measured using sustainability measures. Their impact, on the other hand, have broader spectrum, and for that we need 5P model.

5P model is suitable to separate internal and external impact of stakeholders. Internal impact is considered to be process and product and external are social, ecological and economical aspect of megaproject. To understand how stakeholders are influencing the megaproject we need to know how their actions were with respect to project and how their influence affected the project.

The first part is analysed through the first and second P (process and product), their interest is measured by "the triple bottom P's" and impact are measured with two sets of measures: the "iron triangle" (budget, time, scope) named as "side effects" and the "the triple bottom P's". When stakeholder interests were analysed, the hypothesis was made that each of them can have personal and/or global interest in project. This hypothesis is supported by Australian survey on infrastructure projects in which are identified two distinct ways in which the call of sustainability is heeded by the stakeholders:

- External Pressure (Global pressure, government requirement and business survival)
- Internal Volition (Human survival, community expectation and individual volition). (Lim & Yang, 2008)

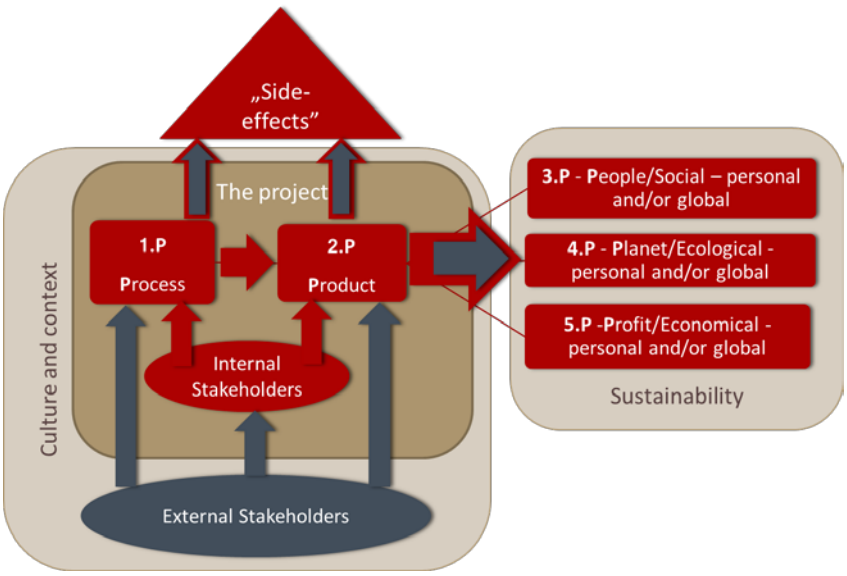

Figure 2: Stakeholder impacts on megaproject performance (Burcar Dunović et al, 2014)

The assessment was done in 6 steps by the project manager:

I. Identification of stakeholders: Identification of stakeholders important for the megaproject, it's role and type according to Gibson (2000) - external stakeholders being those affected by the project in a significant way, but not directly involved in execution of the project such as

internal.

II. Stakeholder assessment by rating: POWER (the ability to change the process): very high (5), high (4), medium (3), low (2), very low (1); GRADE OF INTEREST (willingness to engage): very high (5), high (4), medium (3), low (2), very low (1); ATTITUDE towards the project: totally negative -3, negative with some positive views (-2), negative with a lot of positive views (-1), positive with a lot of negative views (+1), positive with some negative views (+2), totally positive (+3)

III. Assessment of the type and rate the level of interactions/relationships between the stakeholders: cooperation (5), coopetition (4,3,2,1,0,-1,-2,-3,-4), competition (-5)

IV. Assessment and analysis of interest: For each identified stakeholder STATE (in words) AND RATE (on scale from 0 (none) to 5 (very high)) their INTEREST in the project.

V. Assessment of impact: For each identified stakeholder rate their IMPACT on project on scale from -5 (very high-negative) to 0 (none) to 5 (very high-positive)

VI. Analysis of impact: For each identified stakeholder explain in words HOW they IMPACTED the project.

4. Stakeholder analysis results

This chapter will present the most important results of stakeholder analysis and demonstrate the methods that can be applied using the proposed framework..

The first tool for stakeholder analysis is the ***power-interest matrix***. (Figure 3) It shows how each stakeholder is positioned in order to plan stakeholder management actions. The most favourable situation is when all stakeholders have favourable interest in project. Since it is rarely possible, the project manager needs to raise the interest for the project to the most powerful stakeholders. The power interest matrix below shows several anomalies. The first is that two of the owners of the project (HEP and Sisačko moslavačka County) have low interest and power. Other anomaly is that the Media is more interested in the project than Public.

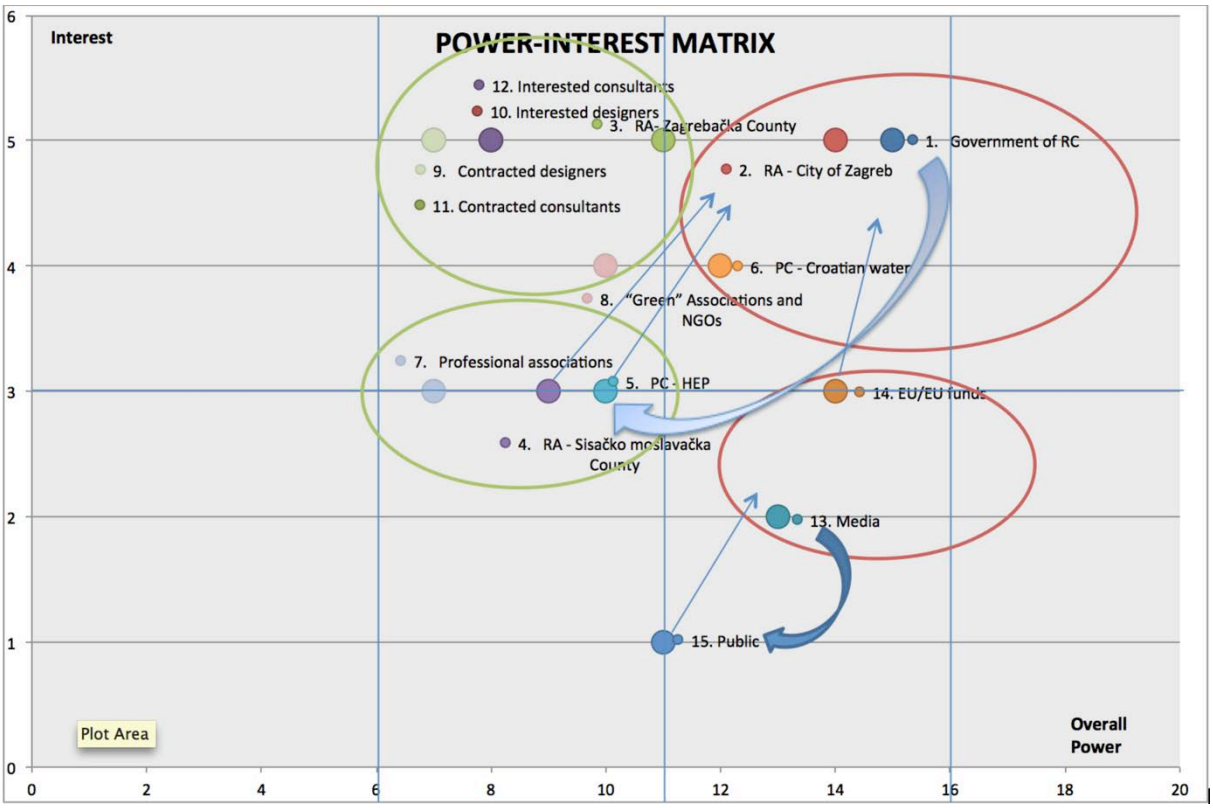

Figure 3: Power-interest matrix

The second graph (Figure 4) ***Grade of interest-Attitude-Overall Power*** shows that interest and attitude are compatible, except in the case of the HEP. In the third graph (Figure 5) ***Overall power- Interest x Attitude-Overall Impact*** is evident that Croatian Waters have the greatest impact on the project.

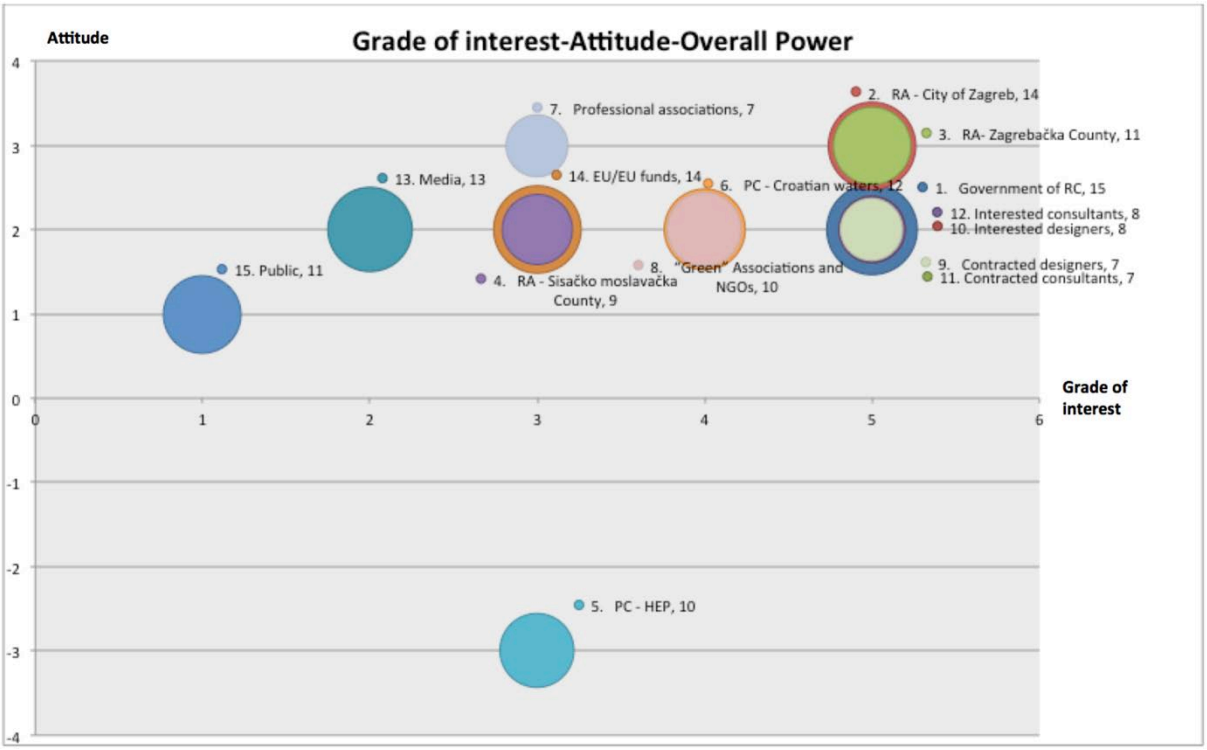

Figure 4: Interest-Attitude-Power matrix

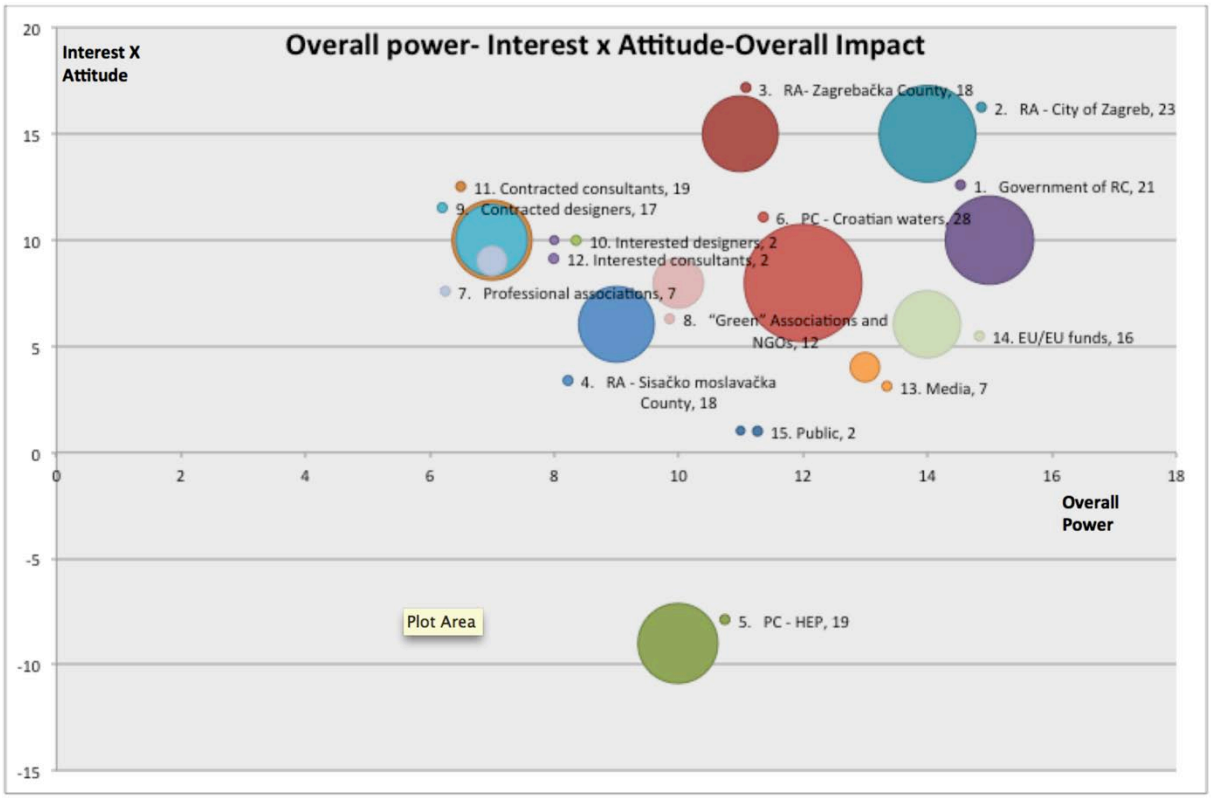

Figure 5: Interest-Attitude-Power matrix

The ***Project impact graph*** (Figure 6) shows average values of project execution impact (2P-Process and Product), project management success impact (time, budget and scope) and basic sustainability impact (3P). The greatest impact on the project execution have Contracted designers together with City of Zagreb and Croatian waters, Government and Professional associations. There is one more anomaly connected to HEP as project Owner – it has negative impact on project execution and project management success.

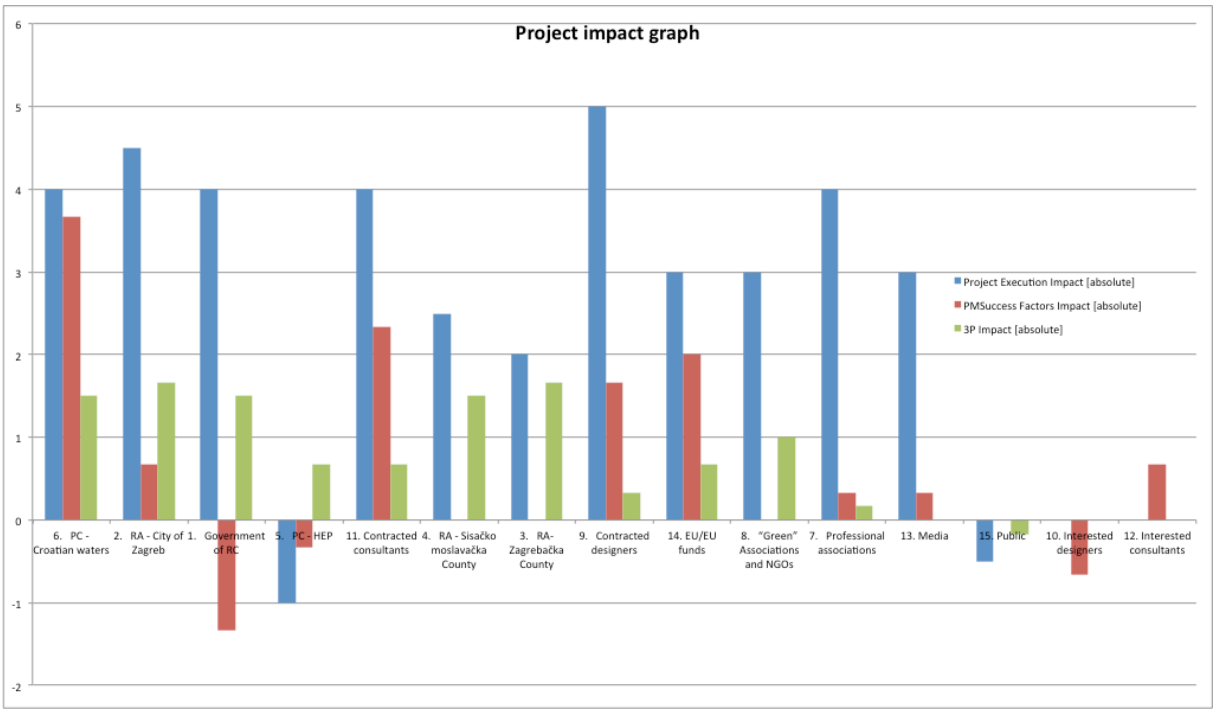

Figure 6: Project impact graph

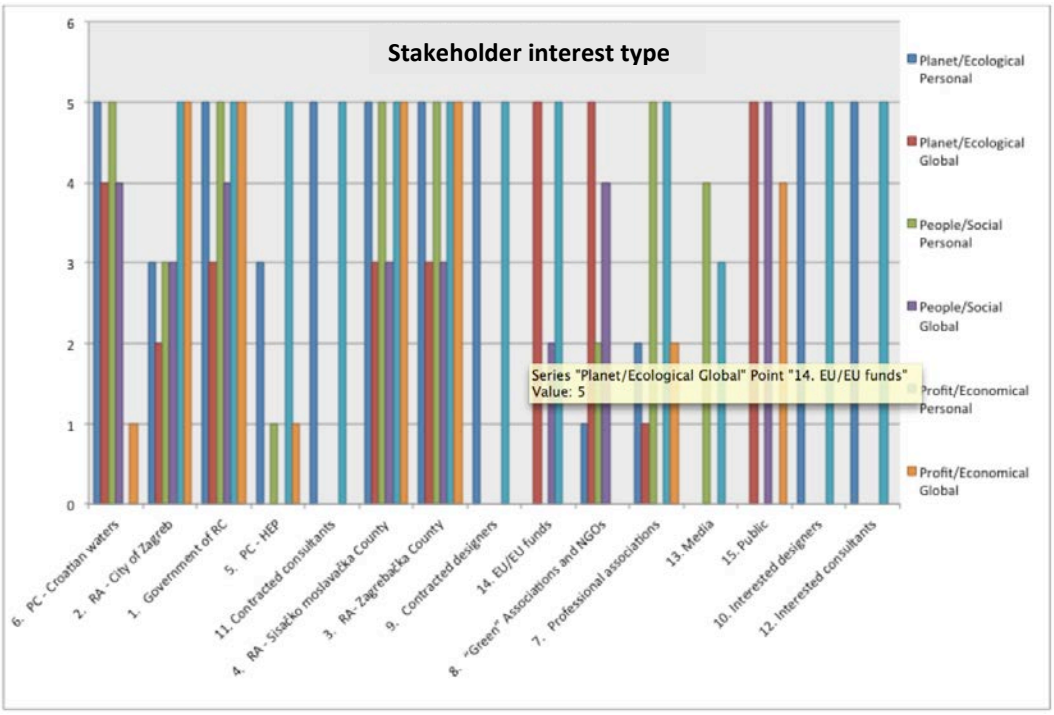

Figure 8: Project interest graph

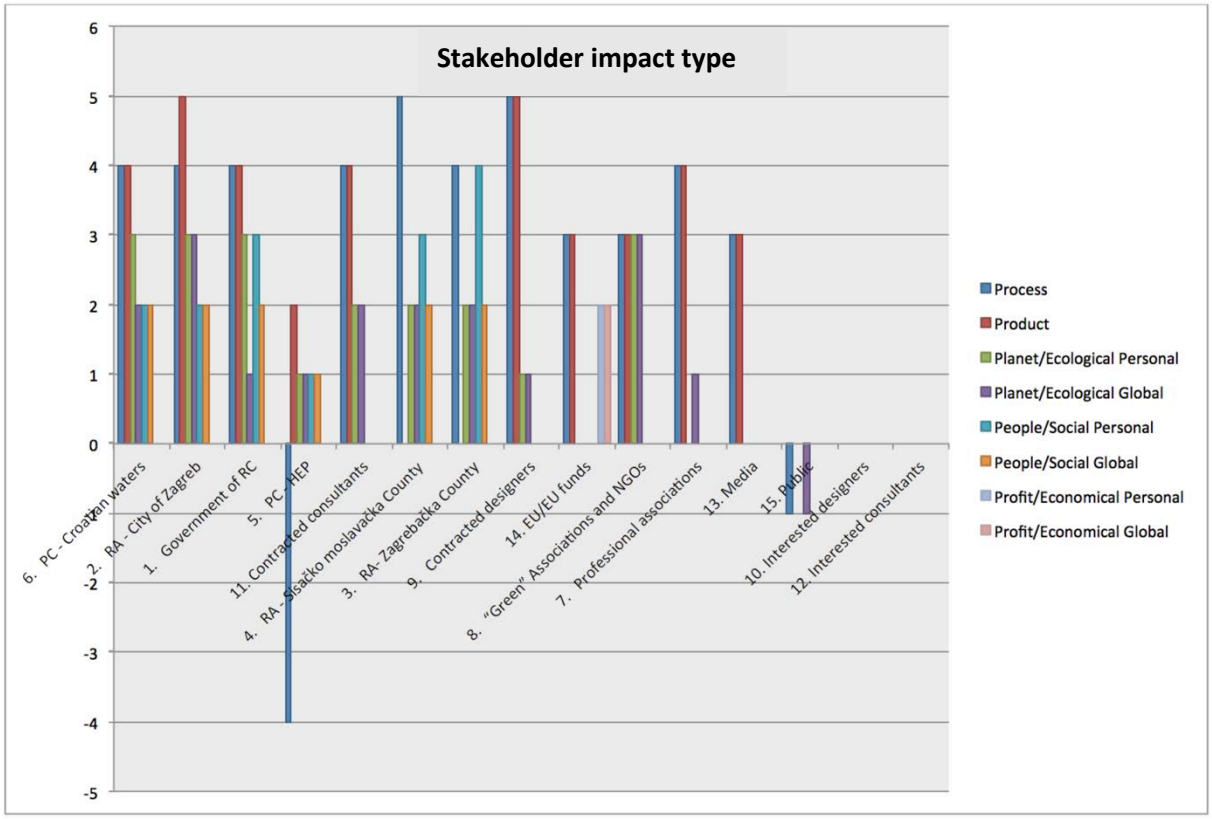

Figure 9: Project 5P impact graph

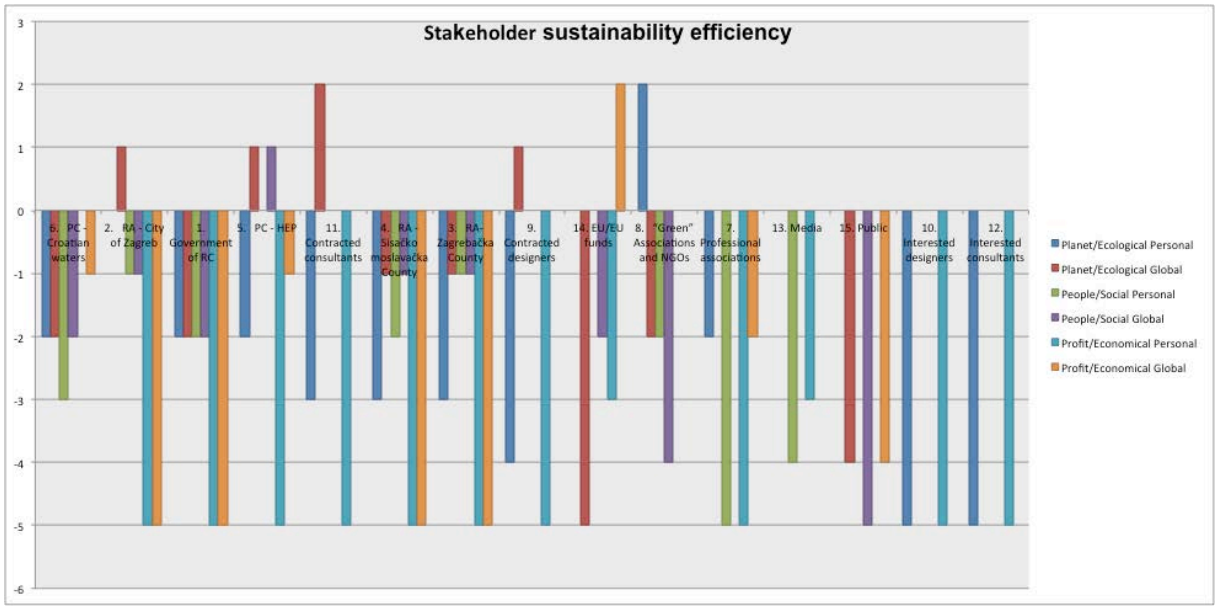

Figure 10: Stakeholders sustainability efficiency

Stakeholder efficiency analysis (Figure 10) is based on analysis of difference between impact and interest (Figure 8 and Figure 9). Stakeholders who achieved the same level or greater impact than interest, they are considered to be efficient. Non efficient stakeholders, those who didn't achieved balance between interest and impact, may disturb the project trying to realize their interest. The analysis shows that in terms of 3P the most efficient stakeholders are HEP, Sisacko-Moslavacka County and Green Association and NGOs, but in term of overall

efficiency the most efficient is City of Zagreb and the second is EU/EU Funds.

5. Discussion and conclusion

This analysis have shown the anomaly that HEP as owner of the project is not interested and have negative attitude. As management actions did not changed that situation, it lead to the slowing down the project progress in the front end of the project. That was result of combination of active participation of HEP and passive participation of Croatian Waters and Central government. As work with media have been neglected, they lost interest, which led to the total lack of interest of public. Public as impactive stakeholder could have influence the Central government and prevent the slowing down the progress of project.

In this paper the new, extended approach of stakeholders analysis is presented on particular case study. It has shown that stakeholder analysis based on power-interest matrix, which is the most usual, is not informative enough. This approach will improve information on stakeholders and help project managers to predict the stakeholder's behaviour, introducing the new value stakeholder efficiency. The verification and validation of the new stakeholder value will be part of future research on more cases.

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An MCDA Framework for Selecting, Evaluating and Prioritizing Road Infrastructures Improvement Projects

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Abstract

The effective road infrastructure maintenance not only serves the basic need for safe transport of people and goods but it is also considered vital for the region's growth and development. The paper introduces the Analytic Network Process (ANP) as an approach for the selection, evaluation and prioritization of public road infrastructures improvement projects and particularly those concerning the regional road network. The relative decision making process is highly complex, as it encompasses various, often conflicting decision criteria, that are related not only to the safety and techno-economic dimension but also to the social implications, the region's development and the political/strategic constraints. The paper analyses the aforementioned criteria and identifies the dependencies among them, within the framework of the ANP approach. The conclusion is that the specific research approach can provide the decision makers (DMs) with a structured and systematic framework for the analysis of alternative public investments related to road improvements, while ensuring public trust and establishing a system of transparency in public administration.

Keywords: project selection; road infrastructures maintenance projects; multicriteria decision analysis; ANP; road safety

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1. Introduction

The portfolio management relates to the selection, prioritization and management of projects aimed at achieving the strategic objectives of a public or a private organization (PMI, 2006). As far as the public organizations are concerned, Wheeler et al., 2010,Fitsilis et al., 2014 and Mackie et al., 1998 identify possible impediments which prevent the assessment process and the optimal project portfolio selection. The general conclusion is that the public organizations face this situation to a greater extent than the private organizations globally, as besides the classical decision criteria that are taken into account in almost every decision-making process (technical, financial, etc.), the public organizations are required to take into consideration issues with political and social origin, which are difficult or impossible to be quantified.

The current study proposes the ANP methodology as a useful tool for DMs in their efforts to prioritize road maintenance projects (RMPs) for implementation, taking into account the routine and periodic maintenance activities for paved roads. The criteria used during this process extracted from the literature review and the answers that five Greek transportation stakeholders gave to a relevant questionnaire.

2. Literature review

2.1. Decision Making (DM) methods

The existing methods for an organization's portfolio management are many. Norrie, 2006 proposes the use of a Balanced Strategic Scoring Model during the project selection procedures in the public sector. His purpose is to enable a project scoring based on both financial and non-financial measures and outcomes appropriate to the organization's strategy. As far as the developing countries are concerned, Asaka et al., 2012 at first explore the problems associated with decision-making in the public sector and secondly enumerate the existing decision-making models: 1) Non-numeric models (operating necessity model, sacred cow model, competitive necessity model, product line extension model, comparative benefit model) 2) Numeric models (profitability models, cost-benefit analysis (CBA), scoring models, goal programming, weighted factor scoring model). Bellos et al., 2010 propose the use of the Analytical Network Process (ANP) for the prioritization of public projects and emphasize on revealing the criteria that have to be taken into account during this process. Cheng et al., 2005 focus on the construction projects and they similarly propose the ANP.

Concerning the transport appraisal, Bistow et al., 2000 review the methods used in the countries of the European Union, based on the EUNET Fourth Framework RTD project. Initially, they mention that, in the majority of the EU member states, transport infrastructure is predominantly publicly owned, therefore the appraisal is usually concerned with achieving a range of social objectives. Thus, the methods like the CBA, the environmental impact assessment and the Multi-criteria Analysis (MCA) are used. In the UK, the methodology for the appraisal of transport projects is undergoing a period of substantial change (Vickerman, 2000). Until recently, the road projects have been subjected to a formal CBA using a standard procedure called COBA (Vickerman, 2000,Hayashi et al., 2000). However, the UK government elected in 1997 had as one of its priorities to move towards a new system, introducing in that way the New Approach to Appraisal (NATA). NATA retains COBA as the key element, but in this method each criterion has, where possible, both qualitative and quantitative elements (Vickerman, 2000). Hayashi et al., 2000 present an excellent study of the international comparison of background concept and methodology of transportation

project appraisal. They claim that the methods differ among each country due to its distinct histories of the development of history and practical application. They provide a detailed table with excellent data, through which we conclude that the most common methods are the CBA and the MCA. Finally, the reader is advised to study the book of Wirick, 2011, which provides an almost full list of decision making methods and tools that have proven useful in both public and private organizations.

The existence of numerous and complex decision making criteria, the difficulty in quantifying them, the existence of interactions between them and the desire of the DMs to participate actively in the whole process led to the spread of the Multi-Criteria Decision Analysis (MCDA) in the 60's, as a valuable tool to DMs (Bhusan et al., 2004). The first documented scientific effort to tackle the multi-criteria problems can be considered the work of Pareto in 1896, who laid the necessary axiomatic bases.

There is a variety of MCDA methods (Baker et al., 2002,Chen, 2006) and their number is constantly growing. Dodgson et al., 2009 mention the reasons of this growth and they therefore propose some of the criteria that should be used to select the most appropriate method. In this paper, we will introduce the Analytical Network Process, a binary alternatives-based MCDA method, which is based on preference expressions through comparisons of two (binary) alternatives.

The ANP method includes clusters and nodes. The nodes are organized into the clusters and they represent either the alternative projects to be selected or the decision criteria to be used during the analysis. Dependencies it is possible to exist between the nodes (inner) and between the clusters (outer), which allow ANP to adopt a non-linear structure, achieving in that way a more accurate representation of the decision problem (Buyukyazici et al., 2003)

In contrast with the mono-criteria analysis, the MCDA is based on the alternatives' comparison of alternatives towards a set of decision criteria. The decision criteria are tools (both quantitative and qualitative), which allow the alternatives' comparison according to a specific DM's "point of view" axis (Bouyssou, 1990). Determining the decision criteria requires a comprehensive literature search and the DM's personal contribution, knowledge and experience. The criteria are grouped into the clusters (clustering) according to the nature of them, i.e. whether the goals they meet or their meanings have a relation to each other. Saaty et al., 1990 say that this "homogenization" should be based on a common characteristic. The alternatives express the possible solutions the DM intends to result and they are also grouped into a certain cluster. The dependencies between the nodes occur after the ceteris paribus comparisons between them. These comparisons result to a preference rating assessment, during which the DM tries to rate a node against one other with respect to a node called control criterion. This rating is based on a preference scale 1-9, proposed by Saaty. Thus, assuming that the DM has to set the preference between the nodes X and Y with respect to a control criterion, the following table has to be used (Table 1):

Table 1.Saaty's preference scale

Intensity of importance	Definition	Explanation
1	equal importance	X is equal important to Y
3	moderate importance	experience and judgment slightly favor X over Y
5	strong importance	experience and judgment strongly favor X over Y
7	very strong importance	X is favored very strongly over Y
9	absolute importance	the evidence favoring X over Y is of the highest possible order of affirmation
2,4,6,8	used to express intermediate values	

2.2. Decision Making (DM) criteria

2.2.1. Cluster:Economic

2.2.1.1 Self - Financing capability

OECD, 2007 mentions that regarding to road infrastructure maintenance, the funding remains a major problem, as funds for rehabilitation and reconstruction are still more readily available, in contrast to routine and periodic maintenance that have to compete for limited domestic budget funds. According to Gideon et al., 2013 the core sources of revenues can be classified into internal and external. As far as the internal sources are concerned, Gideon et al., 2013 and ADB, 2012 present some of them: user charges (fines or other road user fees), development levies, income generating projects, local taxes, general budgetary revenues (the organizations take a portion of locally raised funds from their budgets). According to the PEPA Team, the self-financing capability is a fundamental DM criterion for a RMP, as the funds approval and disbursement procedures these are much shorter.

2.2.1.2 External Financing capability

Despite the fact that a project's Self-Financing capability is considered as the most important economic decision criterion, its ability to attract external funding is also significant (Bellos et al, 2010,EBRD, 2013,OECD, 2010). Gideon et al., 2013 and ADB, 2012 list the possible external financing sources such as: the government (via vehicle purchase taxes, the general budgetary revenue, toll road operation rights), other institutions (European Union-EU), private grants (NGOs , citizens), bank loans (World Bank, EIB, EBRD, ADB, State Transportation Infrastructure Bank). The EU allocates the major part of its total budget for the development of road networks and other relevant interventions to its member states via a specific funding structure (ERDF, ESF, EAF, EIB). The European Commission can make direct financial contributions in the form of grants to support projects or organizations which fulfill the interests of the EU or contribute to the implementation of an EU program or policy.

Therefore, this DM criterion relates to the project's capability to be eligible. Each funding source sets its own eligibility requirements, although the general rule is that projects should achieve specific targets based on specific strategies to be funded.

2.2.1.3 Efficiency

The efficiency is a common measure of evaluating investments globally. This broad acceptance is consequently spread to the road infrastructures investments. This need is highlighted in the European Directive 2008/96/EC, 2008. The meaning of the efficiency is related to the capacity level of an investment in returning benefits to the society in a desired time period within which the analysis is conducted. As far as the public sector's investments are concerned, the benefits are not only monetary, but they represent the total contribution of the investments to society. The efficiency assessment tools are many and they are used in order to provide an input to the decision making process, which will consequently be based on more clear and rational estimates: benefit/cost analysis (CBA), efficiency/cost analysis (CEA), net present value (NPV), internal rate of return (IRR), return on investment (ROI), payback period (PBP), the risk (Risk) of an investment. The most frequently used methods are the CBA and CEA. Despite the fact that the CBA is widely used in the RMPs, and there are many tools conducting such analyses (e.g. BCA.Net, STEAM, Cal-B/c, mini-CBA etc), the required data, (financial, technical and social, e.g. the AADT) are difficult to be mined and quantified. Thus, the public organizations avoid conducting CBA analyses and Hakkert et al., 2005 and Elvik et al., 2005 mention lots of reasons explaining this phenomenon. As they also claim, CEA is a more simplified but equally effective method and consequently this suggestion will be used in this study.

2.2.2. Cluster:Political

2.2.2.1 Organization's Strategy

According to Boyne et al., 2004 the Strategy is a pattern of action through which organizations propose to achieve desired goals, modify current circumstances and / or realize latent opportunities and it refers to how objectives and actions are selected and formulated. He notes that in contrast to the case in private sector, strategy need not to be viewed as a "weapon" used to defeat rivals in a competitive struggle, but it is used to improve the public services. According to Bellos et al., 2010 the compatibility of an action (maintenance project) with the organization's policy and strategic choices is a basic criterion for prioritizing the proposed alternative actions. Boyne et al., 2004,Blaug et al., 2006,Wisniewski et al., 2004,Game, 2006 present and suggest various strategy models used by public organizations (e.g. the saga, quest, venture, parlay, static, dynamic models). However, the organization's strategy is mainly defined by the organization's leadership, its political statements and choices. As far as the RMPs are concerned, the adopted strategy is mainly formulated through the daily friction with the region's problems, the political beliefs and statements.

2.2.3. Cluster:Social/Developmental

2.2.3.1. Public opinion

The public opinion (e.g. citizens, NGOs, subsidizers, or other public agencies) greatly influences the final choice of public. The PEPA Team recognizes this influence and reports the terms NIMTOO (Not In My Term Of Office) and NIMBY (Not In My Back Yard), which express the extent to which public agencies and citizens respectively refuse any action of the public sector. According to Bellos et al., 2010, the public sector's projects are highly

influenced by the desires of the citizens or other social/professional groups. Regarding to the road transport, the level of services provided can be improved only by ensuring a continuous way of monitoring and measuring that level. In the US, the Transportation Equity Act of the 21st Century (TEA-21), requires the participating Transport Organizations (Departments of Transport - DOTs) of all States to seek and take into account the public opinion during the transports policy formulation. Despite the numerous methods about mining the public opinion (e.g. public hearings, citizen advisory committees and workshops), the sample surveys (including the phone and online surveys) are the most effective and therefore the most commonly accepted. The phone surveys are highly used in estimating the public opinion regarding road transport issues. However, this traditional method is less and less used, as the new trend is the use of the online methods. The fact that each of these methods face different obstacles during their processes led the literature to propose the combination of these methods (Cunningham et al., 2006). Potoglou et al., 2012 propose that the online methods should be subsidiary used in relation to the phone surveys. This suggestion will be used in the current study.

2.2.3.2. Impacts on the local/regional development

The RMP's contribution to the local / regional development may have many facets and the benefits that are created can be either short term or long term. Bellos et al, 2010 mention that this contribution to the development and the strengthening of the role the organization seeks to have is a key criterion of selection. The literature (Leyland, 2002,Osborne, 1995,Calvo, 1998) refers to the positive impacts that the organization may have on the development and they are listed below:

Direct Impacts on the:
- travel time
- vehicle operating costs
- safety
- direct employment (temporary and permanent)

Wider Impacts on the:
- indirect Employment (temporary and permanent)
- land values
- private capital and labour market
- establishment of new economic activities
- redistribution of income
- accessibility (it can be measured as the quantity of economic or social activities that can be reached using the specific road)
- social inclusion (by improving accessibility and mobility)
- environment
- transport network reliability

2.2.3.3. Contribution to creating environmental benefits

It is widely accepted (OECD, 2010) that many human activities are characterized by

environmental impacts. These activities also include the RMPs, which affect the:

- soil
- water quality
- water drainage
- air quality
- acoustic environment
- flora/fauna
- landscape
- archeological heritage and culture
- population

These effects should be taken into account during the decision making processes by conducting an Environmental Impact Assessment (EIA) procedure. Focusing on the road transports, the Environmental EIA concerning a new road project should focus on the prediction. However, in the case of RMPs the assessment is related to how these alleviate the existing environmental problems, which arose because of the existence of the road. Therefore, during the environmental impact assessment process for RMPs, the DM has not to plan how to prevent the environmental impacts, but he has to find and model mitigating practices (DFID, 2003). More and more environmentalists recognize the road ecology, whose applications are important challenges in the areas of engineering and ecology. The EU Directive 85/337/EC defines the mitigation as measures of preventing, reducing or -if it is feasible- restoring adverse effects. The US Environmental Protection Agency proposed in 2010 seven policies that should be implemented so as road transports to create environmental benefits. Concluding, the RMPs are unlikely to cause extensive environmental impacts and it is possible, if they are properly implemented to have a positive impact on the environment.

The literature offers a large number of EIA methods, both qualitative and quantitative (DFID, 2003). It also offers a great number of such methods for the road infrastructure activities exclusively (Luis et al., 2006). Generally, the qualitative methods are more preferable than the others, as the lack of financial sources and technical experience in public organizations is a common phenomenon and the total decision-making process should be quick, simple and flexible. Of course, these simplifications should not be considered to undermine the validity of a qualitative method, which according to Garbarino et al., 2009 has a clear comparative advantage in the analysis compared to a quantitative method. This study suggests the use of the qualitative method proposed by the (Toro et al., 2013,Toro, 2009), adapted for RMPs, using simultaneously the above-mentioned theory of mitigation.

2.2.4. Cluster:Technical

2.2.4.1. Traffic volume served

The traffic volume served by the road to be maintained is another decision criterion. This number can be expressed by different measurement methods, the most important of which are as follows:

- Traffic volume, which is divided into the traffic volume and the traffic flow rate methods, which both express the users' demand for using the road services and they are calculated in vehicles/h. The most common method is the Annual Average Daily Traffic, which

expresses the total number of vehicles crossing a road section during 1 year (in vehicles/year)

- Speed, which is divided into the time mean speed - $\overline{S}_t$ and the space mean speed - $\overline{S}$)
- Density, which is defined as the vehicle (or the passenger) number using a specified road length in a certain time period (in vehicles/km or passengers/km)
- Occupancy, which expresses the time percentage that a road section is occupied by vehicles
- Travel time over a known length of a road, which expresses the time required to cross a given section of road, measured in units of time per distance and it can be considered as the inverse of speed, ie the "slowness" of a certain road section («tardity»)
- The time/space headway (or spacing), which expresses the time or space between two successive vehicles as they cross a road section

The TRB, 2000 estimates that the 3 first methods (traffic volume, speed, density) are the most significant. However, it proposes the traffic volume method (AADT) as the most suitable, as it is the only compatible with the both two types of traffic flow:

- the interrupted flow, when the road infrastructure is characterized by the existence of a traffic system furniture (lights, traffic signals etc), or other causes that can cause delays or interference to the smooth traffic flow
- the uninterrupted flow, when the road infrastructure is characterized by little or no existence of such delay causes

As a result, the AADT method will be used in the current study.

2.2.4.2. Resources availability

The resources availability is related to the quantity and the technical adequacy of the equipment and the organization's labor force and it reflects the extent to which the organization is ready to implement a RMP. The insufficient funding of these projects is frequent, thus the availability of resources is a basic decision criterion. The equipment's malfunction, its inadequate maintenance, the reduction of the labor force, the lack of specialized staff can significantly affect the decision to implement a RPM.

2.3. Methodology used

2.3.1 Using the ANP

As mentioned above, the current study will use the ANP method. The preference rating system used will be based on the Saaty's scale 1-9, which was presented in the (Table 1). For each of the proposed decision criteria, the DM has to quantify the superiority of one alternative project towards one other. This process requires the conversion of this superiority to the scale 1-9. This can be achieved by using the Percentage Difference (Δ), between the two values these two alternatives get towards a criterion. For example, assuming that the A and B alternatives get the C_A and C_B values towards the C criterion respectively, the Δ calculation is as follows

$$\Delta = \frac{|C_A - C_B|}{\frac{C_A + C_B}{2}} * 100\ (\%) \tag{1}$$

which expresses whether the C_A or C_B value prevails over the other. Thus, the Δ value can be converted into the scale 1-9 as follows (Table 2):

Table 2.Saaty's preference scale conversion to the Δ scale

Saaty's scale	Definition	Δ (%) from	Δ (%) to
1	equally important	0	<1
2	slightly more important	1	<15
3	moderately more important	15	<30
4	more than moderately more important	30	<45
5	strongly more important	45	<60
6	more than strongly more important	60	<75
7	much more than strongly more important	75	<90
8	mightily more important	90	<105
9	more than mightily more important	105	∞

2.3.2 Self - Financing capability assessment

During the assessment of the superiority of a maintenance project over one other another towards this criterion, the DM is recommended to use the utilization percentage (UP), which is given by the ratio of the total budget of the project to be financed from internal sources to the Organization's total available budget. Thus, for a P project, the UP is as follows:

$$UP_P = \frac{\text{Self-financed Project's Budget}}{\text{Organization's total available Budget}} \tag{2}$$

Therefore, the RMP with the minor UP should be selected according to this criterion. For example, assuming that $UP_A = 0{,}2$ and $UP_B = 0{,}1$, then:

$$\Delta = \frac{|UP_A - UP_B|}{\frac{UP_A + UP_B}{2}} * 100\ (\%) = \frac{|0{,}2-0{,}1|}{\frac{0{,}2+0{,}1}{2}} * 100\ (\%) = 66\% \tag{3}$$

Thus, the B alternative is more important (6 in Saaty's scale) than the A one towards the "Self - financing capability" criterion.

2.3.3 External Financing capability assessment

The superiority of one alternative towards this criterion is proposed to be assessed via the external financing percentage (EFP), which is given by the ratio of the amount of external funding that a RMP can receive to its total. Thus, for a P project, the EFP is as follows:

$$EFP_p = \frac{\text{possible external financing Budget}}{\text{Project's total Budget}} \tag{4}$$

Therefore, the RMP with the major EFP should be selected according to this criterion. For example, assuming that $EFP_A = 0{,}3$ and $EFP_B = 0{,}4$, then:

$$\Delta = \frac{|EFP_A - EFP_B|}{\frac{EFP_A + EFP_B}{2}} * 100\ (\%) = \frac{|0{,}3-0{,}4|}{\frac{0{,}3+0{,}4}{2}} * 100\ (\%) = 28{,}5\% \tag{5}$$

and the B alternative is more important (3 in Saaty's scale) than the A one towards the "External financing capability" criterion.

2.3.4 Organization's Strategy assessment

In order for a DM to assess the superiority of a RPM towards this criterion, it should be clarified beforehand who is responsible for Organization's Strategy shaping. If the decisions are taken by a group of executives, the study proposes the meeting of this group in order to define together the primacy of a RPM against another directly on the basis of scale Saaty 1-9.

2.3.5 Impacts on the local/regional development assessment

OECD, 2002 mentions many assessment methods used to estimate this impact and TRB, 2014 proposes its own methods, which are based on both qualitative and mathematical models. Generally, it is extremely difficult to measure the exact relationship between transport infrastructure investment and the local/regional development (OECD, 2002). Even if the CBA is the main tool used by the DMs in such an appraisal, the wider effects cannot be measured. As a result, this study proposes that this assessment should be left to the DMs' personal estimations and insight. Thus, the prioritization process will follow the same procedure as in the (2.3.4) chapter.

2.3.6 Efficiency assessment

As the road safety is one of the most crucial aspects of a RMP (OECD, 2010) the CEA ratio (CER) calculation requires the calculation of the total number of fatalities and serious injuries prevented (benefits) and the total cost (costs) of a RMP following this equation:

$$CER = \frac{\text{present value of all benefits}}{\text{present value of all costs}} \tag{6}$$

Despite the fact that the total costs are relatively easily measurable, as the quantities and values are given, the benefits' calculation will be based on the iRAP, a globally recognized methodology applied to address the problem of road accidents, aiming to increase the road safety through the adoption of the philosophy of the "forgiving road system". The general equation used is the following one:

$$\text{CER} = \frac{\text{present value } \{(F * 70 * \text{GDPpc}) + (SI * 0{,}25 * 70 * \text{GDPpc})\}}{\text{present value of all costs}} \tag{7}$$

where

"F" is the number of total fatalities prevented, which is calculated for each 100m road section as a function of three factors: (1) the safety score of this section (RPS), (2) the type of road user (e.g. car occupants, pedestrians), (3) the type of accidents each user will probably involve to. The calculation of the human life's (statistical life) value follows the willingness-to-pay philosophy. On this basis, it is estimated that this value is 70 times the GDP per capita at current values (GDP per capita - GDPpc) of the country where the analysis is applied. The total fatalities prevented results from the sum of the fatalities prevented for all 100m road sections.

"SI" is the number of total serious injuries prevented. Due to the frequent lack of such data, the ratio of 10:1 is used (10 serious injuries correspond to 1 fatality prevented). Based on the willingness-to-pay philosophy again, the value of serious injury is rated at the 25% of the value of statistical life.

The above calculations are performed by ViDA (vida.irap.org), a free online iRAP's software. ViDA identifies and proposes the most appropriate maintenance activities (countermeasures - full list of 93 types), which substantially contribute to the reduction of fatal and/or serious accidents. The DM is proposed to use the ViDA, in order to detect the activities of the maintenance projects he has to compare. Thus, the total project's CER results from the ratio sum of the benefits to sum of the costs for each activity. Therefore, the RMP with the major CER should be selected according to this criterion. Assuming that $CER_A = 5$ and $CER_B = 8$, then:

$$\Delta = \frac{|CER_A - CER_B|}{\frac{CER_A + CER_B}{2}} * 100\ (\%) = \frac{|5-8|}{\frac{5+8}{2}} * 100\ (\%) = 42{,}85\% \tag{8}$$

and the B alternative is more important (4 in Saaty's scale) than the A one towards the "efficiency" criterion.

2.3.7 Public opinion assessment

As it was previously mentioned, this study proposes the simultaneous use of both phone and online surveys. The sample must exclusively include households located within the responsibility area of the road agency. In order to achieve a confidence level of 95% and error of ±5% in an area of 50 thousand citizens, 381 completed interviews (via the phone or the internet) are required. Initially, each household should be called and the total call duration should not exceed the 10 minutes. If the call is successful, but the interviewee is currently busy or uncomfortable, the interviewer should assign a personal code (PIN) and inform him/her about the possibility of continuing the interview on the internet. The proposed method largely covers the imperfections of each of the two methods.

The questionnaire to be used should be drawn up by the agency's staff adopting the theory

of the Performance Measures, which proposes the use of indicators (sustainable transportation indicators or performance indicators) as tools for the collection and assessment of data relating to how well an organization achieves its goals in providing road transport services. The responsible agencies should develop an appropriate set of these indicators, which will meet their requirements, as there are more than 400 such indicators available. As far as the OECD country members are concerned, they use or they should to use 18 such indicators.

This study proposes the use of the above 7 most important indicators (Table 3), which will be used in the questions in the questionnaires, following the format: "what do you believe is the X alternative's contribution level to the Y indicator's satisfaction?". The answers will be based on a 4-scale point system (0-zero, 1-slight, 2-moderate, 3-sufficient influence).

Table 3.Public opinion's indicators

Attribute/Indicator	Question
accessibility and mobility	What do you believe is the X alternative's contribution level to the travel time reduction?
road safety	What do you believe is the X alternative's contribution level to the road safety improvement?
environment	What do you believe is the X alternative's contribution level to the noise level reduction?
community	How strongly do you believe your opinion will be asked for the X alternative's targets accomplishment?
road program development	How strongly do you believe your opinion will be asked for the procedures followed by the Organization during the completion of the X alternative?
road program delivery	How strongly do you believe your operating expenses (e.g. fuel consumption) will remain stable during the X alternative's implementation?
road performance	What do you believe is the X alternative's contribution level to the upgrade of the road functions?

The total score of each alternative comes from the sum of the scores that the alternative collected for each of the above questions (R). Therefore, the RMP with the major score should be selected according to this criterion. Assuming that R_A = 2223 and R_B = 3045, then:

$$\Delta = \frac{|R_A - R_B|}{\frac{R_A + R_B}{2}} * 100\ (\%) = \frac{|2223-3045|}{\frac{2223+3045}{2}} * 100\ (\%) = 31{,}2\% \tag{9}$$

and the B alternative is more important (4 in Saaty's scale) than the A one towards the "public opinion" criterion.

2.3.8 Contribution to creating environmental benefits assessment

The aim of this study is to characterize a road maintenance project according to how this contributes to the relief of the environment, which is already burdened by the existence of the road. Therefore, the project that influences (positively) the environment more than the others do should be selected, according to the criterion "Contribution to creating environmental benefits".

Each human activity may have different kinds of effects. Focusing on the road maintenance activities, the environmental sectors that may be affected are the following:

- Wildlife Habitat - WH

- Wildlife Diversity - WD
- Flora Diversity - FD
- Surface Water Quality - SWQ
- Land Use Change - LUC
- Air Quality - AQ
- Population - Pp

These sectors can be used as indicators, as they can express the influence level of each project to the environment. Assuming that a road maintenance project P impacts positively on the environment, the total impact ($ImpTotal_P$) is given by the average value of each impact on the above sectors (considering equivalent weights between them). A large $ImpTotal_P$ shows that the P project will affect (positively) the environment to a greater extent. Therefore we have the following equations:

$$ImpTotal_P = \frac{\sum_{I=1}^{n} ImpTotal_{P,I}}{n} \tag{10}$$

$$ImpTotal_{P,I} = w_{ImpPro} * ImpPro_{P,I} + w_{ImpAct} * ImpAct_{P,I} + w_{ImpVul} * ImpVul_{P,I} \tag{11}$$

where:

n	the sectors' number (n=7)
I	each of the above sectors (I={ WH, WD, FD, SWQ, AQ, LUC, Pp })
$ImpPro_{P,I}$	the project's P total impact on the I sector (importance of the Project)
$ImpAct_{P,I}$	the impact of each project's P activity on the I sector (importance of the Activity)
$ImpVul_{P,I}$	the project implementation area's sensitivity to any change in the sector I (importance of the Vulnerability)
w	the relative weight for each of the above 3 factors

$ImpPro_{P,I}$ calculation:

The $ImpPro_{P,I}$ calculation is based on a set of qualitative factors and it results from the opinion of the organization's staff or external consultants. The use of questionnaire is possible to collect their opinion. Thus, for the P project:

$$ImpPro_{P,I} = I+Ex+Mo+Pe+Rv+Sy+Ac+Ef+Pr+Rc \tag{12}$$

where

I	the intensity that the project is likely to affect the sector I
Ex	the extension of the affected area compared to the wider area
Mo	the time (moment) between the project's implementation and the appearance of the first impacts
Pe	the impacts' persistence, i.e. the time they affect the area
Rv	the impact's reversibility, i.e. the environment's capacity to return to a previous

situation
Sy the project's characteristic to have simultaneous impacts, which affect the area in a different way
Ac the impacts' characteristic to be accumulative
Ef the impacts' immediacy
Pr the impacts' periodicity, i.e. their stability to occur at specific intervals
Rc the recovery probability of the environmental conditions to the initial conditions

$ImpAct_{P,I}$ calculation:

The $ImpAct_{P,I}$ expresses the capacity of each of the project's activities to create environmental benefits, as a road maintenance project consists of a set of activities. Considering equivalent weights between them, the $ImpAct_{P,I}$ is calculated as follows:

$$ImpAct_{P,I} = \frac{\sum_{i=1}^{n} ImpAct_{i,I}}{n} \tag{13}$$

where

n the number of the project's P activities
$ImpAct_{i,I}$ the extent to which the i activity influences the I sector

$ImpAct_{i,I}$ calculation:

This calculation requires the use of the Potential Environmental Impact (PEI), which expresses the intensity to which the considered project's activity i has (positive) impact on the sector I. The PEI is characterized by a qualitative description, which results from the opinion of the organization's staff or external consultants. The use of questionnaire is possible to collect their opinion. The qualitative description is then assigned to quantitative values.

PEI assignment in each activity:

The organizations should prepare a list, which will assign PEI values in each activity and for each sector. In case of lack of data, the influence should not be considered as non-existent, but it should be rated as PEI_L. The reader is advised to study the work of Lantran, 1994, who presents a full set of activities and the corresponding PEI value in a + A, + B, + C scale (the + sign is a positive effect).

$ImpVul_{P,I}$ calculation

The $ImpVul_{P,I}$ factor expresses the sensitivity level of the project's P execution area for any change in the I sector. Thus, it is an expression of how the environment can respond to external events. For example, an area A may be very sensitive to changes affecting the quality of the atmosphere, but unaffected in changes concerning the quality of the surface waters.

w calculation:

The following calculation is proposed:
w_{ImpPro} = 0,4

w_{ImpAct} = 0,2
w_{ImpVul} = 0,4

Therefore, the road maintenance project with the major $ImpTotal_P$ score should be selected according to this criterion. Assuming that $ImpTotal_A$ = 47 and $ImpTotal_B$ = 55, then:

$$\Delta = \frac{|ImpTotal_A - ImpTotal_B|}{\frac{ImpTotal_A + ImpTotal_B}{2}} * 100 = \frac{|47-55|}{\frac{47+55}{2}} * 100 = 15{,}6\% \quad (14)$$

and the B alternative is more important (3 in Saaty's scale) than the A one towards the "Contribution to creating environmental benefits" criterion.

2.3.9 Traffic volume served assessment

As mentioned before, the AADT is proposed as the traffic volume served measure. Assuming that the alternatives A and B are implemented in road sections with a respective AADT traffic flow Q_A = 5067 vehicles/year and Q_B = 6034 vehicles/year, then:

$$\Delta = \frac{|Q_A - Q_B|}{\frac{Q_A + Q_B}{2}} * 100\ (\%) = \frac{|5067-6034|}{\frac{5067+6034}{2}} * 100\ (\%) = 17{,}4\% \quad (15)$$

and the B alternative is more important (3 in Saaty's scale) than the A one towards the "Traffic volume served" criterion.

2.3.10 Resources availability assessment

The resources availability assessment is proposed to be based on a binary-values rating system. When the DM has to compare the two alternatives A and B towards this criterion, the scenarios are only three:

- The resources are adequate for both A and B, thus the rating should be 1 in Saaty's scale
- The resources are adequate only for the A, thus the rating should be 9 in this scale
- The resources are inadequate for both RPMs, thus the rating should be 1 in this scale

If a RPM will be conducted by a contractor and not by the Organization, this criterion and this comparison is useless and it should be avoided.

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The Phenomenon of Global Mindset of Multinational Construction (MNCs) Firms in Ghana: Exploring the Lenses of Challenges and Strategic Gains

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Abstract

The superiority of global markets have created a need for organizations to search for new sets of skills to enable them to endure into the future. Whether they operate local or international markets, global challenges are felt in every business especially in the area of adaptation. This paper aims to explore the concept of global mindset and its challenges and strategic opportunities for Multi-National Construction firms in Ghana. The study utilizing structured survey questionnaire attempted to explore the underpinning challenges and strategic gains/opportunities of global mindset identified from literature and preliminary survey in relation to the construction industry in Ghana. The questionnaires were administered to top management professionals such as Project managers, Quantity Surveyors, Architects, Site Engineers and Services Engineers of selected Multi-National Construction firms in Ghana. Out of 45 questionnaires administered, 38 were received. However 35 questionnaires representing 77.78% were deemed fit for analysis. Data gathered from respondents was analysed using descriptive statistics and Mean Score rankings to establish significant levels of the various challenges and strategic opportunities of global mindset. The findings from the research work disclosed the strategic gains/opportunities of global mindset as *improvement in performance; ability to understand global and local markets; global positioning and outlook and early identification of emerging opportunities.* The challenges of global mindset were revealed as *difficulties with socio-cultural adaptation; distressed in new setting; and limits performance.* While the study focuses on Ghana, there are prospects for the findings to be adopted by other countries worldwide towards the improvement of performance and assist researchers in such fields. Further research is recommended to researchers to conduct a study into the strategies for developing global mindset.

Keywords: construction; Ghana; global mindset; multi-national; performance.

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1. Introduction

Mendenhall *et al.,* (2008) explained that globalization is an ongoing process of mutuality and integration of economies, societies, and cultures that occurs through a worldwide network of global communication and trade and has rapidly developed over the past 25 years to the point that it is a reality today. Friedman (2005) further indicated that it is not only true that the world is spherical, it is also of high chaos and continuous change in which a rapidly growing number of companies operate as if the entire world were a single entity. However, the degree of interconnectedness which is as a result of the impact of technology on communication, knowledge creation and information sharing has emerged with the chaos and continuous change of contemporary business environment. Globalisation is constantly developing extremely dynamic, complex, borderless and multicultural context within which contemporary businesses must strive to operate.

However, organisations must find constructive ways in order to adapt to survive and the most adaptable organisations will be best positioned to explore the possibilities hidden amid the chaos and to respond with innovative solutions to the complex challenges they encounter. Rhinesmith (1993) explained that for organizations to be viable, they need to have a global outlook in their operations, whether domestic or international. Furthermore, a growing number of academics and practitioners view global mindset as a critical success factor that affects a variety of organizational outcomes (Murtha *et al.,* 1998; Gupta and Govindarajan, 2002; Levy, 2007). However, this emerging consensus reflects recognition that the present-day competitive landscape requires a shift in focus from structural and administrative mechanisms to mindset-based capabilities (Bartlett and Ghoshal, 1990).

Rhinesmith (1993) highlighted that global mindset has come to stand for everything that is supposedly global or transnational, from individual attitudes, skills, competencies and behaviors, to organizational orientations, structures and strategies, to policies and practices. In short, the diversity of perspectives and the pervasive use of the concept of global mindset have resulted in conceptual ambiguities, as well as contradictory empirical findings. Evans *et al.,* (2002), describe global mindset as a set of attitudes that predispose individuals to cope constructively with competing priorities rather than advocating one dimension at the expense of others.

As global competition continues to intensify, global mindset has emerged as a key source of long-term competitive advantage in the global market place (Levy *et al.,* 2007). The concept of global mindset bears a strong relevance for multinational companies (MNCs) as they intrinsically seek to operate profitably across different countries, cultures and contexts (Levy *et al.,* 2007). Furthermore, Gregerson *et al.,* (1998) stated that a global mindset, in its simplest form will allow a manager from

Anaman and Osei Amponsah (2007) highlighted that the construction industry plays an important role in any economy and its activities are also vital to the achievement of the socio-economic development goals of providing shelter, infrastructure and employment. Indeed, the interdependence of the construction sector and economic development has been addressed by various writers and in all cases, there is evidence indicating a direct link between investment in construction and economic growth. In Ghana, just like many other developing countries the construction industry is huge and has a significant aspect in economic development. No matter what one does, there is construction, as it cuts across all sectors. From a low point in the 1970s and 1980s, the share of Ghanaian construction industry in the GDP has moved up from 4.5% in 1975 to 8.5% by the turn of the century and

has been doing about the same level since (Gyadu-Asiedu, 2009). This shows that the industry has a huge potential of leading the way for the economic development of developing countries such as Ghana if well exploited. Thus in specific terms, the Ghanaian construction industry could be the instrument for achieving the infrastructural guidelines of the Millennium Development Goals (MDGs) and The Ghana Poverty Reduction Strategy II (GPRS II) agenda. One of the main agenda of MDGs and GPRS II is to address human development issues of which Cotton *et al.*, (2005) noted that the agenda is achievable by the provision of infrastructure for services and employment through the construction industry.

Multi-National Construction firms that ignore global mindset do that at their own peril. The ones that most effectively develop this quality in their employees will have a distinct advantage over their competitors (Beechler and Baltzley, 2008). Global mindset is a pre-requisite for multi-national construction firms in order to provide a competitive advantage. Although various works have been conducted around the concept of, and proposed methodologies required to cultivate a global mindset (Gupta *et al.*, 2002; Arora *et al.*, 2004), existing literature fail to provide evidence on the challenges and strategic gains of global mindset on Multi-National Construction firms. Therefore it became imperative to explore the lenses of challenges and strategic gains of Multi-National Construction firms in Ghana due to Global Mindset.

Pires *et al.*, (2006) attest that there are difficulties associated with adaptation of Multi-National Construction firms and these have been identified as the main source for many stress-induced reactions experienced on international assignments in confronting the day-to-day culture and norms of the host country. Furthermore there are numerous descriptions and literature on global mindset which when put together does not yield conclusive definition of a global mindset and the problem is further exacerbated by the fact that there are some fundamental inconsistencies with literature as well (Levy *et al.*, 2007). According to Morrison (2000) global leadership mindset should be a requirement for all Multi-National Construction firms and must not be only limited to the American, European or Asian firms. Julien (2006) explained that no empirical research has been conducted on global mindset of Multi-National Construction firms in developing countries like Ghana. Subsequently, no work has also been carried out on the performance of these firms. Furthermore, a research has also not been conducted into the corporate social responsibilities of these firms. The protracted neglect by researchers to champion global mindset in the construction industry could have contributed to its unpopularity in most developing countries like Ghana.

Therefore, this paper is among the pioneering empirical studies on Global mindset in the context of the Ghanaian Construction Industry (GCI) and is therefore articulated with the aim to explore the lenses of challenges and strategic gains of Multi-National Construction firms in Ghana due to Global Mindset.

2. Conceptual explanation of Global Mindset

Various Authors have different definitions for global mindset. Evans *et al.*, (2002), explained global mindset as a set of attitudes that predispose individuals to cope constructively with competing priorities rather than advocating one dimension at the expense of others. Global mindset can also be considered as the necessary competence to have and a pre-requisite for successful internationalization of companies and are built gradually over time by most Multi-

National Companies (MNCs) in their quest to enter and succeed in foreign markets (Nummela *et al*., 2004). Additionally, Global mindset has also been defined by Maznevski and Lane (2004) as the ability to develop and interpret criteria for personal and business performance that are independent from the assumptions of a single country, culture or context and to implement those criteria appropriately in different countries, cultures or contexts.

As global competition continues to intensify, global mindset has emerged as a key source of long-term competitive advantage in the global market place (Levy *et al.*, 2007). The concept of global mindset bears a strong relevance for multi-national companies (MNCs) as they intrinsically seek to operate profitably across different countries, cultures and contexts (Levy *et al.*, 2007). Furthermore, Gregerson *et al.*, (1998) stated that a global mindset, in its simplest form will allow a manager from one part of the world to be comfortable in another part and perform well on account of knowledge and skills that are based on understanding and awareness.

Gupta and Govindarajan (2002) defined a global mindset as "one that combines openness to and awareness of diversity across cultures and markets with a propensity and ability to synthesize across this diversity". Arora *et al.*, (2004) did not offer their own definition of a global mindset but cited Rhinesmith's view on a global mindset as " one that scans the world from a broad perspective", which alludes to the fact that people with a global mindset are able to adapt to their environment and view the world from different outlooks. Whilst and Blonski (2010) also defined a global mindset as one that "enables people to embrace complexity and paradox".

Boyd *et al.*, (2011) offered a definition of a global mindset linked to the work of Javidan *et al.*, (2010) that focuses on a) intellectual capital which covers knowledge of international business and an individual's ability to continue learning, b) psychological capital which ensures one is open to exposure to different cultures and change, and c) social capital which is the ability to build relationships with different stakeholders.

3. The Global Construction Industry

Global business is characterised by any form of transaction taking place across national borders for the purpose of satisfying the needs and demands of individuals and firms (Rugman and Collinson, 2009). The opportunities developing from globalisation, while elevating competition in domestic markets provide construction firms with access to international markets. A number of construction firms already operate in international markets, trading their design services and construction products amounting to significant monetary value (Reina and Tulacz, 2010). Globalizing a construction business is a complex process involving decisions on what international region, country or market to enter and succeed.

Construction firms could exploit international markets in at least two forms: (a) outsource their selected core or non-core business functions or operations to an international operator and/or (b) offer the firm's products or services in the international market. Construction firms can choose to internationalise their business through an import or export mode or foreign direct investment mode (FDI) (Menipaz and Menipaz, 2011). Furthermore construction firms can reckon their business as being reigned by design, production and assembly. It can also be dominated by a hybrid of the aforementioned processes.

Teece (2007) explained that construction businesses could internationalise by being innovative in understanding their potentialities. This would enhance their sustained

competitive advantage in the industry. However Lambert and Cooper (2000) affirmed that the most significant paradigm shift of contemporary business management is that construction companies no longer compete as single sovereign entities, but rather as supply chains. However supply chains fundamentally aim at ways of delivering products and services to clients through efficient and effective flow of materials, plant, people, finances and information. Supply chain in the construction industry would help share business information and maintain good business relationships.

The most important barrier against trade is distance. Distance could constitute a barrier against the transportation of goods safely, on time, securely and with acceptable prices. However globalisation has made the construction industry feasible with technological developments and trade agreements that enhance sustainability in the construction industry. Globalisation further enhances cross-border civilisation which enable Multi-National Construction firms to operate without boundaries in various locations.

4. Developing global mindset capabilities of MNC firms in Ghana

The basic features of global mindset are the use of wide and numerous views as well as the ability to balance between contradictions, value diversity, foster teamwork, and exhibit receptiveness. Regarding global virtual teams, cultural intelligence teaches employees and managers ways to effectively work across cultures. Interestingly, Thomas and Inkson (2009) noted a paradox of cultural intelligence. That is, in order to acquire cultural intelligence one must practice by working in culturally different environments and with culturally different people; however, in order to work effectively with these different people in different environments, one needs to first be culturally intelligent. Indeed, a variety of experiences and training involve strategies for developing cultural intelligence and facilitating global mindset in Multi-National Construction firms' managers and employees. Furthermore international transfers and assignments, membership in cross-border project teams and task forces, international coordination roles can all be considered in developing global mindset. Distinctively earmarked for leaders of Multi-National Construction firms, international transfers and assignments are the strongest propellers for growing global mindset.

However, contemporary Multi-National Construction firms require managers who would easily embrace multiple cultures and work effectively within a global team. Training of managers using the conventional approaches of cultural training involves only country-specific noesis which is not enough and therefore requires the cultural intelligence approach. Cultural intelligence involves assessing an individual's specific competencies to render training in various ways.

According to Gupta and Govindarajan (2002) global mindset within Multi-National Construction firms can be acquired formally and informally. The formal path involves learning of new language skills and building knowledge about diverse cultures and markets where the MNC firms operate. The latter can also be acquired through informal means. It is further highlighted that expatriate assignments, cross-border collaborations and utilization of diverse location for team functions or meetings are some of the few informal ways that Multi-National Construction firms could choose to integrate within their leaning and development needs.

5. Performance implications of MNC firms

The universal principle of global mindset embodies the ability to stretch our highly diverse geographic and cultural cognitive filters through which one sees the world to a level where we

can integrate them into a hybrid perspective (Mansour, 2009). A construction firm is considered to have a global mindset when it has insights of diverse markets and cultures and can integrate across this diversity to gain new markets and products emerge (Mansour, 2009). The first of the key characteristics of global mindset for a construction manager is that, there is a genuine connection with people throughout the entire organization. Secondly is the capacity to manage under the ever changing circumstances. The third is the ability to strike a balance between global integration and local responsiveness. Finally, it relates to the ability to exhibit business intelligence and organizational intelligence (Kedia and Mukherji, 1999). Kedia and Mukherji (1999) further explained that intimate knowledge of the firm's capability within a set business context, current and future, and skills to put the knowledge into action are the two most fundamental attributes any Multi-National firm ought to focus on in order to advance their cause of gaining global mindset maturity. The competencies of management are very critical in the realisation of global mindset maturity which would enhance performance.

Performance is the accomplishment of a given task measured against predetermined standards of accuracy, completeness, cost, and speed. In a contract, performance is considered to be the accomplishment of an obligation, in a manner that discharges the performer from all liabilities under the contract. The Baldridge National Quality Programme (BNQP) (2008) describes performance as "outputs and outcomes from processes, products and services that permit evaluation and comparison relative to goals, standards, past results, and other organisations. In order to achieve performance improvement, the actual performance should be measured relative to a specified benchmark**.** Managers of construction firms who have the general tendency necessary for global mindset are more tolerant of other peoples and cultures, consider cultural diversity an asset, thrive on ambiguity, balance contradictory forces, and rethink boundaries which result in performance improvements. According to Gregerson *et al.,* (1998) global mindset, in its simplest form will allow a construction firm's manager from one part of the world to be comfortable in another part and perform well on account of knowledge and skills that are based on understanding and awareness.

6. Challenges and Strategic gains of global mindset in MNCs

Clashes in cultural orientation can have a major influence on the success or failure of a MNCs, but understanding the culture of the host country is only one part of orientation process (Varner and Palmer, 2006). One of the most important factors for MNCs when preparing to work successfully in a foreign country, is to know his or her own cultural orientation and how they influence "acceptable" behaviour within that cultural context (Maddi, 1999). Furthermore Maddi (1999) affirmed that it is crucially important to learn to overcome the belief that MNCs own cultural mindset would be the same in every other country and thus avoid judging culturally different behaviours negatively. The difficulty is that the majority of people are not consciously aware of their own cultural mindset. Typically in everyday life we are not aware of our own cultural behaviour since we consider it as natural way of being. This phenomenon is because we have adopted certain cultural demeanour from infancy and comply without witting effort (Varner and Palmer, 2006). This self-knowledge can come in to play for example in situations where negotiators might be more successful if they know why they feel what they feel. Thus, knowing oneself can contribute to success by being more realistic about how others see us. Additionally, a MNCs needs to not only know their priorities but also be familiar with the company's priorities and this will result in improvement in their performance (Varner and Palmer, 2006).

A pitfall to the success of MNCs is the problem of adaptation to the new country. MNCs experience emotional cycle and typically hit a low between six and twelve months after

starting an assignment (DeLollis, 2007). Difficulties connected with socio-cultural adaptation have been identified as the main source for many stress-induced reactions experienced by contractors on international assignments in confronting the day-to-day culture and norms of the host country (Pires *et al.*, 2006). The inability to perform effectively in the new environment typically results in lower than expected performance, poor management, low productivity, and failure to meet corporate objectives. Moreover, meeting the construction firm's objectives is dependent upon the MNCs successful sociocultural adjustments.

However, Oberg (1960) explained sociocultural adaptation as the anxiety that results from losing all our familiar signs and symbols of social intercourse. This adjustment phase refers to the subjective well-being or mood of the MNCs and means the ability to adjust and is related to stress and grappling contexts. Black *et al.*, (1990) suggest that the new unfamiliar setting upsets old routines and creates feeling of uncertainty in everyday life of the MNCs. At the same time, sociocultural adjustment is connected to foreign contractor's behavioural competence in social interaction. Earlier studies by Barhem (2008) have identified several factors that influence sociocultural adaptation, such as: Language fluency, Length of residence in the new culture, Cultural knowledge, Amount of interaction, Identification with host nationals, Acculturation strategies of the company. Failing to meet these factors during sociocultural adaptation process can produce stress and even depression in the MNCs which may result in a lack of productivity in the workplace or even premature return.

7. Research Methodology

This paper adopted a quantitative approach of enquiry for its data collection. The data collection utilised both primary and secondary sources. An intensive literature review was undertaken which discovered the academic paradigms supporting the subject which helped to identify the benefits and challenges of global mindset. After the literature review, survey questionnaires were designed using five-point Likert scales for the various questions where 1=strongly disagree 2=disagree 3=neutral 4=agree 5=strongly agree. The questionnaires were administered to management professionals in the various MNC firms who were sampled for the study. The management professionals included Project Managers, Quantity Surveyors, Site Engineers, Services Engineers and Architects. Literature revealed that most Multi-National Construction firms were located in the Greater Accra region of Ghana and for that reason, Accra as the capital was chosen for the study. The breakdown of the respondents involvement in the study include, 8 Project Managers, 10 Quantity Surveyors, 7 Site Engineers, 6 Services Engineers and 4 Architects.

Due to the difficulties encountered in assessing the population size, snowball sampling technique was adopted to locate the respondents and purposive sampling technique was used to arrive at the sample size. Kumar (1996) describes the snowball sampling technique as a process of selecting a sample by networking. The snowball sampling is an approach for locating information on rich-key informants. De Vos *et al.*, (2002), affirms that snowball sampling is valuable in research since it is directed at individuals that are difficult to identify. Using this approach, a few potential respondents were contacted and asked whether they know any other respondent with the characteristics that you were looking for in your research. This technique was adopted to reach hard-to-get respondents. A total of (10) ten MNC firms were contacted with (35) thirty-five self - administered questionnaires asking respondents to rate the relative importance of identified challenges and strategic gains of MNCs due to global mindset. Data was analyzed using a simple statistical tool that is Mean score ranking technique for ranking the challenges and strategic gains identified. Mean score ranking was used by Cheung *et al.*, (2012) to determine the relative importance of critical success factors

for public private partnerships (PPP) between the Hong Kong Special Administrative Region and Mainland China. The same method is adopted in this study within the various groups (i.e. management professionals). The five-point scale ranging from 1 (strongly disagree) to 5 (strongly agree) was adopted to calculate the mean score for each of the challenges and strategic gains as follows:

$$MS = \frac{\sum(f \times s)}{N}, \ (1 \leq MS \leq 5)$$

Where, S is the score given to each challenge or strategic gain by the respondents (ranging from 1 to 5), f is the frequency of each rating (1-5) for each challenge and strategic gain, and N is the total number of respondents.

8. Results and Discussion of Findings

8.1 Respondents Profile

The breakdown of the respondents involvement in the study include, 8 Project Managers, 10 Quantity Surveyors, 7 Site Engineers, 6 Services Engineers and 4 Architects of Multi-National Construction firms studied. Majority of respondents were Quantity Surveyors of the MNC firms.

8.2 Strategic gains of MNCs due to Global Mindset

The respondents were asked their opinions on the strategic gains of MNCs due to global mindset. This was carried out on a five point Likert scale ranging from 1 (Strongly disagree) to 5 (Strongly agree).Table 1 shows the ranking in descending order of these strategic gains using the method of mean score rankings from the perspectives of the five groups of respondents.

Table 1: Strategic gains of MNCs due to Global Mindset

Strategic Gains	***Mean***	***Std. Deviation***	***Rank***
Improvement in performance	*4.49*	*0.82*	*1st*
Understanding of global and local markets	*4.31*	*0.72*	*2nd*
Global positioning and outlook	*4.26*	*0.82*	*3rd*
Early identification of emerging opportunities	*4.20*	*0.90*	*4th*
Promoting internationalism	*4.17*	*0.79*	*5th*
Development of cultural awareness and openness	*4.11*	*0.90*	*6th*
Sharing of best practices	*4.06*	*0.97*	*7th*
Anticipation of change long before it occur	*4.03*	*1.07*	*8th*
Help to identify priorities	*4.00*	*0.94*	*9th*
Inter- cultural adaptation	*3.94*	*1.03*	*10th*
Cultural orientation adjustment	*3.77*	*0.97*	*11th*
Efficient cross border collaboration	*3.74*	*1.01*	*12th*

It can be inferred from Table 1 above that respondents' identification of the strategic gains of MNCs due to global mindset was grounded in to improvement in performance, understanding of global and local markets, global positioning and outlook, early identification of emerging opportunities and promoting internationalism. However, respondents ranked cultural orientation adjustment and efficient cross border collaboration very low (11th and 12th respectively).

Improvement in performance

Managers who have the general disposition required for global mindset are more liberal with other people and cultures, consider cultural diversity an asset, thrive on ambiguity, balance contradictory forces and reconsiders international boundaries. Global mindset of managers result in improvement in their performance wherever they find themselves (Kedia and Mukherji, 1999). It is however not storming that respondents in the study named *improvement in performance* as the most significant strategic gain of global mindset to MNCs.

This strategic gain of global mindset was the highest ranked (4.49, 1st) in Table 1. This is in confirmation with Levy *et al.,* (2007) that multi-national companies with global mindset concepts operate profitably and improve performance across different countries, cultures and contexts. Moreover MNCs with global mindset operate comfortably perform well other countries on account of knowledge and skills developed.

Ability to understand global and local markets

Global mindset includes the power to stretch our diverse geographical and cultural cognitive filters through which one sees the entire world as a level where people integrate into hybrid perspective. (Mansour, 2009). A firm is regarded as having a global mindset when it has insights of diverse markets and cultures and has the ability to integrate across this diversity to acquire new markets and products. The first of the key characteristics of global mindset for a manager of a firm is that, there is a genuine connection with people throughout the entire organization. Secondly is the capacity to manage under the ever changing circumstances. The third is the ability to strike a balance between global integration and local responsiveness. The most relevant value of global mindset exist in enabling Multi-national construction firms to combine speed and response to changes in the market places in order to understand global and local markets so as to build cognitive bridges across them (Levy *et al.,* 2007). In this study respondents ranked *Ability to understand global and local markets* (*4.31, 2nd as in Table 1),* as the second most relevant strategic gain of global mindset to Multi-National construction firms. This infers that MNCs with global mindset would be able to understand each market of operation being it global or local markets.

Global positioning and outlook

Merton (1957) explained that global consumers of products and services are within the reach of local context and reside locally, they require globally accepted standards and thus very demanding. Possessing a global mindset would enable firms meet the ever demanding preferences. Moreover global mindset gives firms that global outlook that helps them to meet the needs of their clients. This strategic gain acquired a mean score of 4.26 and was ranked 3rd from Table 1. The study revealed that MNCs acquiring a global outlook through the possessing of global mindset is a very relevant strategic gain.

Early identification of emerging opportunities

Respondents indicated that MNCs with global mindset's identification of emerging opportunities in time is very relevant to the retention in business. This affirms Gupta and Govindarajan (2002) assertion that one of the benefits of global mindset to MNCs is being

able to identify emerging opportunities early and a faster roll-out of new product concepts and technologies. Furthermore early identification of emerging opportunities (Mean score=4.20, ranked 4th in Table 1) has been revealed in this study as a significant strategic gain to MNCs with global mindset.

8.3 Challenges faced by MNCs due to Global Mindset

The respondents were asked their opinions on the challenges faced by MNCs due to global mindset. This was carried out on a five point Likert scale ranging from 1 (Strongly disagree) to 5 (Strongly agree).Table 2 shows the ranking in descending order of these challenges using the method of mean score rankings from the perspectives of the respondents.

Table 2: Challenges faced by MNCs due to Global Mindset

Challenges	***Mean***	***Std. Deviation***	***Rank***
Difficulties with socio-cultural adaptation	*4.11*	*0.99*	*1st*
Distressed in new setting	*3.97*	*1.15*	*2nd*
Limit performance	*3.86*	*1.12*	*3rd*
Uncertainty in everyday life	*3.83*	*1.25*	*4th*
Stressful situations	*3.80*	*1.26*	*5th*
Depression due to new environment	*3.77*	*1.31*	*6th*
Prisoner of differences in another culture	*3.74*	*0.95*	*7th*
Strain on contractor due to new setting	*3.71*	*1.02*	*8th*
Inability to perform in different settings	*3.71*	*1.47*	*9th*
Premature return to home country	*3.31*	*1.39*	*10th*

From Table 2 above that respondents' identification of the challenges faced by MNCs due to global mindset was anchored on difficulties with socio-cultural adaptation, distressed in new setting, limit performance, uncertainty in everyday life, and stressful situations. However, respondents ranked inability to perform in different settings and premature return to home country very low (9th and 10th respectively).

Difficulties with socio-cultural adaptation

Socio-cultural adaptation is very essential to the business environment of Multi-National companies. This adaptation enables MNCs to operate effectively across the globe. Most MNCs upon arrival in different locations globally find it very relenting to adapt to the socio-cultural practices of their host locations. Difficulties connected with socio-cultural adaptation have been identified as the main source for many stress-induced reactions experienced by MNCs on international assignments in confronting the day-to-day culture and norms of the host country (Pires *et al.*, 2006). It was not surprising when respondents in this study identified *difficulties with socio-cultural adaptation* as the most relevant challenge faced by MNCs.

This challenge was top-ranked (4.11, 1st) in Table 2. This in support of Tung (1981) that meeting the firm's objectives is dependent upon the MNCs successful socio-cultural adaptation. Oberg (1960) explained socio-cultural adaptation as the anxiety that results from losing all our familiar signs and symbols of social intercourse. This adjustment phase refers to

the subjective well-being or mood of the MNCs and means the ability to fit in and is associated with stress and coping contexts. Difficulties with socio-cultural adaptation was a major concern reported in this section and a major challenge faced by respondents so as to improve their performance in their new settings.

Distressed in new setting

Distressed in new setting which was indicated by White *et al.,* (2011) that MNCs in new settings feel distressed with its individuals exhibiting low hardiness in the form of increased depression and anxiety. However hardy individuals are upbeat, optimistic, and view challenges in a positive light. Hardy individuals are also able to view activities as attractive and pleasant, as being a matter of personal choice, and as important stimulus for learning. This challenge obtained a mean score of 3.97 and ranked 2nd in Table 2. The table revealed that distressed in new setting is a significant challenge to MNCs due global mindset.

Limits performance

Limitations on performance of MNCs was emphasized as a key challenge. The finding revealed that MNCs upon arrival in their new settings face situations that limit their performance. This affirms Kedia and Mukherji (1999) assertion that MNCs on assignments in other countries take a long time to settle in order to improve upon their performance. Limits performance of MNCs was ranked 3rd with a corresponding mean score value of 3.86. MNCs must find constructive ways in order to adapt to survive, and the most adaptable organizations will be best positioned to explore the possibilities hidden amid the chaos and to respond with innovative solutions to the complex challenges they face in order to improve their performance.

9. Conclusion and Recommendations

Global mindset has become extremely relevant for the survival of MNCs throughout the world. Although most MNCs with global mindset capabilities are better positioned to succeed on international assignments, these MNCs still face certain challenges despite the numerous strategic gains identified. A key obstacle to the success of MNCs is the adaptation to the new country. Difficulties connected with socio-cultural adaptation have been identified as the main source for many stress-induced reactions experienced by MNCs on international assignments in confronting the day-to-day culture and norms of the host country (Pires *et al.*, 2006). Notwithstanding, this study contributes to the existing knowledge on the challenges and strategic gains to MNCs due to global mindset in the Ghanaian context. The findings of the study affirm the argument that developing a global mindset increases the MNCs performance and success.

The recommendations advanced regarding this study with a bid to improve the performance of MNCs are: MNCs must devise a training ‘policy’ to train its workforce on cultural-intelligence where training is based on individual weaknesses in order to help them adjust fully into their new settings when they are on assignments since the conventional methods of cultural training rely on country-specific knowledge are not adequate, measures must be adopted to achieve the benefits of global mindset as established. In addition, MNCs must be proactive in dealing with the challenges presented by global mindset in order to improve their performance. Being proactive will prepare the MNCs to provide contingency plans to cater for these challenges.

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RESEARCH AND EDUCATION

BIM in Teaching - Lessons Learned from Exploratory Study

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Abstract

Building Information Technology bears promise to bring integration into fragmented AEC industry, as well as large potentials for optimization and management of building performance along life cycle. However, the adoption in Central Europe is much slower than in the USA or Scandinavia; the designers and planners are sceptical about BIM benefits.

In order to build up capabilities and thus support BIM adoption in the practice, BIM skills have be built up already in university teaching. This endeavour is the central aim of the BIM_sustain project accomplished at the Vienna University of Technology. In winter term 2012/13 and winter term 2013/14 we accomplished interdisciplinary BIM-supported design labs with student participants from architecture, civil engineering and building science. The teams used different modelling and simulation software constellations for building design and analysis. The software-constellations were evaluated in terms of BIM-interoperability, and the design process was documented by means of time and activity assessment, surveys on team performance, process satisfaction and technology acceptance and focus group interviews.

In this paper we will present the results of the evaluation of both courses and analyse the differences resulting from the different course design in the two consequent terms.

The first course was dominated by the issue of interfaces, whereas the second course, where better functioning software combinations in terms of data transfer were used, was dominated by the issues related to the collaboration and teamwork.

Our results are not only informative for the configuration of interdisciplinary BIM-supported university teaching, but can be derived for the practice as well, especially in the areas of project management, software usage, modelling conventions or incentive systems.

Keywords: BIM, exploratory study; colaboration, simulation; analysis

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1. Introduction

Building Information Modelling (BIM) as powerful tool bears significant potential to enhance the integrated project delivery, as well as to accelerate its implementation in the practice (Fellows and Liu, 2010).Thereby BIM represents a catalyst for the reduction of largely fragmented AEC (CWIC, 2004) – so is the hope both on the academic as well as industry side. BIM tools offer support for interdisciplinary planning and design, where by digital, parametric building model represents a joint knowledge base, enabling interdisciplinary data exchange and management along the life cycle of a building (Penttilä, 2006). BIM tools offer numerous possibilities for coupling of various analysis and simulation tools, thus enabling energy and resources analysis and optimization in the early design stages (Azhar et al., 2011).

The adoption of BIM tools is significantly slower in Central Europe compared to the Scandinavian or Anglo-Saxon countries (McGraw-Hill, 2010). Further on, empirical evidences for actual BIM benefits are hardly available (Jung and Joo, 2011), since very few of the adopters are actually employing any measuring strategies. The greatest challenges for the implementation of BIM tools have been identified outside of the technical domain – in the realm of processes, stakeholder-networks and policies (Gu and London, 2010; Linderoth, 2010; Succar, 2009).

Within this background, a research project BIM_sustain funded by Austrian Funding Agency FFG was carried out at the Vienna University of Technology, as research led teaching, in order to analyse the benefits of BIM supported planning and to develop a framework for guidelines for the AEC practice. The project was carried out in the cooperation of three Departments of the Faculties for Civil Engineering, Architecture and Mechanical Engineering, together with seven BIM software developers and vendors. The research aim was to identify BIM potentials for process-integration; through empirical research using experimental study. The study was carried out as interdisciplinary design course, taking place in the winter semester of 2012/13 (pilot experiment) and 2013/14; with follow up in 2014/15, with the students of architecture, civil engineering and master of building science.

This paper is structured as following: In the next chapter we will present the design and the structure of the empirical study (courses), the team-structure and used software-constellations. In the third chapter we will present the results of the study obtained through quantitative analysis of the post-questionnaires, time-sheets and protocols; closer attention will be paid to the differences of the both courses resulting from the changed design of the study. In the fourth chapter we will summarise and discuss the results, presenting the experience of the teaching staff and in the last chapter we will draw the conclusions for the practice as well as for the future design of BIM-teaching classes.

2. Experiment Design

In order to evaluate the possible benefits of BIM supported design, we organised an experimental study as interdisciplinary, interfaculty design course: “Interdisciplinary BIM-supported planning concepts”. The course was organized and carried out and as collaboration of two faculties – Faculty for Civil Engineering, Institute for interdisciplinary building process management, and Faculty for Architecture, Department for Building Science and Department for Design and Architecture. The course, simultaneously the experimental study, was accompanied and evaluated by the research partner Institute for Management Sciences, Faculty for Mechanical Engineering, who was mainly in charge for the data gathering.

Thereby not only the students of architecture, engineering and building science were obliged to work in interdisciplinary teams, but the teaching team as well.

The course had two major aims:

- To teach and demonstrate functionalities of BIM tools
- To evaluate BIM tools in interdisciplinary design setting, with special focus on interfaces

The interdisciplinary teams had an assignment to compile in collaborative manner the architectural, structural, ventilation model and conduct thermal and lightning simulation, as well as calculate the energy certificate. The models and related data had to be exchanged between the team-members. The teams worked with different software constellations, employing following software: Archicad, Allplan, Revit, Tekla, RFEM Dlubal, Scia, Plancal, Archiphysik, Dialux, Energy Plus; in order to test the compatibility and functioning of interfaces. The process was accompanied by the Institute for Management Sciences, gathering data through pre-questionnaires, evaluation-questionnaires, and focus-group interviews. The students were asked to record the time-effort and conducted tasks using time sheets and protocols, which enabled exact assignment of time to specific task.

The research aim was to evaluate the multi-disciplinary collaboration and potential for enhancement of integration using BIM tools on two levels – assessing the satisfaction with technology – through evaluation of interoperability, usability and usefulness (TAM model); and satisfaction on people-process level – evaluating cooperation, results and process.

Through conducted research the insights in the functionality of BIM tools for the modelling requirements of specific disciplines (architectural design, structural analysis, thermal and daylight simulation) as well as interoperability for data exchange between the part-taking disciplines could be assessed.

Through out the first cycle (WS 12/13) 11 teams, with overall of 35 students were taking part – including 9 architects, 11 civil engineers and 15 building scientists. In the second cycle (WS 13/14) 12 teams took part, with overall of 44 students – 13 architects, 8 civil engineers, and 23 building scientists.

		Architekt		Bauingenieur			Building Science		
		CAD		CAD	FEM		CAD	Berechnungen
1	1	Allplan	1	Allplan	Scia Engineer	1	Allplan	Allplan
2	1	Autodesk Revit Architecture	1	Autodesk Revit Structure	SOFiSTiK	2	Autodesk Revit MEP	PLANCAL
3	2	ARCHICAD 16	1	TEKLA	Dlubal	1	PLANCAL	PLANCAL
4	2	ARCHICAD 16	1	Allplan	Dlubal	2	PLANCAL	PLANCAL
5	1	Autodesk Revit Architecture	1	Allplan	Scia Engineer	1	PLANCAL	PLANCAL
6	1	ARCHICAD 16	1	Allplan	Dlubal	2	Autodesk Revit MEP	PLANCAL
7		Allplan	1	TEKLA	SOFiSTiK	1	Autodesk Revit MEP	PLANCAL
8	1	Autodesk Revit Architecture	1	TEKLA	Scia Engineer	1	Allplan	Allplan
9	1	ARCHICAD 16	1	Autodesk Revit Structure	Dlubal	1	PLANCAL	PLANCAL
12	1	ARCHICAD 16	1	Allplan TEKLA	Dlubal	1	Autodesk Revit MEP	PLANCAL
13	2	ARCHICAD 16	1	TEKLA	SOFiSTiK	2	Autodesk Revit MEP	PLANCAL

Fig. 1. Software-Matrix and Teams in WS 2012/13

The assignment of the first cycle comprised a design of a low energy office building, where as the students were given a functional and spatial program, a layer structure, the pre-set zero, and a colour scheme for room stamps. The students were assigned to the specific software, according to their experience level, which was assessed via pre-questionnaire. The questionnaire assessed: demographic data, relevant professional experience (full employment equivalent months) as well as the experience with the single software tools.

Each team was assigned a specific software constellation, for the compilation of architectural, structural and ventilation model. The software-matrix, reflecting simultaneously the team structure, was developed by the research (teaching) team, in order to obtain the greatest possible diversity of the software constellations (Fig. 1).

The task of the team was to develop an integrated design, consisting of architectural model comprising functional and formal concept, a load bearing structure model, ventilation model, and an energy concept with proof-of-concept (simulation and optimization) in collaborative manner.

In the following cycle (WS 13/14) the design of the course was changed based on the experience and student feedback of the former cycle. In this term the task was changed to a design of a multi-functional culture centre, providing a specific location (Margaretengürtel, 1050 Vienna). We organized a moderated Kick-off Workshop, where students were able to choose the team as well as the software. Some of the participants opted for learning the new software, choosing the team with similar interests rather than the familiar software. However, the post-questionnaire indicated that the familiar software was more important for the team-choice than choosing the team with similar interests for the most of the participants (Fig. 2).

In this term, next to the models required in the pilot-experiment (architecture, structure, ventilation and daylight) also an acoustic simulation was a part of the assignment.

		Architekt		Bauingenieur				Building Science	
		CAD		CAD	FEM			CAD	Berechnungen
1	1	Allplan	1	Allplan	Scia		2	Allplan	Allplan
2	1	ARCHICAD 16	1	TEKLA	Dlubal		2	PLANCAL	PLANCAL
3	1	Autodesk Revit Architecture	1	Autodesk Revit Structure	Dlubal		2	Autodesk Revit MEP	PLANCAL
4	2	ARCHICAD 16	1	Autodesk Revit Structure	Dlubal		2	PLANCAL	PLANCAL
5	1	ARCHICAD 16	1	Autodesk Revit Structure	Scia		2	Autodesk Revit MEP	Allplan
6	1	Autodesk Revit Architecture	1	Allplan	Scia		2	PLANCAL	PLANCAL
7	1	ARCHICAD 16	1	Allplan	Dlubal		2	Allplan	PLANCAL
8	1	Autodesk Revit Architecture	1	TEKLA	Dlubal		2	PLANCAL	PLANCAL
9	1	ARCHICAD 16					2	PLANCAL	PLANCAL
10	1	ARCHICAD 16					2	PLANCAL	Allplan
11	1	ARCHICAD 16					2	Autodesk Revit MEP	Allplan
12	1	ARCHICAD 16					2	Autodesk Revit MEP	PLANCAL

Fig. 2. Software-Matrix and Teams in WS 2013/14

The course was in both terms accompanied by the software-companies, who offered training for specific software, according to the pre-determined schedule. The companies also supported the data transfer process and carried out the model integrity and collision proofs.

3. Results

The conducted study was evaluated through quantitative analysis, based on the evaluation of the post-questionnaires and of the time-sheets and protocols compiled by the students.

The post-questionnaires included inquiries related to the satisfaction with the process, result and team-work; as well as the technology-related questions including satisfaction with interoperability, usefulness and usability.

These latent constructs where measured by multiple items on a 5-point Likert scale ranging from low/disagree (1) to high/agree (5).

After the examination of the quality of scale using Cronbachs α, the median per construct was built and the evaluation according to the discipline: Architecture (ARCH), Civil Engineering (CI) and Master of Building Science (BS); as well as over all disciplines.

In the second cycle the students were obliged to lead protocols and exact time-sheets with attributed activities, in order to enable the assessment of time-effort necessary for a specific activity.

Additionally, a qualitative evaluation was carried out in form of focus-group interviews, also serving for de-briefing of the students, where the interviews with participants of each discipline (architects, engineers and building scientists) were carried out at the end of the experiment.

The post-questionnaires assessed team-satisfaction (Fig. 3) with:
- process ("I have performed my tasks efficiently.") – 4 questions
- result ("The aims that I have set have been achieved.") – 4 questions
- cooperation – 4 questions

The software related questionnaire (Fig 4.) included questions related to:
- ease of use ("The software increases my productivity.") – 6 questions
- usability ("In total I think the software is useful for my tasks.") – 6 questions
- according to technology acceptance model (TAM) of Davis (1989) model and additionally
- interoperability as a BIM specific feature of software applications

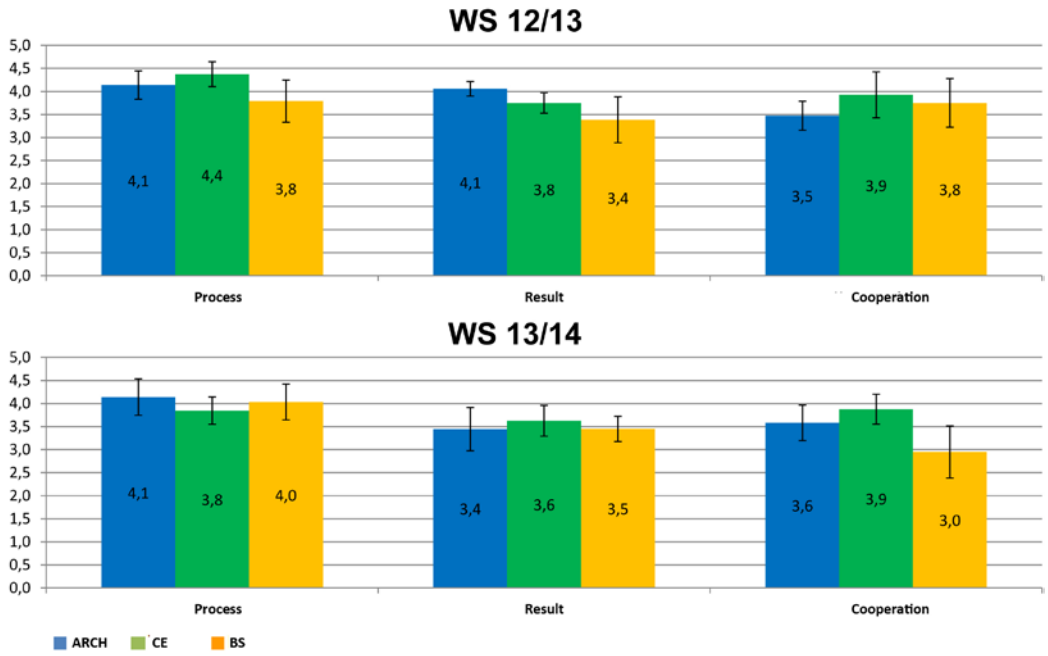

Fig. 3. Evaluation of satisfaction with Process, Result and Cooperation in team for WS 2012/13 and 2013/14

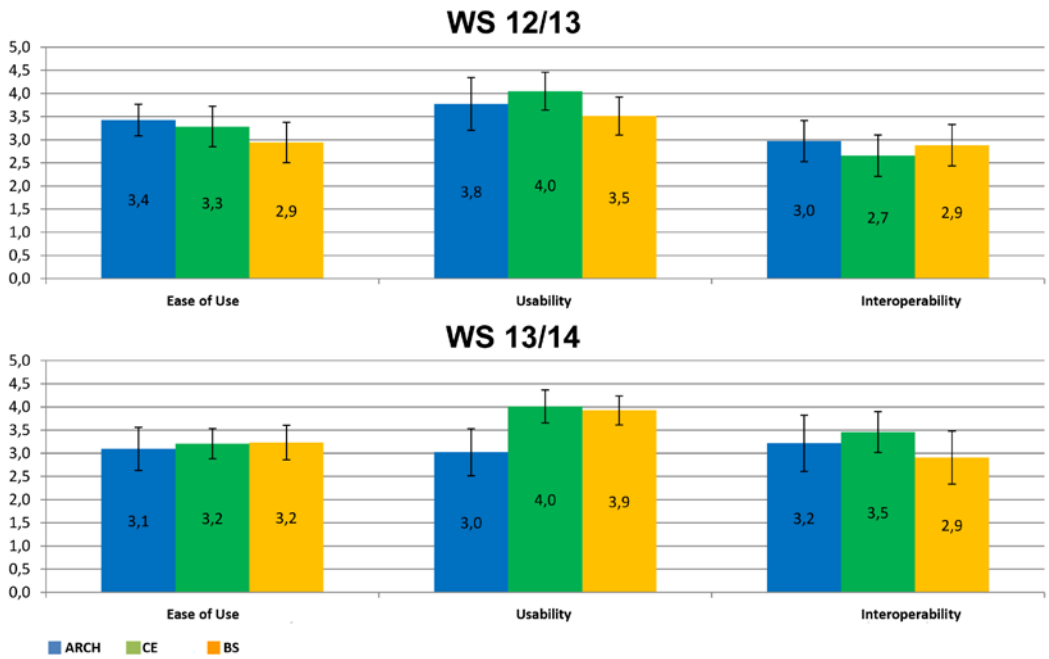

Fig. 4. Evaluation of satisfaction with Process, Result and Cooperation in team for WS 2012/13 and 2013/14

By trend the usability is perceived as highest by the civil engineers, since they profit from the models in the process of analysis and simulation. Interoperability is perceived in both cycles as the category with lowest performance, especially so by the subsequent disciplines who import the architectural models. Lack of interoperability is resulting in the wrong interpretation of geometry, leading to significant efforts for repairing of models or even complete re-modelling.

The lowest is satisfaction with the cooperation in the planning team, against the expectation in the second cycle where the kick-off meeting was introduced.

The time-assessment (Fig. 5) shows that the direct communication respective coordination within the team is the second-high time intensive task, next to the actual planning in form of technical planning (modelling) and conceptual design; which supports the hypothesis that BIM-supported planning is communication and coordination intense.

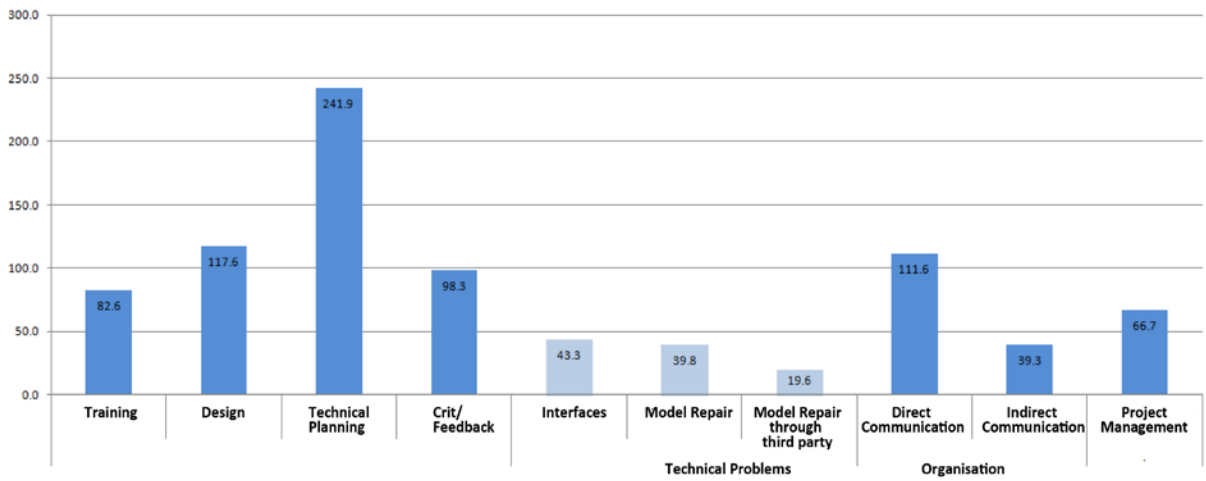

Fig. 5. Time effort in hours for specific activity (task), based on evaluation of time sheets in WS 2013/14

4. Lessons Learned

4.1. Lessons learned from the pilot-experiment

The hypothesis, that the introduction of BIM alone would support or enhance the integrated planning, was not confirmed. The students were working in sequential manner, starting with the creation and modelling of architectural model, over structural modelling till thermal and daylight simulation and optimization in the end. The teams were not teams, but groups, until the point of last presentation, where the team forming finally took place (the joint model had to be presented). This can be related to the lack of Kick-Off workshop. The participants reported numerous problems and conflict, mostly resulting due to the incompatible software-constellations lacking working interfaces.

Due to the inter-faculty collaboration, the course was awarded varying number of ECTS (credits) at different faculties. The architects obtained in this cycle only 2,0 ECTS, the civil engineers 6,0 ECTS and master of building science even 8,0 ECTS in their respective curricula. The difference in the ECTS resulted in numerous conflicts, due to unequal task distribution and related credits / awards.

4.2. Lessons learned from the second cycle

Learning from the pilot-experiment, the second cycle was more thoroughly structured and designed. Integrated working cycles were interlaced with sequential phases; a Kick-Off Workshop was organized for team-building and -forming. The proposed software-combinations were chosen more carefully with respect to interoperability, in order to support the planning process. A better team-spirit, easier coordination and stronger joint vision could be observed as result. In this cycle the awarded ECTS were more balanced, due to the facts that the architects obtained 5,0 ECTS, since BIM course took place as the “Design Studio” in the specific curriculum.

4.3. Lessons learned both cycles

The students have concentrated basically either on the learning of the new software or on the new functionalities of the software (compilation oft he IFC files for data-transfer). The second learning focus was the multidisciplinary collaboration, which is also a learning process. With these simultaneous new tasks, the students were not able to concentrate and optimize the actual design task. This phenomenon was observed in both cycles – this is the so called trade-off of interests, which can be expected when a task with several newly imposed requirements is posed.

Interoperability is one of the most important issues, on the software level, as well as on the level of people and process, being the origin of many conflicts and re-modelling efforts.

Next to the problem of lacking software interoperability, the further cause of conflict was the diverging modelling semantics – the way each discipline perceives and models the space and consequently the geometry.

For example the architectural modelling of the pillar is from slab to slab; where as the structural engineers requires continuous pillar in the full height of built structure for a proper analysis. The structural model obtained from architectural software is full of gaps; automated model repairing procedure is still lacking. The question remains, whose responsibility or task it is to repair the slabs.

The differences considering the modelling quality emerged not only between the students of various disciplines, but also between the teaching team and the students. The teachers criticised the lack of the model and design quality, where as the students evaluated their own performance despite all of the difficulties related to the software and team-communication as good. This can be interpreted as the relative self-assessment – compared to the import-export software problems and necessary team-coordination efforts, the final result for the participants is satisfactory. Thereby employing solemnly the self-assessment through questionnaires and focus-groups for the evaluation of the quality and performance is not sufficient.

The positive experiences related to the collaboration in the integrated processes outweigh the negative ones, especially so for the architects and civil engineers, the data exchange and collaboration in the early design stages in experienced as inspiring and interesting.

However some of the architects feel put under pressure and limited in the creativity when working in such setting. Helpful is the experience in specific discipline, such as e.g. building science master with architectural bachelor background, since the process-knowledge was already there, so the requirements of the discipline could be considered.

Early determination of modelling standards was typical for the very efficient groups. The architect took over management and coordination functions in many groups, since they had free resources after creating the original model. Diverging motivation and incentives can be conflict-triggers, as obvious from the varying ECTS issue, a problem that can be transferred one-to-one to the practice. An intensive collaboration on a joint BIM-knowledge model makes a group-dynamics an important topic in BIM research.

Finally, the organization of a multidisciplinary university course without explicit support and placement in curricula is particularly difficult, since the curricula are very extensive and do not foresee this kind of collaboration. This insight can be used as a parable for the practice, where an awareness for necessary resources and exact planning and design of multidisciplinary collaboration on corporate or project-level is needed.

5. Conclusion

The evaluation of the collected data shows that for the realization of integrated planning the sole adoption of BIM-tools is not sufficient. In the pilot experiment the students were planning in sequential manner, the modelling of the one discipline followed in succession to the other. In the second cycle due to the course design (Kick-Off meeting, a series of joint workshops) it was possible to achieve a better process integration.

The topics of software interoperability dominated the focus group interviews, which served for feedback and reflection, conducted at the end of the course with the partaking disciplines.

The lack of the operability of used software resulted in additional work-effort, leading to conflicts in work-load distribution – e.g. who will undertake the necessary repairs or re-modelling? This problem was especially clear in the so called BIM (Building Information Modelling) to BEM (Building Energy Modelling) step; where architectural models were transferred in the thermal simulation software environment, where the transfer is possible only using proprietary interfaces, and on the other hand numerous geometry interpretation problems emerge due to the semantical model differences.

The students were confronted with two new tasks – learning of the new BIM software or new functionalities related to the data transfer within known BIM software which was not used in the practice; as well as the learning of the simultaneous, interdisciplinary planning. The introduction of two new tasks resulted with relatively low project-quality (design-quality).

The participants anticipated the additional time effort and chose pro-actively a design of reduced complexity; or were forced to lower the design ambitions; due to the fact that the data transfer and team coordination consumed too much time.

The necessity for further development of open interfaces such as IFC, development of modelling standards and procedures, but also necessity for design of design process; as well as BIM skills and training could be identified as critical factors for successful implementation of BIM in the AEC practice.

Finally we see the hypothesis confirmed that BIM software is useful for planning, simulation and optimization; however these processes require a more intensive communication and team coordination as the design-process using traditional CAD tools.

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Project Management Software Based on BIM to Evaluate Construction Time and Cost

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Abstract

The proposed paper represents the achieved research results obtained within study semester at the master degree using the Project Management Software based on building information modeling (BIM). The main purpose of the research was to simulate the integration of a selected Project Management Software in a Construction Company in the pre-construction and construction phase of a construction project. The main goal was to collect and evaluate suitable data that are necessary for Contractor on site to complete a construction project timely and within the budget. The research work within student practical work was performed in six steps. In the first step, one 3D model was chosen from four different available models. In the next step, the 3D model was divided into four proportional groups of construction elements for further consideration in separate groups of students. All students groups have the same starting-point which was not limited from the used technology and materials, as well as execution of time and cost point of view, but at the end they had to offer a real propose. In the next step they had to make the decision about technology and materials for construction. Further the appropriate norms for used resources and their costs per unit should be defined. The main goal of the fifth step was to use the Project Management Software Vico Office 5.0 to collect all data and implement them into the final solution that represents 4D and 5D information model. Finally they had to present the obtained results and findings with regard to advantages and disadvantages of the usage of this software, eventual obstacles in their work and suggestions for improvements and further research.

Keywords: project management; project scheduling; cost estimating; building information modeling; BIM

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1. Introduction

Appropriate cooperation of all participants in the process of construction project activities and the simultaneous usage of proper software in all phases are gaining in importance in construction industry. This leads in an individual phase of the construction project to great number of data which are complimented and upgraded; and their integrated processing presents the challenge for software developers.

In the past, results of separate treatment of the construction project were gained in the certain phase, and they represented the individual part of the project. Many times this led to various discrepancies, errors and defects in the integrated processing of the construction project (Koskela et al., 2002). Moreover, inefficient management of construction projects resulted into large differences between the planned and accomplished tasks of the construction projects (Ballard and Howell, 2003). Many researches and observations of implementation of the projects at that time showed that such a concept model often brought about failures in terms of timely accomplishment, expected costs and desired quality (Abdelhamid, 2004). Many negative experiences in projects led to the need after revision of used principles of project management. Partial results were presented at Sixth Annual Survey of Owners (FMI/CMAA, 2006) where so-called Lean Construction Principle was defined, presenting modeling of production system for reduction of consumption/loss of materials, time, and costs at maximal realised values. Therefore, the activities in construction industry are researched at Lean Construction Institutes worldwide and many already implemented tools, techniques and methods (CPM, work breakdown structure, etc.) are combined; Building Information Modeling (BIM), process design, offsite fabrication, Just in Time (JIT) and unique systems such as Last Planner System (LPS), Target Value Design, and the Lean Project Delivery System (LPDS) are implemented.

The implementation of a modern approach, named building information modeling (BIM) (Eastman et al., 2011) has radically changed integral processing of projects in construction industry (AEC). The basic concept of this approach is chain connection of all participants who contribute to the integrated information of construction projects with single phases, stored in one place (Pučko et al., 2014). Therefore, 3D model enables object design, 4D information model enables time scheduling, 5D information model enables cost estimating, 6D information model provides users with information about the operation and maintenance of the facility throughout its life cycle. Sections of information modeling with respect to construction project phases are shown in Figure 1.

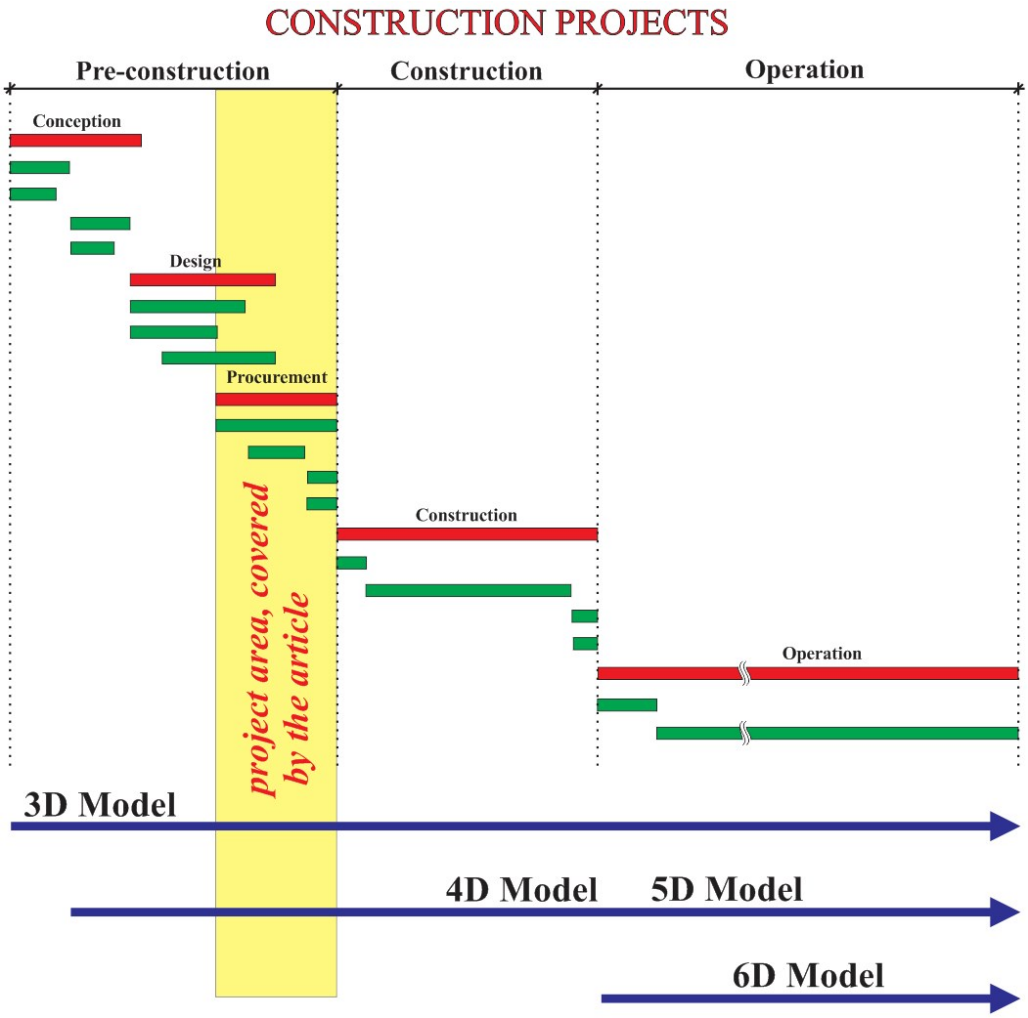


Fig. 1.Construction projects phases, sections of information modeling and the project area, covered by the article

The article presents step by step students' work and their usage of the Vico Office 5.0 software for project management with preliminary preparation of input data, their appropriate processing and elaboration of 4D and 5D information model of the chosen construction project. The conclusion presents students' findings with regard to advantages and disadvantages of the usage of this software, eventual obstacles in their work and suggestions for improvements and further research.

2. The Usage of The Software for Project Management with BIM in Educational Process

The subject Project management in construction in Master study programme Civil Engineering provides basic knowledge in construction project management with lectures, tutorials and laboratory work. Students work in groups on a practical example from a construction project in pre-construction phase. In this way they simulate the process of pre-construction project phase as the work in construction companies and where they plan the use of suitable resources for activities in respect to available technology. However, the deadline and costs of the project are pre-determined in the construction company, but the students do not have these limitations. Hence, they can freely choose the technology and materials, and they are not limited by the deadlines and costs. In this way innovative approach to project implementation is ensured. Nevertheless, the final result should provide real implementation in practice so that a quality project could be implemented within reasonable time and costs. The students should provide variant solutions of project implementation and finally decide for the most suitable version. This is explained in their presentation of the results within 4D and 5D information model of the construction object. They also name potential obstacles in the

process of implementation, adjustments and limits.

Since practical work is limited to 15 hours of tutorials and 15 hours of laboratory work only, all other activities for the conclusion of practical example are students' individual work. This is why we used a finished 3D model of construction object to skip the conception and design phase of a construction project. Furthermore, the phase of implementation is also not processed practically, because the observation in real time of the construction on site is impossible. Consequently, 6D information model of the construction object is also not feasible.

The students use various software tools for their practical work in their own judgement (MS Office, ArchiCAD, Revit, Autocad ect.), but the main emphasis is on the programme tools for project management with BIM, which is Vico Office 5.0.

3. Practical Example

The student practical work was performed in six steps, which are presented in details in the paper below.

3.1. First step – 3D model choice

Architectural bureau Arhilab d.o.o. from Maribor provided 3D models of different construction objects for research and study purposes, as shown in Figure 2. All those 3D models of construction objects were made by ArchiCAD 12 software.

Fig.2. 3D models of construction objects

Together with students we closely examined each 3D model and discussed the possibilities of its implementation in tutorials. We discussed about the types of construction technologies, possible materials, resources for implementation, etc.

We decided upon 3D model of the object called "Vila ob parku" (eng. "Park villa") which was commissioned for the known investor. Anyway, the building was not implemented, so this 3D model is a project study. The expected location is beside the city park in Maribor, the situation is seen from Figure 3.

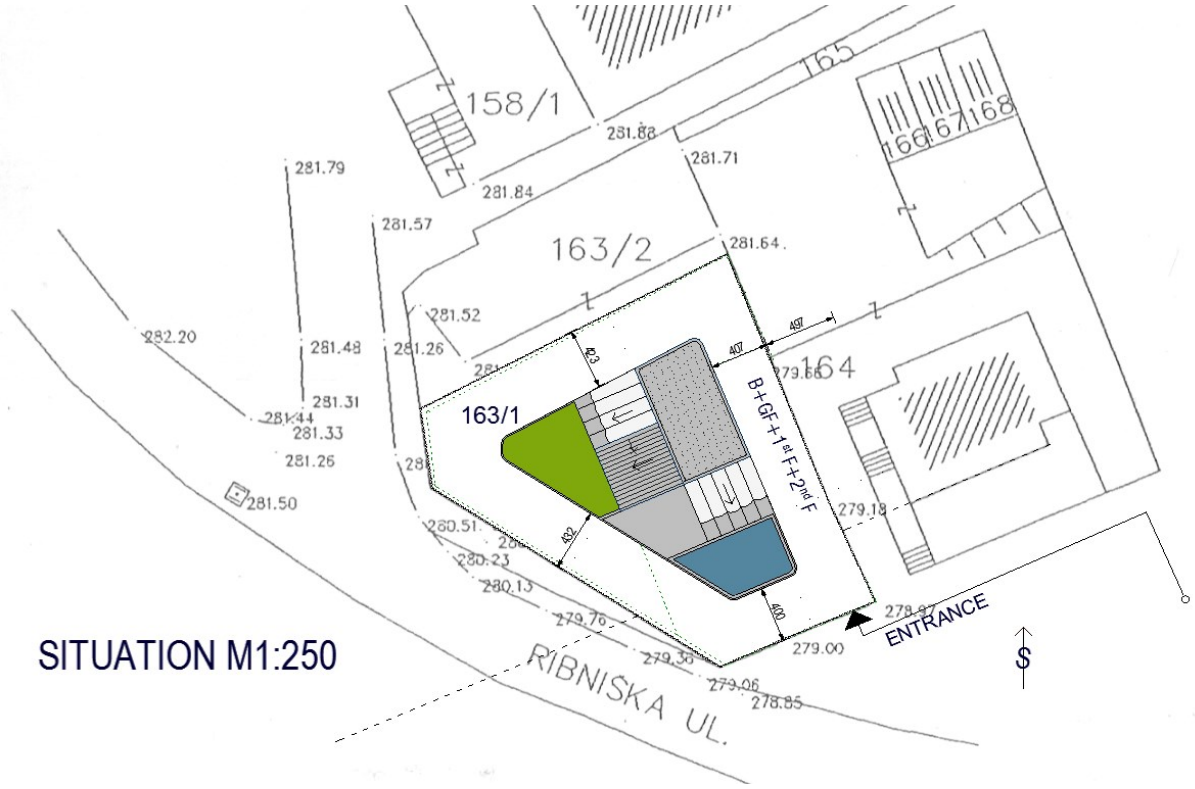


Fig.3. Location of the object “Vila ob parku”

The students were given 3D model only (without technical report, quantity take-off, and similar) and were left to choose the method of construction technology, construction materials and required equipment for object construction. In this way students could use the knowledge, gained in the courses of their study.

Four groups of students were formed; each group discussed only certain category of construction elements (evident from Table 1). The detailed analysis of the “Vila ob parku” design was made by all.

The object analysis provided the following findings: the residential object has four apartments and it consists of four floors. The basement is intended for parking in the open part of the object, and for house depository, bicycles and staircase in the closed part. Two apartments are on the ground floor. The area of the first one is 83.92m^2, the area of the second one 65.95m^2. The size of the apartment on the first floor is 147.78 m^2. The living area of the apartment on the second floor is 133.21 m^2 and the size of the open terrace is 16.65 m^2. The roof is flat with the pitch of 2% and has a central vertical drainage system.

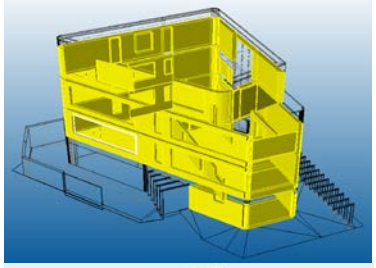
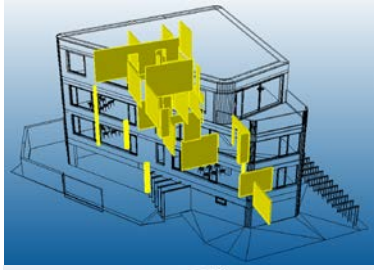
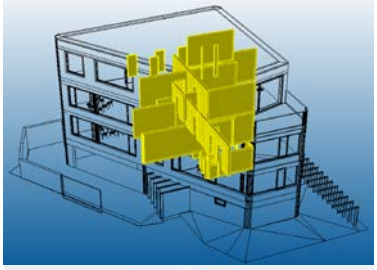
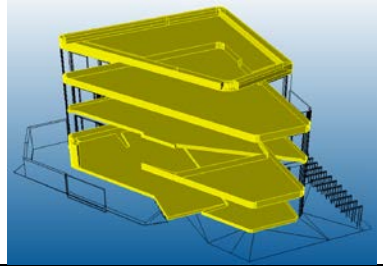
3.2. Second step – Division of 3D model of construction obect

First, the pre-made 3D model was exported from ArchiCAD software into Vico Office 5.0 software with the option “Publish to Vico Office” for further object processing. Exported 3D model was first activated in Takeoff Manager module; where individual construction elements were properly rearranged by floors. 38 construction elements were determined. The main construction elements were determined as:

- External walls
- Slabs
- Internal walls
- Non-load bearing walls
- Doors
- Windows
- Columns

The signs for individual floors were standardized: B – basement, GF – ground floor, 1stF – first floor, 2ndF – second floor. The sign for roof as construction element was R. Construction elements on the floors were selected for each student group, as shown in Table 1.

Table 1. Construction elements processed by student groups

Student group number	Construction elements	View by Vico Office
1	EXTERNAL WALLS WINDOWS	
2	NON-LOAD BEARING WALLS COLUMNS	
3	INTERNAL WALLS DOORS	
4	FOUNDATION SLABS (B_009 AND B_010) SLABS CORNER COLUMN ROOF (R_001) ATTIC (R_002)	

3.3. Third step – Determination of construction technology and materials for implementation

Together with students we established the implementation possibilities for given construction elements. We listed the usage of various materials, possible implementation technologies and we subjectively evaluated foreseen costs and needed implementation time. Finally, we determined feasible and in construction practice the most frequent solutions for implementation of individual construction elements. We expected these solutions to give satisfactory results in terms of quality, costs and time. Solutions for technologies and materials of implementation of individual construction elements are shown in Table 2.

Table 2. Technology and materials of construction elements determined by student groups

Student group number	Project theme
1	EXTERNAL WALLS: Variant A: RC execution Variant B: masonry execution WINDOWS: Variant A: wooden Variant B: PVC
2	NON-LOAD BEARING WALLS: Variant A: masonry execution Variant B: gypsum execution COLUMNS: Variant A: RC execution Variant B: prefabricated
3	INTERNAL WALLS: Variant A: RC execution Variant B: masonry execution DOORS: Variant A: wooden Variant B: PVC
4	FOUNDATION SLABS (B_009 and B_010) – RC execution SLABS: Variant A: RC execution Variant B: prefabricated CORNER COLUMN ROOF (R_001) – RC execution of slab, isolation, final layer ATTIC (R_002)

3.4. Fourth step – Use of corresponding norms and unit price

For further discussion of works implementation based on certain technologies and materials, students were given study material which comprises construction works norms. We used norms published by Chamber of Craft and Small Business of Slovenia, Construction section, namely:

- norms for earthworks and sewage systems
- norms for concrete and reinforced concrete works
- norms for masonry works
- norms for carpentry works

Moreover, study material provided the average gross salary and average sales prices of mechanization and building materials for September 2014 (hereinafter Average prices), published by Chamber of Commerce and Industry of Slovenia, Chamber of Construction and Building Materials Industry of Slovenia.

Students were advised to gain information about internal norms used by construction companies, if possible. In this case, the information should be considered. They were also advised to prove the material prices listed in Average prices and to get real prices from appropriate suppliers of used materials.

Students agreed to use the same qualification or signs as listed in individual norms, i.e. twelve-digit code. In terms of Average prices they agreed to use unified qualification: sign DE and serial number for workers, ME and serial number for mechanization, MA and serial number for material, as shown in Figure 4.

DE 01	High skilled worker
DE 02	Skilled worker
DE 03	Trained worker
DE 04	Semi skilled worker
DE 05	Non skilled worker

ME 001	Excavator MH 5
ME 002	Excavator MH 6
ME 003	Excavator RB 6
ME 004	Excavator RB 9
ME 005	Bulldozer CAT D-5

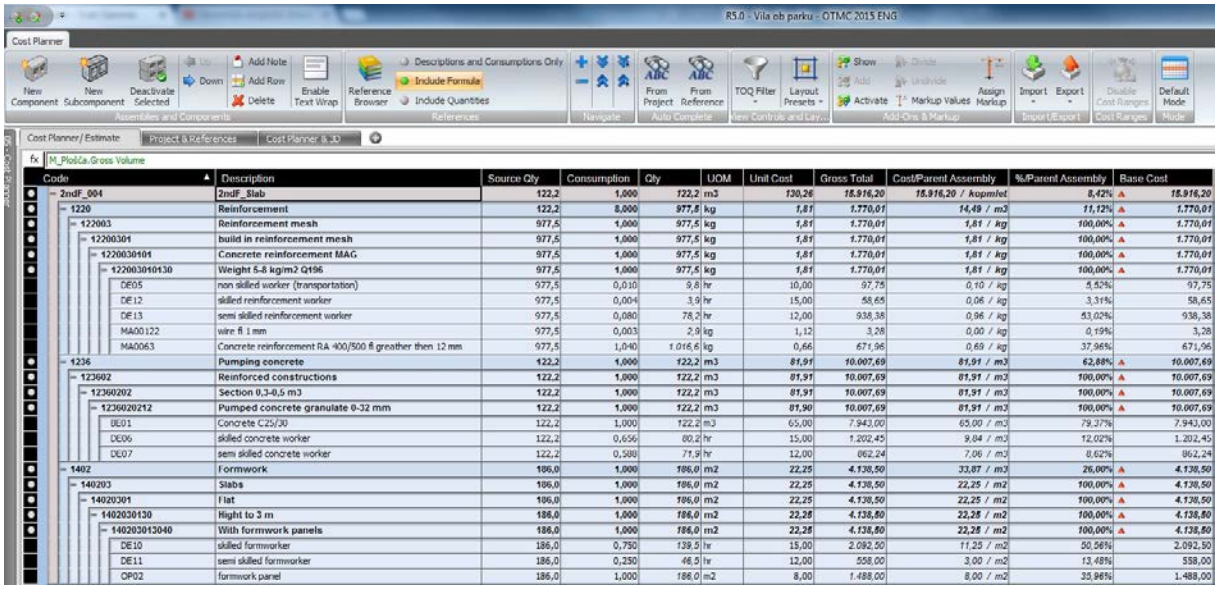
MA 0001	Quarry stone 4-8 mm
MA 0002	Quarry stone 8-16 mm
MA 0003	Quarry stone 16-32 mm
MA 0004	Fine sand 0-4 mm
MA 0005	Sand 4-8 mm

Fig.4. Unify qualification for workers, mechanization and material

3.5. Fifth step – Use of Vico Office and collection of data input, their evaluation and realization of appropriate solution with 4D and 5D information model

Processing in Vico Office software can be continued by activation of Cost Planner module after the preparation of 3D model (in the second step of the process) and collection of input data based on certain technologies, materials, norms and resource prices (in the third and fourth step of the process). Cost Planner module provides for each construction element (a) technology type based on appropriate norms; (b) determination of quantities, which are identified from given geometry of a construction element in the form of functional record; (c) required resources for which unit prices are recorded. All records that we want to include into cost calculation for the whole project are now activated in this module. Figure 5 shows an example of activated cost calculation for accomplishment of construction element 2ndF_004, accomplishment of reinforced concrete slab in the 2nd floor. This is one of the construction elements, studied by the fourth group of students. Realization of reinforced concrete slab in the 2nd floor requires the following technological processes, for which appropriate norms were used (norm number):

- Formwork (1402)
- Reinforcement (1220) and
- Concrete works (1236)



Code	Description	Source Qty	Consumption	Qty	UOM	Unit Cost	Gross Total	Cost/Parent Assembly	%/Parent Assembly	Base Cost
2ndF_004	2ndF_Slab	122,2	1,000	122,2	m3	130,26	15.916,20	15.916,20 / kopm/et	8,42%	15.916,20
1220	Reinforcement	122,2	8,000	977,5	kg	1,81	1.770,01	14,49 / m3	11,12%	1.770,01
122003	Reinforcement mesh	977,5	1,000	977,5	kg	1,81	1.770,01	1,81 / kg	100,00%	1.770,01
12200301	build in reinforcement mesh	977,5	1,000	977,5	kg	1,81	1.770,01	1,81 / kg	100,00%	1.770,01
1220030101	Concrete reinforcement MAG	977,5	1,000	977,5	kg	1,81	1.770,01	1,81 / kg	100,00%	1.770,01
122003010130	Weight 5-8 kg/m2 Q196	977,5	1,000	977,5	kg	1,81	1.770,01	1,81 / kg	100,00%	1.770,01
DE05	non skilled worker (transportation)	977,5	0,010	9,8	hr	10,00	97,75	0,10 / kg	5,52%	97,75
DE12	skilled reinforcement worker	977,5	0,004	3,9	hr	15,00	58,65	0,06 / kg	3,31%	58,65
DE13	semi skilled reinforcement worker	977,5	0,080	78,2	hr	12,00	938,38	0,96 / kg	53,02%	938,38
MA00122	wire fi 1 mm	977,5	0,003	2,9	kg	1,12	3,28	0,00 / kg	0,19%	3,28
MA0063	Concrete reinforcement RA 400/500 fi greather then 12 mm	977,5	1,040	1.016,6	kg	0,66	671,96	0,69 / kg	37,96%	671,96
1236	Pumping concrete	122,2	1,000	122,2	m3	81,91	10.007,69	81,91 / m3	62,88%	10.007,69
123602	Reinforced constructions	122,2	1,000	122,2	m3	81,91	10.007,69	81,91 / m3	100,00%	10.007,69
12360202	Section 0,3-0,5 m3	122,2	1,000	122,2	m3	81,91	10.007,69	81,91 / m3	100,00%	10.007,69
1236020212	Pumped concrete granulate 0-32 mm	122,2	1,000	122,2	m3	81,90	10.007,69	81,91 / m3	100,00%	10.007,69
DE01	Concrete C25/30	122,2	1,000	122,2	m3	65,00	7.943,00	65,00 / m3	79,37%	7.943,00
DE06	skilled concrete worker	122,2	0,656	80,2	hr	15,00	1.202,45	9,84 / m3	12,02%	1.202,45
DE07	semi skilled concrete worker	122,2	0,588	71,9	hr	12,00	862,24	7,06 / m3	8,62%	862,24
1402	Formwork	186,0	1,000	186,0	m2	22,25	4.138,50	33,87 / m3	26,00%	4.138,50
140203	Slabs	186,0	1,000	186,0	m2	22,25	4.138,50	22,25 / m2	100,00%	4.138,50
14020301	Flat	186,0	1,000	186,0	m2	22,25	4.138,50	22,25 / m2	100,00%	4.138,50
1402030130	Hight to 3 m	186,0	1,000	186,0	m2	22,25	4.138,50	22,25 / m2	100,00%	4.138,50
140203013040	With formwork panels	186,0	1,000	186,0	m2	22,25	4.138,50	22,25 / m2	100,00%	4.138,50
DE10	skilled formworker	186,0	0,750	139,5	hr	15,00	2.092,50	11,25 / m2	50,56%	2.092,50
DE11	semi skilled formworker	186,0	0,250	46,5	hr	12,00	558,00	3,00 / m2	13,48%	558,00
OP02	formwork panel	186,0	1,000	186,0	m2	8,00	1.488,00	8,00 / m2	35,96%	1.488,00

Fig.5. Cost calculation for construction element 2ndF_004

Cost calculation in Figure 6 shows that the realization of 186.00 m^2 area of reinforced concrete slab requires formwork with panel boards, propping up to 3.00 m height, and all necessary additional material and considers the work of a skilled or semi-skilled worker. Accomplishment costs for these works are 4,138.50 € or 22.25 €/m^2. The material or equipment costs are 1,488.00 €, which represents 35.96 % of all costs; cost of labour is 2,650.00 €, which represents 64.04 % of all costs.

Cost calculation for reinforcement and concrete works of reinforced concrete slab is treated in similar way as for formwork. It is seen from these two calculations that reinforcement cost is 1,770.01 € and concrete works cost equals 10,007.69 €.

Overall costs for reinforced concrete slab in the 2nd floor (construction element 2ndF_004)

are 15,916.20 €, as shown in Figure 6. Figure 6 also shows the costs of realization of individual technological processes and their shares.

Code	Description	Source Qty	Consumption	Qty	UOM	Unit Cost	Gross Total	Cost/Parent Assembly	%/Parent Assembly
2ndF_004	2ndF_Slab	122,2	1,000	122,2	m3	130,26	15.916,20	15.916,20 / kopmlet	8,42%
1220	Reinforcement	122,2	8,000	977,5	kg	1,81	1.770,01	14,49 / m3	11,12%
1236	Pumping concrete	122,2	1,000	122,2	m3	81,91	10.007,69	81,91 / m3	62,88%
1402	Formwork	186,0	1,000	186,0	m2	22,25	4.138,50	33,87 / m3	26,00%

Fig.6. The total cost of realization of construction element 2ndF_004, the cost of individual technological process and their shares

All student groups calculated costs in the same way for their package of construction elements, altogether for 38 construction elements of the object. Some groups have prepared the variant cost calculation for individual construction elements regarding different technologies and materials, therefore the total value of the project remained mystery until the presentation, which is described in the sixth step.

Afterwards, the groups of students started further planning of object construction in Task Management module. First, they determined all activities of object construction; each activity formed individual construction element. The sub-activities within individual activities are defined as technological processes, required for realization of individual construction elements. Sub-activities for construction element 2ndF_004 (accomplishment of reinforced concrete slab in 2nd floor) are (figure 7):

- formwork,
- reinforcement and
- concrete works.

Task Manager

Code	Name	Qty	UOM	Hrs/UOM	..	Work	Duration
000	Vila ob parku - OTMC 2015 SLO						167,01
1stF_001	1stF_External walls						5,00
1stF_002	1stF_Internal walls						4,00
1stF_003	1stF_Non-load bearing walls						3,00
1stF_004	1stF_Slab						11,00
1stF_005	1stF_Doors						2,00
1stF_006	1stF_Windows						2,00
1stF_007	1stF_Columns						3,00
2ndF_001	2ndF_External walls						5,00
2ndF_002	2ndF_Internal walls						4,00
2ndF_003	2ndF_Non-load bearing walls						3,00
2ndF_004	2ndF_Slab						11,13
2ndF_004_a	Reinforcement					91,88	4,89
2ndF_004_b	Pumping concrete					152,02	3,34
2ndF_004_o	Formwork					186,00	2,91
2ndF_005	2ndF_Doors						2,00
2ndF_006	2ndF_Windows						2,00
2ndF_007	2ndF_Terrace railing						2,00
B_001	B_Console roof						4,00
B_002	B_Peripheral wall						4,00
B_003	B_Glass barrier						1,00
B_004	B_Corner column						4,00
B_005	B_Columns						4,00
B_006	B_External walls						3,69
B_007	B_Internal walls						4,00
B_008	B_non-load bearing walls						3,00
B_009	B_Parking slab						10,71
B_010	B_Foundation slab						3,48
B_011	B_Paving way						5,00
B_012	B_Green plot						2,00
B_013	B_Doors						2,00
B_014	B_Windows						2,00
GF_001	GF_External walls						5,00
GF_002	GF_Internal walls						4,00
GF_003	GF_Non-load bearing walls						3,00
GF_004	GF_Slab						11,00
GF_005	GF_Doors						2,00
GF_006	GF_Windows						2,00
GF_007	GF_Columns						3,00
R_001	R_Slab						11,00
R_002	R_Attic						5,00
R_003	R_Glass facade						9,00

Fig.7. Construction elements as project activities and technological processes as their sub-activities

After determination of activities and sub-activities, the students processed appropriate links from Cost Planner module to activities in Task Management module, which are the basis for

calculation of activity duration. Figure 8 shows connection of data for activity 2ndF_004 in Task Management module with data in Cost Planner module.

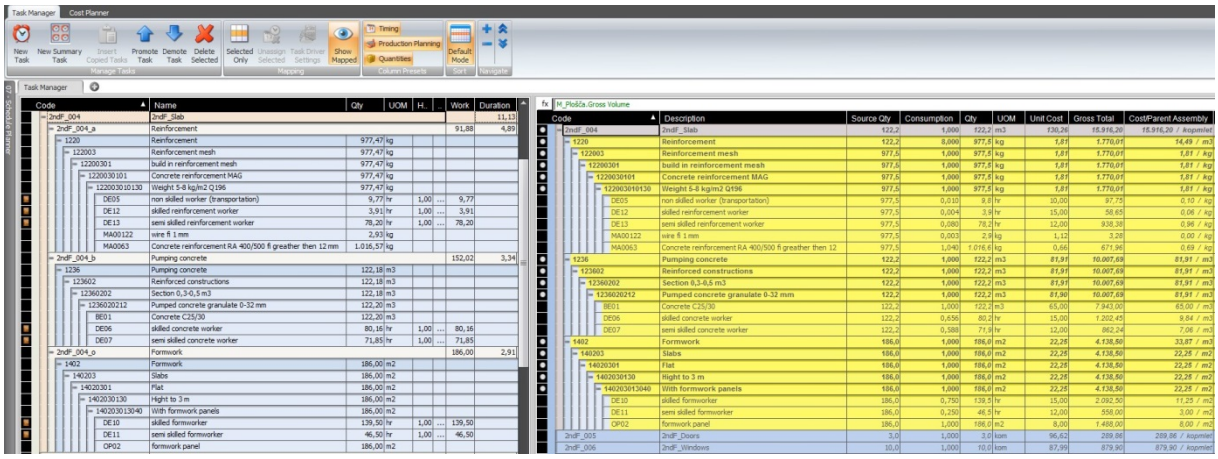


Fig. 8. Presentation of data in Task Management module and data in Cost Planner module for construction element 2ndF_004

Students processed all 38 project activities in the same way. When they had finished this procedure for the whole project, they started with real time scheduling in Schedule Management module.

Schedule Planner external application within Schedule Management (Figure 9) is used in Vico Office software for project scheduling treated as BIM construction projects. Namely, they ensure dynamic connection between data in 3D, 4D and 5D information models. The application can be also used as independent software for project scheduling, e.g. for construction projects without 3D model of the object (when only 2D project documentation is available, for example). A disadvantage for such cases is that direct connection between project scheduling and a building cannot be established and they must be treated separately.

Fig.9. Activation screen of Schedule Planner software for project scheduling of buildings

Afterwards, students used Schedule Planner software to determine connections between activities. They took in consideration individual technological realization of construction elements and established sequence of individual activities based on their knowledge and gained practical experiences. In this way they determined previous activities (predecessor) and next activities (successor), except for the first (where they determined successor only) and the last (where they determined the predecessor only). They chose between the next types of activity connections: Finish – Start, Start – Start and Finish – Finish and considered time lags, called Lag, if necessary. Determination of connections between activities for construction element 2ndF_004, realization for reinforced concrete slab in the 2nd floor, is shown in Figure 10.

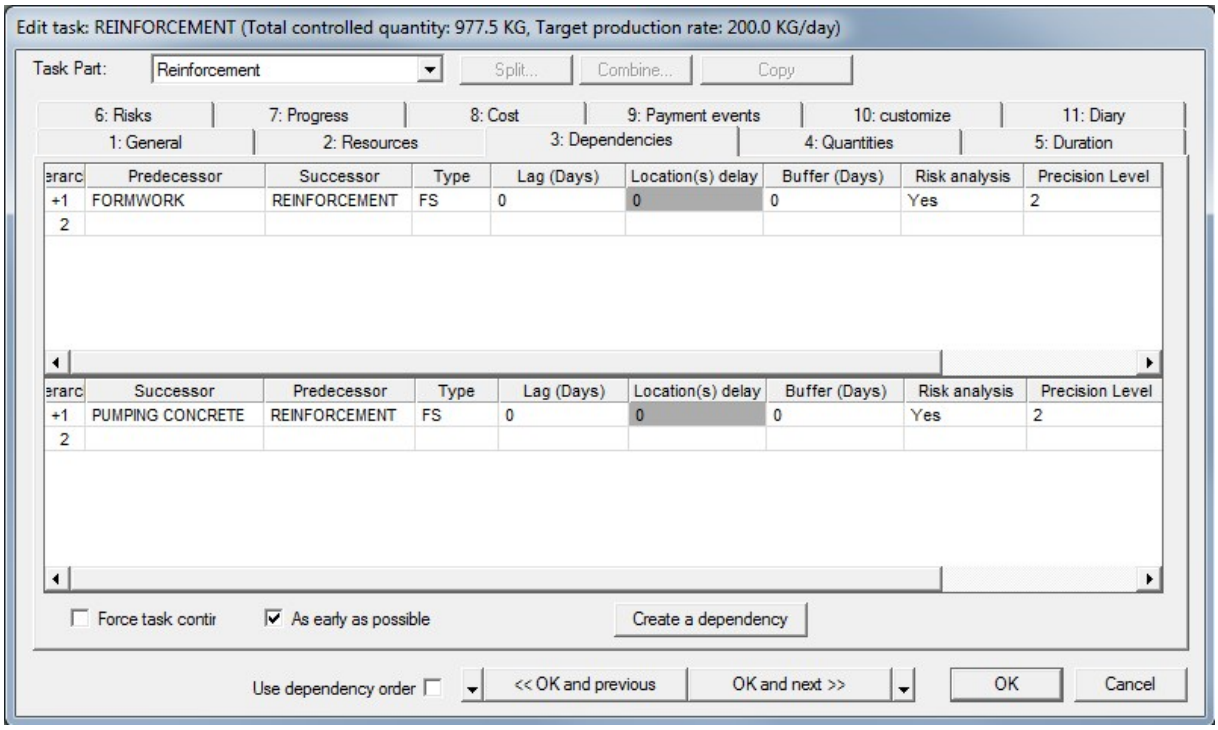


Fig.10. Predecessor and successor for construction element 2ndF_004

The resources already determined in Cost Planner were then generated for each activity and the number of workers groups to perform individual activities was properly entered. In this way, the relevant data were gained to calculate activity duration.

Figure 11 shows the above mentioned used for activity of reinforcement of reinforced concrete slab in the 2nd floor, where two groups of workers are expected (marked with A) and the activity duration is 4.9 days (marked with B).

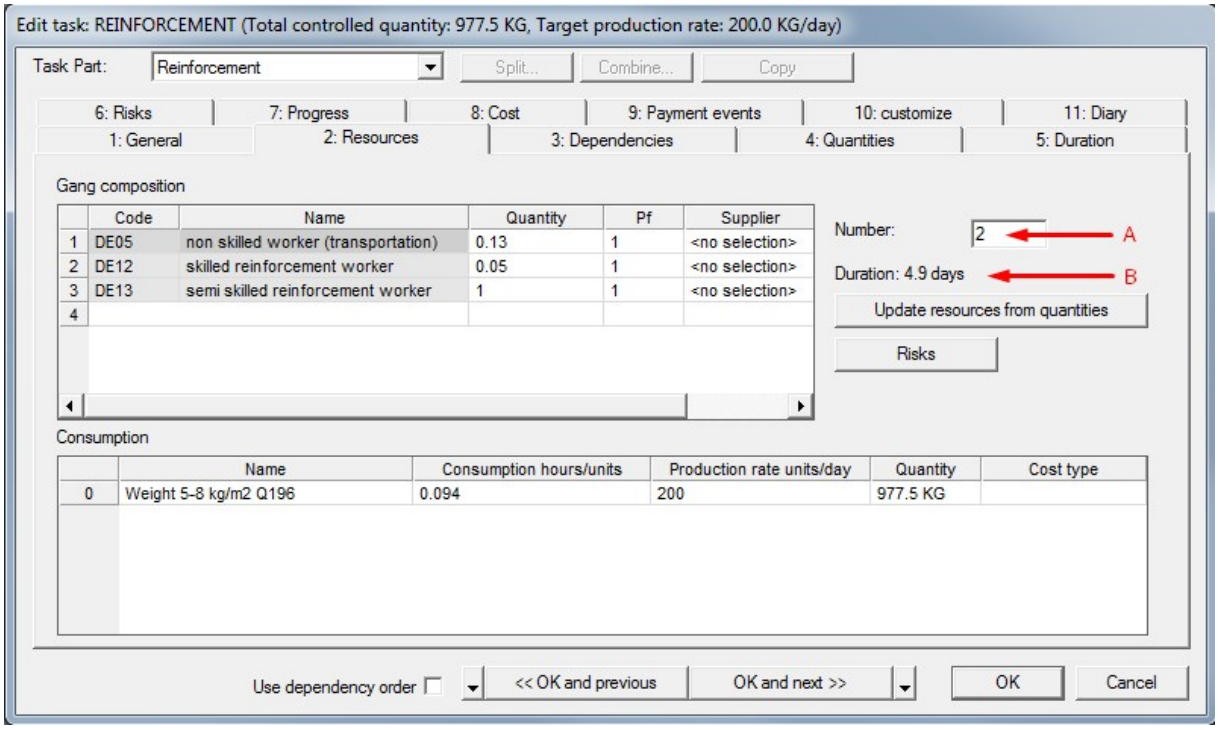


Fig.11. Number of worker groups and activity duration for reinforcement of concrete slab in the 2nd floor (activity 2ndF_004)

When students determined groups of workers for each activity and gained calculated time of duration of all activities, they provided network diagram for the whole construction project "Vila ob parku" according to given connections between activities, as shown in Figure 12. Project schedule can be shown as Gantt chart (Figure 13) and Flowline (Figure 14).

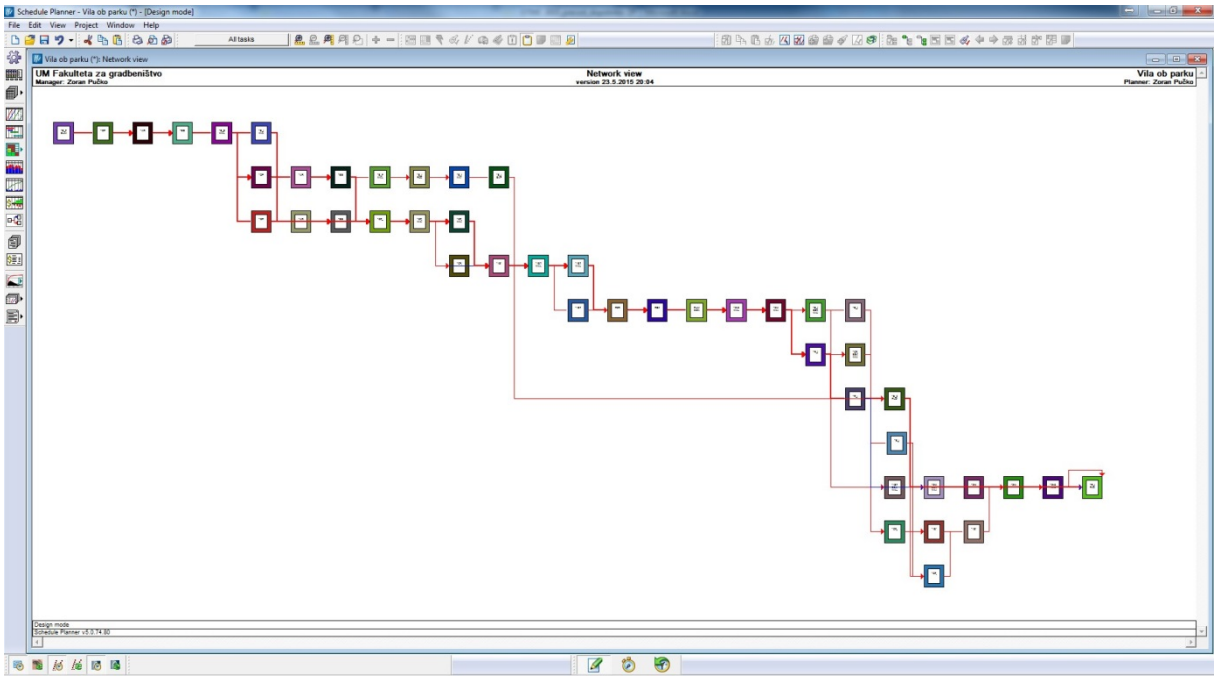


Fig.12. Network diagram for "Vila ob parku" construction project

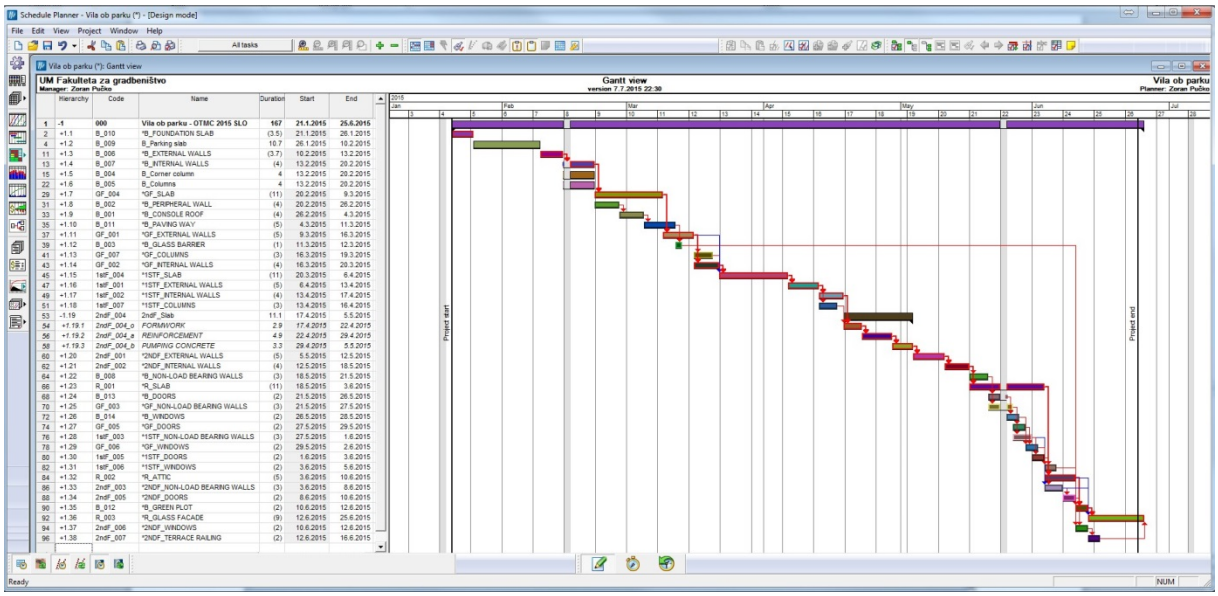


Fig.13. Gantt chart of the project schedule

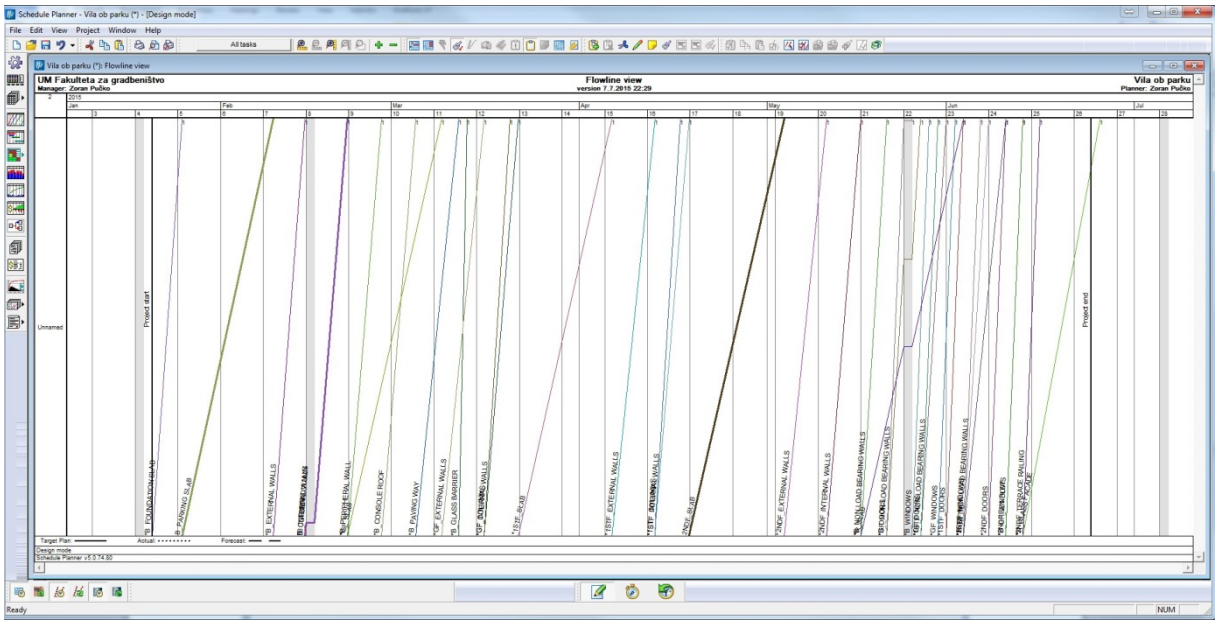


Fig.14. Flowline of the project schedule

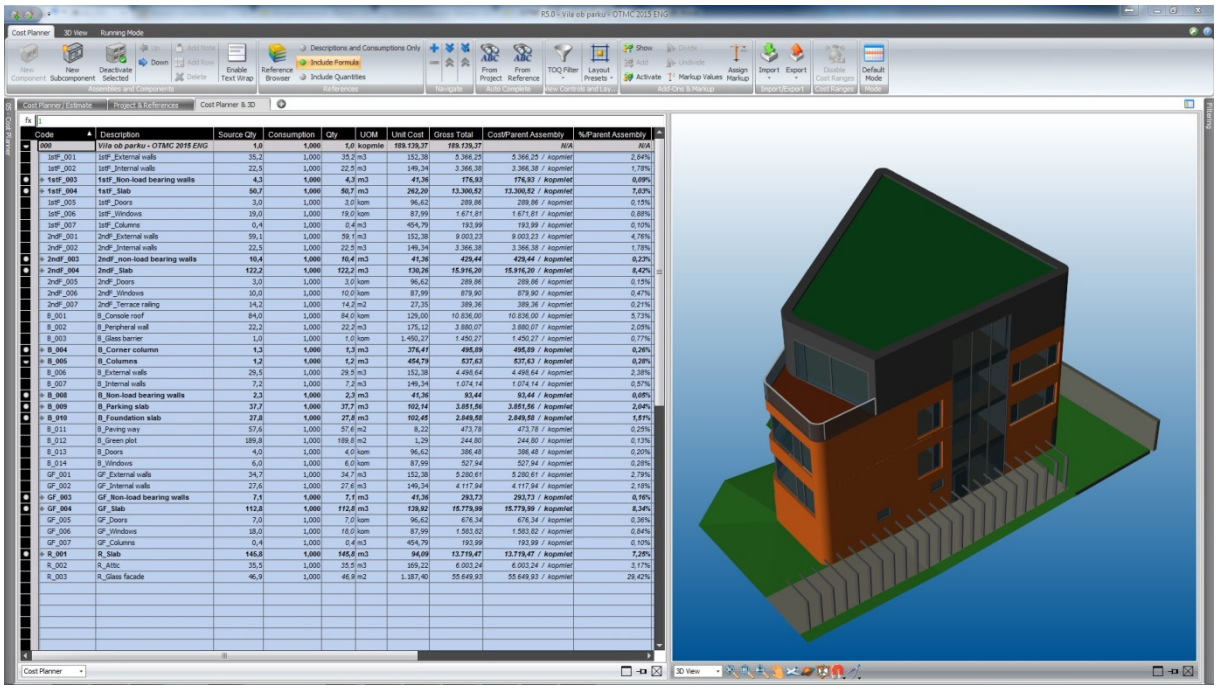
3.6. Sixth step – Result presentation and argumentation, description of activity and proceedings and possible obstacles or limitations

First, each group of students discussed individual packages of construction elements as determined and described in the second step.

They independently collected data about materials and construction technologies to prepare and process input data in Vico Office 5.0 software, as described in the third and fourth step.

Already during initial activities, described in the fifth step, both, students and mentors realized that more time is needed as initially predicted. Therefore, we agreed not to calculate variants with different materials and technologies in Cost Planner module for individual construction elements. So, students determined suitable realization of construction elements. As a result, each group received the 5D information model for their construction elements, when their activities in Cost Planner were finished. Within each group, partial information about expected costs was gained rather than total costs.

Students determined activities in Task Management module for their package of construction elements in the fifth step. They could not continue their work in Schedule Management module or Schedule Planner application, because this would require connection of all activities from the project. For example, the first group discussed external walls, i.e. B_006, GF_001, 1stF_001 and 2ndF_001 activities, but they could not connect them to previous activities, processed by the fourth group, which were slabs or activities marked as B_009, B_010, GF_004, 1stF_004, 2ndF_004 and R_001, as well as with the further activities of the third group which were internal walls, marked as B_007, GF_002, 1stF_002 and 2ndF_002 activities. Therefore, all data were first generated in Cost Planner module and Task Management module for the entire project. As a result, the whole 5D information model and information about expected costs for the entire object was gained in Cost Planner module for the first time. After joining all data of all groups, the value of total costs was calculated to 189,139.37 € (Figure 15).



Code	Description	Source Qty	Consumption	Qty	UOM	Unit Cost	Gross Total	Cost/Parent Assembly	%/Parent Assembly
000	Vila ob parku - OTMC 2015 ENG	1,0	1,000	1,0	kopmle	189.139,37	189.139,37	N/A	N/A
1stF_001	1stF_External walls	35,2	1,000	35,2	m3	152,38	5.366,25	5.366,25 / kopmle	2,84%
1stF_002	1stF_Internal walls	22,5	1,000	22,5	m3	149,34	3.366,38	3.366,38 / kopmle	1,78%
1stF_003	1stF_Non-load bearing walls	4,3	1,000	4,3	m3	41,36	176,93	176,93 / kopmle	0,09%
1stF_004	1stF_Slab	50,7	1,000	50,7	m3	262,20	13.300,52	13.300,52 / kopmle	7,03%
1stF_005	1stF_Doors	3,0	1,000	3,0	kom	96,62	289,86	289,86 / kopmle	0,15%
1stF_006	1stF_Windows	19,0	1,000	19,0	kom	87,99	1.671,81	1.671,81 / kopmle	0,88%
1stF_007	1stF_Columns	0,4	1,000	0,4	m3	454,79	193,99	193,99 / kopmle	0,10%
2ndF_001	2ndF_External walls	59,1	1,000	59,1	m3	152,38	9.003,23	9.003,23 / kopmle	4,76%
2ndF_002	2ndF_Internal walls	22,5	1,000	22,5	m3	149,34	3.366,38	3.366,38 / kopmle	1,78%
2ndF_003	2ndF_non-load bearing walls	10,4	1,000	10,4	m3	41,36	429,44	429,44 / kopmle	0,23%
2ndF_004	2ndF_Slab	122,2	1,000	122,2	m3	130,26	15.916,20	15.916,20 / kopmle	8,42%
2ndF_005	2ndF_Doors	3,0	1,000	3,0	kom	96,62	289,86	289,86 / kopmle	0,15%
2ndF_006	2ndF_Windows	10,0	1,000	10,0	kom	87,99	879,90	879,90 / kopmle	0,47%
2ndF_007	2ndF_Terrace railing	14,2	1,000	14,2	m2	27,35	389,36	389,36 / kopmle	0,21%
B_001	B_Console roof	84,0	1,000	84,0	kom	129,00	10.836,00	10.836,00 / kopmle	5,73%
B_002	B_Peripheral wall	22,2	1,000	22,2	m3	175,12	3.880,07	3.880,07 / kopmle	2,05%
B_003	B_Glass barrier	1,0	1,000	1,0	kom	1.450,27	1.450,27	1.450,27 / kopmle	0,77%
B_004	B_Corner column	1,3	1,000	1,3	m3	376,47	495,89	495,89 / kopmle	0,26%
B_005	B_Columns	1,2	1,000	1,2	m3	454,79	537,63	537,63 / kopmle	0,28%
B_006	B_External walls	29,5	1,000	29,5	m3	152,38	4.498,64	4.498,64 / kopmle	2,38%
B_007	B_Internal walls	7,2	1,000	7,2	m3	149,34	1.074,14	1.074,14 / kopmle	0,57%
B_008	B_Non-load bearing walls	2,3	1,000	2,3	m3	41,36	93,44	93,44 / kopmle	0,05%
B_009	B_Parking slab	37,7	1,000	37,7	m3	102,14	3.851,56	3.851,56 / kopmle	2,04%
B_010	B_Foundation slab	27,8	1,000	27,8	m3	102,45	2.849,58	2.849,58 / kopmle	1,51%
B_011	B_Paving way	57,6	1,000	57,6	m2	8,22	473,78	473,78 / kopmle	0,25%
B_012	B_Green plot	189,8	1,000	189,8	m2	1,29	244,80	244,80 / kopmle	0,13%
B_013	B_Doors	4,0	1,000	4,0	kom	96,62	386,48	386,48 / kopmle	0,20%
B_014	B_Windows	6,0	1,000	6,0	kom	87,99	527,94	527,94 / kopmle	0,28%
GF_001	GF_External walls	34,7	1,000	34,7	m3	152,38	5.280,61	5.280,61 / kopmle	2,79%
GF_002	GF_Internal walls	27,6	1,000	27,6	m3	149,34	4.117,94	4.117,94 / kopmle	2,18%
GF_003	GF_Non-load bearing walls	7,1	1,000	7,1	m3	41,36	293,73	293,73 / kopmle	0,16%
GF_004	GF_Slab	112,8	1,000	112,8	m3	138,92	15.779,99	15.779,99 / kopmle	8,34%
GF_005	GF_Doors	7,0	1,000	7,0	kom	96,62	676,34	676,34 / kopmle	0,36%
GF_006	GF_Windows	18,0	1,000	18,0	kom	87,99	1.583,82	1.583,82 / kopmle	0,84%
GF_007	GF_Columns	0,4	1,000	0,4	m3	454,79	193,99	193,99 / kopmle	0,10%
R_001	R_Slab	145,8	1,000	145,8	m3	94,69	13.719,47	13.719,47 / kopmle	7,26%
R_002	R_Attic	35,5	1,000	35,5	m3	169,22	6.003,24	6.003,24 / kopmle	3,17%
R_003	R_Glass facade	46,9	1,000	46,9	m2	1.187,40	55.649,93	55.649,93 / kopmle	29,42%

Fig.15. Project costs and 5D information model of the building “Vila ob parku”

For the first time, gathering all input data of each group resulted in collection of all project activities in Task Management module. The activities continued in Schedule Management module and Schedule Planner application where all activities were first connected, and then the worker groups were determined in order to get activity duration. Therefore, the whole 4D information model of the construction project and information about estimated duration for the whole construction project, project start and project finish date for construction phase were gained in Schedule Management module and Schedule Planner application for the first time. The project started on 21 January 2015 and finished on 25 June 2015, duration of a project is 167 working days. The project schedule and 4D information model of the construction project is shown in various forms, as it can be seen from Figure 12 for a Network diagram, in Figure 13 as Gantt chart and in Figure 14 as Flowline view.

Activities following the mentioned steps for the construction project „Vila ob parku“, based on 3D model, and resulted in 5D information model to provide information about costs; and in 4D information model to provide information about required time for completion of the construction project.

Some limitations and agreed adaptations were identified during the work with students. The main restriction comes from limited time within the tutorials in subject Project management in construction which does not allow enough time for quality and precise implementation of construction project with BIM. Therefore, only construction works in most construction elements for the practical example of construction project “Vila ob parku” were discussed; construction elements for non-load bearing walls were taken into account as craft work and no installation work was foreseen. Unfortunately, variant solutions were not carried out so we did not have the opportunity to decide on more rational (optimal) realization of the construction project.

However, the students believe that pre-knowledge in the field of operational construction is necessary for this work as well as practical experiences on site and proper computer literacy.

4. Conclusion

This paper presents the research work within the educational process with student groups at the master degree using the Project Management Software Vico Office 5.0 based on building information modeling (BIM). The main purpose of the research provided through student practical work was to give an insight of time and cost planning of the construction project employing BIM. An example based on the application of Vico Office 5.0 software was used in

sixth steps and presents the process to make a 4D and 5D information model of the construction project “Vila ob parku”. The first step was to choose a 3D model from four different available 3D models. In the second step the 3D model was divided into four proportional groups of construction elements, to be treated with four groups of students. The third step was to select the used technology and materials for construction. In the fourth step the appropriate norms with information about used resources and their costs per unit were defined. The most important was the fifth step where the Project Management Software Vico Office 5.0 was used to collect all data for implementation of the final solution that represents 4D and 5D information model. In the sixth step the conclusions of the whole work process were presented and discussed with the student groups. The main conclusion suggested that nowadays the implementation of modern software including BIM in construction projects is necessary in the educational process because this concept represents the state of the art in the AEC industry. Employment of BIM in education and in construction practice is a technological progress with many advantages for all participants and the new generations of construction management experts must earn this knowledge.

Acknowledgements

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Project Based Learning in an Interdisciplinary Engineering Project – Project MemBrain

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Abstract

Project Based Learning (PBL) is a teaching method that has re-emerged in recent years as an alternative to traditional education. The demands of the work market have grown in such a way that certain skills are required of young engineers, which cannot be acquired through traditional education. Literature research suggest that PBL is better suited for today's engineering education, but PBL itself has a few shortcomings compared to the traditional education.

This paper details the implementation and the implications of project based learning on an interdisciplinary and a technologically complicated project. The project in the focus is the MemBrain project, a student application to the international competition where the goal was to design and build a passive smart house in which the participants were students and mentors from 13 faculties of the University of Zagreb. The paper gives an introduction into what PBL is and a literature review with a focus on the advantages and disadvantages of PBL. A survey was then carried out among the students of Faculty of Civil Engineering University of Zagreb who participated in the MemBrain project with the goal to examine their opinions on PBL in general and their experience on the project. Those findings were compared to the findings in the literature review and conclusions were made.

Keywords: Project based learning; PBL; project memBrain; passive house; interdisciplinary engineering project; student competition

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1. Introduction

Learning methods in the field of civil engineering and engineering in general haven't changed much from the late 1950s (Dym, 2004) despite the large body of education research that demonstrates its ineffectiveness (Mills and Treagust, 2003). The current model consists of first learning the basic sciences such as math and physics, generally in the first years of study which can but do not necessarily mean the entire undergraduate course. Those basics serve as a foundation for learning more engineering centred sciences, in the later years of undergraduate courses and in graduate courses, where students can apply scientific principles to technological problems (Dym et al., 2005).

The modern engineering profession constantly deals with uncertainty, incomplete data, conflicting demands, government bodies, environmental groups and the general public (Mills and Treagust, 2003). Some of those problems faced by engineers are exclusive to the modern industry practice and are not generally parts of syllabi in engineering courses. Some skills related to those requirements could not perhaps be taught in the traditional large classes with lecture based delivery which are the norm, especially in the early years of study (Mills and Treagust, 2003).

Graduates from those types of college courses were perceived by both the industry and the academia as being unable to participate in the industry straight out of faculty because the change of focus from theory to practice (Dutson et al., 1997). They do graduate with good knowledge of engineering science but don't know how to apply that knowledge in practice (Mills and Treagust, 2003).

Therefore, the future employers have called for a change in engineering programs (Mills and Treagust, 2003) and the new accreditation approach shifts emphasis from what is being taught to what is being learned (Koehn, 1999). Critical issues in education that need to be addressed according to Mills and Treagust (2003) are:

1. Engineering curricula are too focused on engineering science and technical courses without providing sufficient integration of these topics or relating them to industrial practice. Programs are content driven.
2. Current programs do not provide sufficient design experiences to students.
3. Graduates still lack communication skills and teamwork experience and programs need to incorporate more opportunities for students to develop these.
4. Programs need to develop more awareness amongst students of the social, environmental, economic and legal issues that are part of the reality of modern engineering practice.
5. Existing faculty lack practical experience, hence are not able to adequately relate theory to practice or provide design experiences. Present promotion systems reward research activities and not practical experience or teaching expertise.
6. The existing teaching and learning strategies or culture in engineering programs is outdated and needs to become more student-centred.

Issues no. 1, 2, 3, 4 and 6 that arise in engineering education can easily be addressed by implementing project and/or problem based learning (PBL) in the curricula and issue no. 5 must be dealt with for PBL to be implemented (Mills and Treagust, 2003).

Additional issues with traditional engineering education are expressed by Linder (1999) and Brerenton (1999) in regards to the student's skills of approximation and intuition, respectively. Linder administered a test in which students were asked to give an estimation of a physical quantity in a short time. The results were in the ranges of three to five orders of magnitude form the correct answer. This shows that the students have weak conceptual understanding of basic engineering (Linder, 1999). Brerenton (1999) studied how engineering students develop engineering intuition by constantly shifting their thinking paradigm from engineering theory to engineering practice. Both of those problems are also easily solvable by implementing PBL in the engineering curricula.

The remainder of the paper will describe in detail what PBL is, what are the advantages and disadvantages compared to the traditional engineering curricula and describe the current application of PBL in Croatia. Secondly, the paper will give an overview of the MemBrain project and the application of PBL on the project, the experiences of both students and faculty and what were the lessons learned.

2. Project Based Learning

Project Based Learning is an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem (Savery, 2006). Other authors (Torp and Sage, 1998) describe PBL as a focused, experiential learning organized around the investigation and resolution of messy, real-world problems. They describe students as engaged problem solvers, seeking to identify the root problem and the conditions needed for a good solution and in the process becoming self-directed learners.

Other definitions include the values of PBL in regards to the skills necessary for the 21st century such as: Project-Based Learning (PBL) is an innovative approach to learning that teaches a multitude of strategies critical for success in modern business environment. Students drive their own learning through inquiry, as well as work collaboratively to research and create projects that reflect their knowledge. From gleaning new, viable technology skills, to becoming proficient communicators and advanced problem solvers, students benefit from this approach to instruction (Bell, 2010).

PBL is not only applicable to the faculty courses. Its beginnings can be found in the elementary schools in the United States in the early 20th century based on the idea of learning by doing (Barron et al., 1998). It, however, only took hold in a small number of classrooms due to inadequate material resources, little time to create new curricula, large class sizes, and over-controlling administrative structures (Barron et al., 1998). It took nearly half a century for PBL to be reconsidered as a teaching method and only since it became evident that current methods of teaching are not providing students with adequate qualifications and not just regarding the technical skills but also soft skills. Therefore, the goals of PBL are manifold and include at least the development of team skills, the development of learning or critical thinking skills, the development of content knowledge relevant to the course, and the ability to apply that knowledge (Helle et al., 2006).

The advantages of PBL over traditional teaching methods listed in the literature are numerous and include:

- student control over the learning process in regards to pacing, sequencing and the actual content of learning (Duffy and Cunningham, 1996);
- a sense of ownership over the learning process (Helle et al., 2006) and, as a result, a greater satisfaction with the process (Green, 1998);
- increased student motivation (Green, 1998) and interest in their field of study;
- students are better informed about the profession they have chosen, which leads to stronger sense of belonging, identification with the faculty (Frank et al., 2003) and increased retention rates (Dym et al., 2005);
- improved sense of responsibility and accountability since they are not accountable only to the teacher, but also to their colleagues (Frank et al., 2003, Bell, 2010);
- students develop a deep and integrated understanding of the learning content and process (Krajcik et al., 1999);
- contextualisation (Helle et al., 2006) and better understanding of the application of their knowledge (Helle et al., 2006, Mills and Treagust, 2003);
- enables knowledge transfer from one context to another (Bransford et al., 1999);
- even if students acquire less knowledge, they remember more of the acquired knowledge (Gijbels et al., 2005);
- students also gain some interdisciplinary knowledge and soft skills such as learning to work in teams (Frank et al., 2003);

- increases students' ability to think, problem solving skills and develops engineering thinking and intuition (Frank et al., 2003);
- teaches students how to retrieve information from textbooks, the internet, interview experts and from other sources (Frank et al., 2003);
- exposes students to some of the engineering skills, to all phases of design, from initial requirements to the completed project, making them better trained for working as engineers (Frank et al., 2003).

Advantages for teachers are not as numerous and include (Frank et al., 2003):

- more challenging, interesting and motivating type of teaching;
- continually receiving new ideas and also learning from students;
- classroom management is simplified when students are interested and involved.

Disadvantages are far less numerous than the advantages and are more related to the problems for teachers and faculty administration than for the students. The disadvantages for the students include higher time demands (Frank et al., 2003), less rigorous understanding of engineering fundamentals (Mills and Treagust, 2003) and problems with team members who give less effort in the group (Mills and Treagust, 2003).

Problems with implementing PBL from the teacher's and institutional point of view based on the literature review and on personal experiences includes but is not limited to:

- PBL requires simultaneous changes in the curricula (Barron et al., 1998)
- organisation and administration of PBL courses can be time consuming (Helle et al., 2006);
- the assessment of student work is more difficult (Helle et al., 2006);
- teachers are so specialised that they are unable to supervise a project in their field (Helle et al., 2006);
- teacher may not be in contact with the industry and cannot transfer practical knowledge to the students;
- the change of the teacher's role from a 'provider of facts' to rather a mentor, facilitator, helper and mediator for learning (Hill, 1997);
- raised cost of education (Dym et al., 2005);
- shortage of faculty members for implementing such teaching methods;
- requirement of interest, cooperation and institutional support from various stakeholders in education;
- faculty resistance to changes (Mills and Treagust, 2003);
- hierarchical knowledge structure, meaning that many topics must be learned in a certain order, because missing essential parts will result in failure to learn later concepts (Mills and Treagust, 2003);
- long-term sustenance of PBL courses may be a problem (Dym et al., 2005).

PBL in Croatia is present for some time in one of its most basic forms, the project exercise form which is defined as type of PBL in which students apply knowledge and techniques already acquired in an academic way to the representation of an engineering problem. In Faculty of Civil Engineering University of Zagreb, students use their knowledge acquired during class to solve various tasks which are representations of real world problems. Examples include structural design of concrete, masonry, wooden and metal structures, road and railroad design, cost planning, time planning, design of geotechnical and hydrotechnical structures and other. Students can also do their master thesis either as a more detailed study of a topic from any of the courses or as an application of acquired knowledge to a real world problem.

Other examples of PBL have only emerged in the last few years and are exclusively extracurricular activities, meaning they are not in any way a part of formal education and student participation is entirely voluntary. The existence of such projects is also based on the extra effort of those few teachers who wish to further educate their students and improve their competences. They are not in any way formally compensated for their extra effort.

The last example of PBL are student projects for student competitions organised by either student or professional associations, such as the MemBrain (MemBrain, 2014) project for the Solar Decathlon Europe (Solar Decathlon Europe, 2014) competition which will be described in the following section.

3. MemBrain project

MemBrain (2014) is a student project designed and constructed for the Solar Decathlon Europe 2014 (SDE) competition. SDE is an international competition in building passive, smart, energy efficient and ecologically friendly houses. The idea was formed in the 1990s in the United States with a goal to educate young engineers of the need for environmental protection and to educate the public and raise awareness for the growing problems of energy consumption and construction waste generation. The first competition took place in 2000. In Washington D.C. and has become so popular that has spread into several other regional Solar Decathlon competitions, including Solar Decathlon Europe and Solar Decathlon Asia.

Application to SDE is open for all Universities and Polytechnics which contain civil, electrical and mechanical engineering and architectural studies. It is a student competition, meaning that all work is supposed to be done by students, with support from their faculty advisors, industry professionals and institutional support from their University. The added benefit to this competition is that besides all the benefits of PBL mentioned earlier also offers students a chance to work in multidisciplinary teams and actually physically construct the project that they themselves have designed.

Some of the students at the University of Zagreb believed that they had the necessary knowledge and abilities to participate in the competition and the UNIZG team was formed. The team consisted of more than 60 students from 14 different faculties and was assisted by more than 30 faculty members from their faculties. The support was manifested as consultations and advices about the project, assistance in making contacts with industry professionals and more. The faculties and the University also supported the project both materially and financially.

Concept MemBrain is a prefabricated, montage wooden smart house that was completely designed and constructed by students. The bearing structure consists of steel height adjustable foundations, glued laminated timber floor slabs and columns and wooden walls for horizontal stability. The façade on the north side is wooden and insulated with sheep wool, and on the three other sides is made of two layers of double and triple glazed glass panels.

Fig. 1. MemBrain house, South-East façade

Heating, ventilation and air conditioning system consists of an air to water heat pump, ventilation system and of phase-change materials. The roof houses photovoltaic (PV) panels shaped like an accordion which can extend and contract depending on the angle of the Sun, maximizing the efficiency of the PV panels and also providing shade for the inside of the house. All of the systems are connected to the central computer that operates the house and can also be controlled by smartphone or tablet.

The spatial layout is defined by the distance between the load bearing columns which amounts to 1,2 meters. Total area of the house is 7,2×9,6 meters, with useful living area being just over 60 m^2. The house is modular and can be widened horizontally by adding more modules and/or vertically by adding up to three stories. One large open living place contains the bedroom, living room and kitchen, while the bathroom and engine rooms are separate rooms in the north part of the house. The winter garden is located between the two glass panels on the south side.

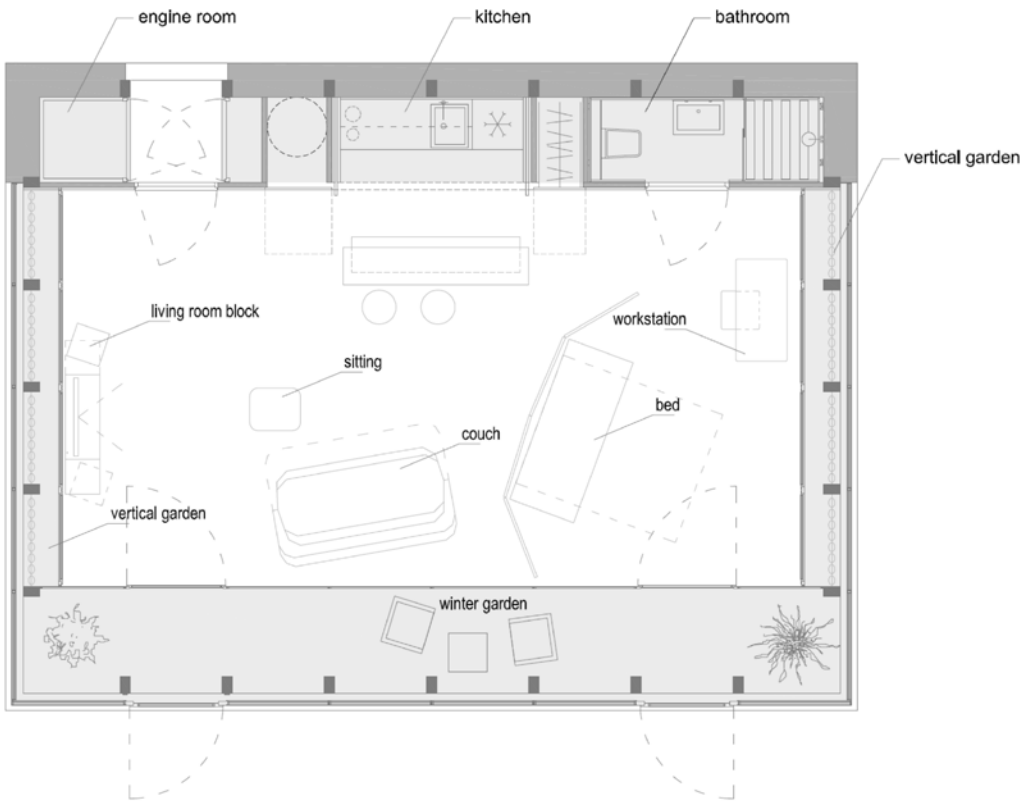

Fig. 2. MemBrain house floor plan

4. Project Based Learning in the MemBrain project

4.1. Methodology

The aim of the paper was to compare the students' view of PBL's advantages and disadvantages to those found in the literature review and to identify their general opinion on PBL and their mentors. For that purpose, a survey was performed among the students of the Faculty of Civil Engineering who participated in the MemBrain project. Survey was carried out online, and consisted of 25 questions divided in four categories: basic questions about the interviewee, questions related to personal growth through the project, students' opinions on PBL and their experiences with their mentors. The questions were chosen to determine whether students have noticed the benefits and disadvantages of PBL themselves, what their

perception on PBL itself is and to determine how well the mentors have managed in their new roles.

Students from the Faculty of Civil Engineering University of Zagreb were divided into two teams based on their fields of specialisation and their roles on the project. Those teams were Construction and materials and Construction management. Total of 7 students participated in the survey, three of which from the Construction and materials team and four from the Construction management team. Total number of members of the both teams is 14, which means that the sample is 50% of the total number of participants. Both student team leaders also participated in the survey.

Answers to the questions were available in the Likert scale ranged from 1 to 5, with the following descriptions:

1 – I completely disagree with the statement
2 – I disagree with the statement
3 – I do not agree or disagree with the statement
4 – I agree with the statement
5 – I completely agree with the statement

4.2. Results

The results will be shown by a series of charts in which on the X-axis is the chosen answer and the Y-axis shows the frequency of the given answer. Questions are formulated as a statement and the interviewees were required to choose an answer on a scale from 1 to 5 based on their experiences on the MemBrain project. Numbers 1 to 5 correspond to the answers described in the previous section. Also, since there are total of 22 such questions the results are grouped based on similarity and aggregated by three or four questions per chart. The remaining 3 questions were related to the team affiliation of the respondent, their year of study and whether they were a team member or a team leader.

The first chart (Fig. 3) consists of the answers to questions regarding teamwork, interdisciplinary knowledge, insight into the other related professions and to the soft skills. It shows that the students generally completely agree with the statements. Students agree the most about the advantage of gaining the interdisciplinary knowledge and agree the least with the advantage of improving teamwork skills. This is probably because the students have already developed those skills during their formal education.

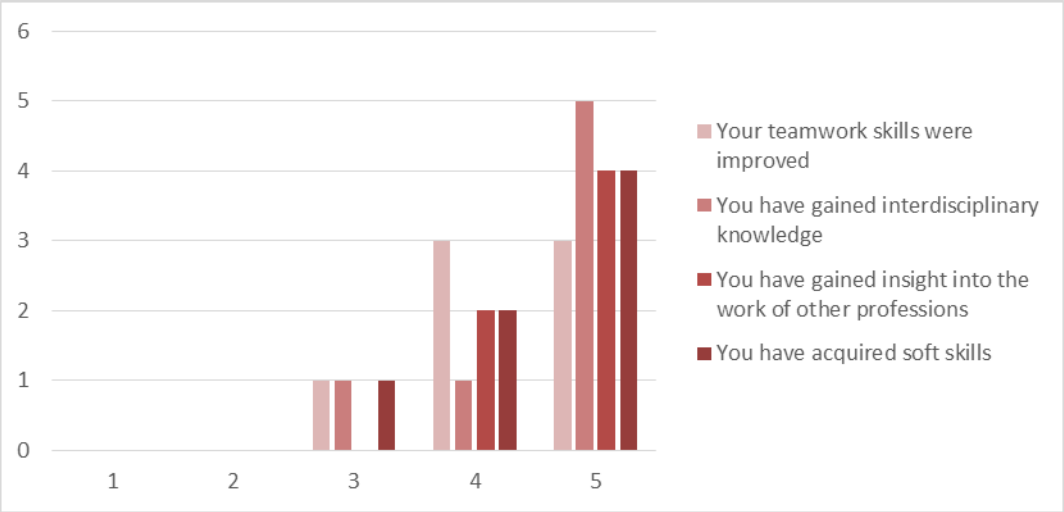

Fig. 3. Results chart #1

Results chart #2 (Fig. 4) aggregates the questions related to the important engineering skills such as critical thinking and engineering intuition, and to the motivation and work responsibility. Students generally agree that they have developed engineering intuition, although by a small margin. The same is true with the motivation for studying. Work responsibility and engineering intuition have gained higher scores, meaning that students really believe that their intuition and responsibility have improved during their work on the project.

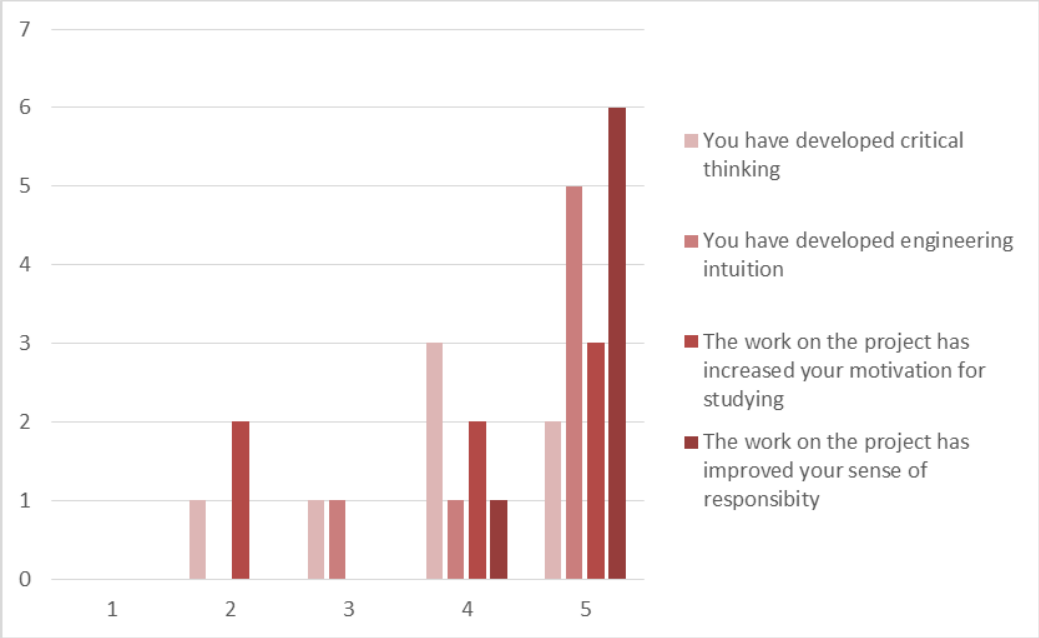

Fig. 4. Results chart #2

The third chart (Fig. 5) shows that the students have differing opinions about the statement relating the usefulness of knowledge gained in the project for their college classes where they in general slightly disagree with the statement and to the question about the development of learning skills where they in general slightly agree with the statement. A bit larger agreement is with the statement that they have learned how to retrieve information.

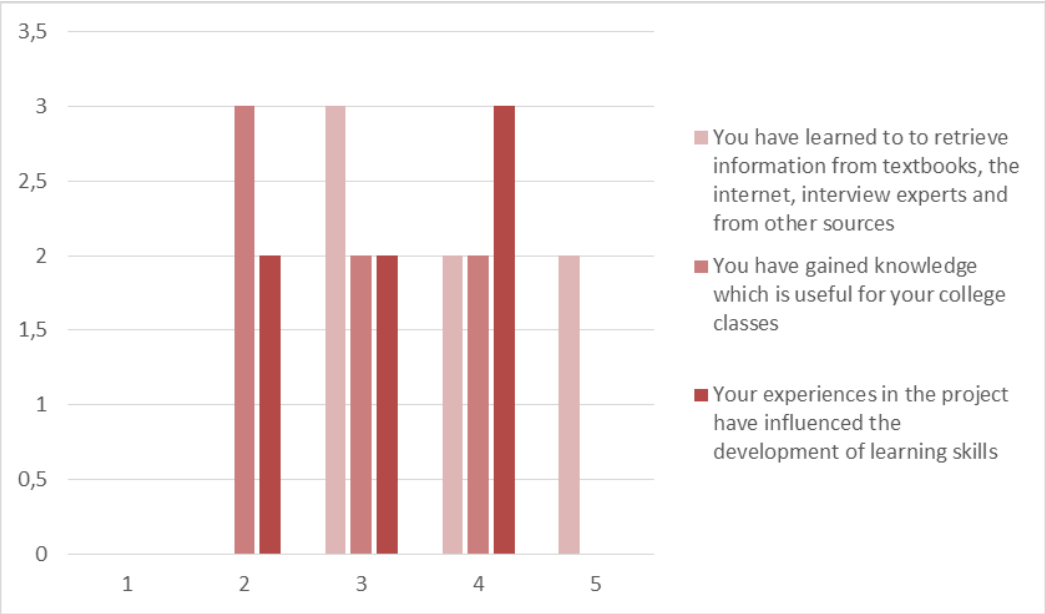

Fig. 5. Results chart #3

The next chart (Fig. 6) details the students' opinion of PBL in general. They overwhelmingly agree that PBL better prepares students for working in the industry and that more PBL classes should be introduced into engineering curricula. They, however, strongly disagree that students would have worse knowledge of engineering fundamentals and disagree that it would be too time consuming to have a larger number of PBL classes.

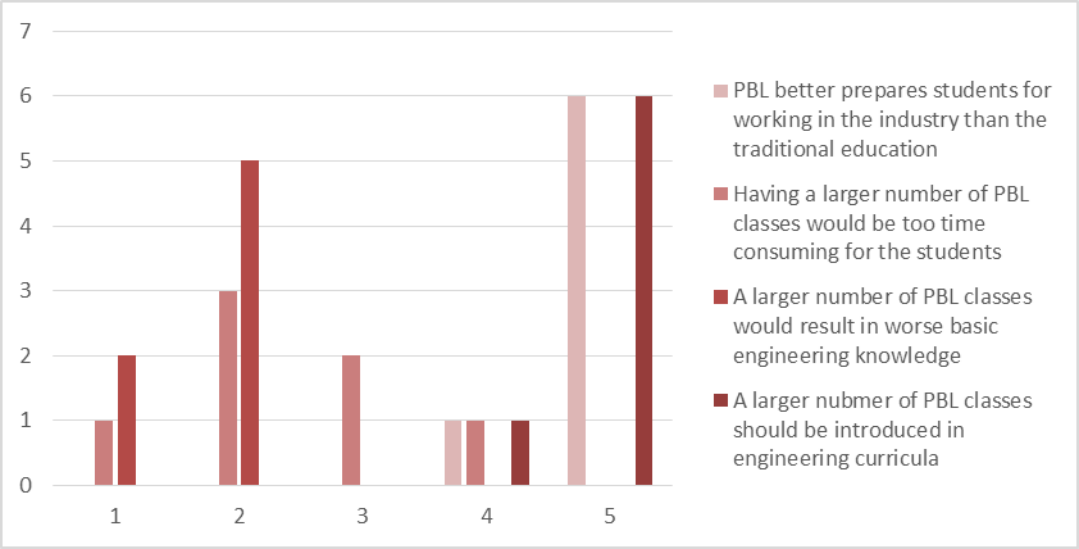

Fig. 6. Results chart #4

Results chart #5 (Fig. 7) describes the students' opinion on the applicability of knowledge gained in class to the project and to the industry, and the applicability of knowledge gained in the project to class and to the industry. Students slightly agree that the knowledge gained in education is applicable the project work and slightly disagree that it is applicable to the work in the industry. This is troubling since students don't perceive the knowledge gained in the faculty as something which would be useful to them later in their professional careers. On the other hand, students perceive the knowledge gained in the project extremely useful for the work in the industry. They also slightly agree that the knowledge acquired in the project is applicable in further education.

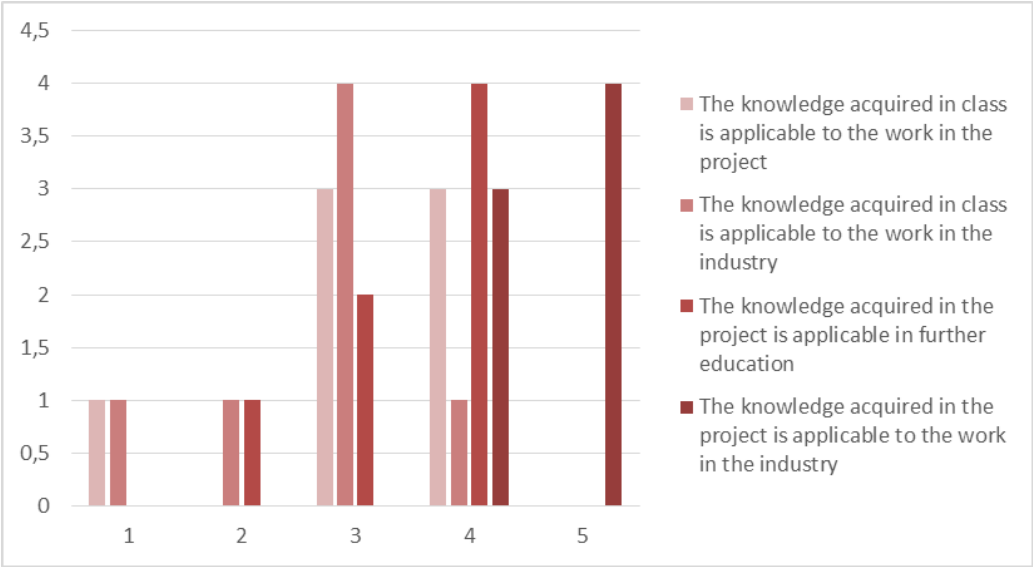

Fig. 7. Results chart #5

The last chart (Fig. 8) shows the students' satisfaction with their mentors on the project. While they are generally satisfied with the mentor's knowledge of the subject matter they have conflicting opinions on the level of received help and on the general usefulness of their mentors. Few of the students are not satisfied with the help that their mentors have offered and believe that their mentors were not useful to them. About the same number of students are slightly satisfied, while a few of them are neither satisfied nor dissatisfied. These results are perhaps the most unexpected in the research and would need to be further discussed with the students to find out what was the reason for such discontent.

Fig. 8. Results chart #6

5. Conclusion

Advancements in technology and a vastly increased volume of knowledge needed to be an engineer have shown that the current traditional teacher centric model of education is starting to become an inadequate method of teaching. A re-emergence of Project Based Learning, a method known for almost a century, may be the key to upgrade the way engineering students are taught. The advantages of PBL were shown in the paper as well as the problems arising from its implementation and while it may not be the complete answer to the problems in education of future engineers it is a step towards the solution.

The case described in the paper is a student project for the international competition in building sustainable, low energy smart houses, which is currently the brightest example of all the advantages PBL has to offer in Croatia. Therefore, the research was focused on determining whether the advantages proposed in the literature are also perceived as such by the students who were a part of this project. Other interests of the research were the students' general attitude towards PBL and their satisfaction with their mentors. The research was conducted by an online survey and only among the students of Faculty of Civil Engineering University of Zagreb.

Results have generally confirmed the advantages of PBL, however, not by as much as was expected. Some proposed advantages were deemed as advantages only by a close margin. The second segment of the survey has also yielded some interesting results. Students strongly believe that PBL is better in preparing them for work in the industry and that more PBL courses should be introduced. It is disconcerting that the students believe the knowledge acquired during the traditional education is not applicable to the work in the industry.

Perhaps the most interesting results are related to the questions about their mentors. Although generally the student's opinion of the mentors is positive, some students were not satisfied with the help they received from their mentors. This is the area that perhaps requires further inquiry the most.

The research was focused only on students of the civil engineering and should be expanded to include students from all engineering faculties which have participated in the project. It would also be useful to include the students' mentors in the research and to interview them about their experiences on the project and their views on PBL.

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Role of Fieldwork in Engineering Education in the Field of Construction Management and Transportation Engineering

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Abstract

The paper describes approaches to conducting fieldwork education in construction management and transportation engineering at the Faculty of Civil Engineering in Osijek and at the Polytechnic of Zagreb. Fieldwork is an important part of civil engineering study programs in the field of construction management and transportation engineering, both in university studies and in professional studies. The main purpose of fieldwork is to complement the students' theoretical knowledge and to provide a complete insight into the issues of construction management and technology by strengthening the teaching process in which one creates a clear picture of the students' future work and provides them with knowledge and skills through direct contact with the profession. This paper presents and describes the process of conducting fieldwork in several course subjects during the academic year 2014/2015. The paper also points out the need for evaluation of educational achievements in fieldwork through a series of elements and emphasizes the importance of a holistic approach aimed at ensuring maximum performance of fieldwork for students as well as successful results in teaching.

Keywords: fieldwork; study programme; construction management; transportation engineering; educational achievements; holistic approach

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1. Introduction

Fieldwork is an important part of the civil engineering study programs in the field of construction management and transportation engineering, both in university and in professional studies. Depending on the planned subject matter, it is conducted as half-day, full day or several days long work (field trip). The main purpose of fieldwork is to complement the theoretical knowledge of students and provide them with a complete insight into the issues of construction management and technology by strengthening the teaching process in which one creates a clear picture of the students' future work and provides them with knowledge and skills through direct contact with the profession. Very often fieldwork is organized in such a way that the subject matter of courses in construction management and technology is linked with a variety of other courses, thus achieving better quality of content while meeting the teaching objectives of several courses. This paper describes the organization and implementation of fieldwork at the Faculty of Civil Engineering Osijek and at the Polytechnic of Zagreb by connecting the courses in the field of construction management and transportation engineering.

2. Fieldwork in study programs at faculties and polytechnics

2.1. Fieldwork in documents of the Faculty of Civil Engineering Osijek

Faculty of Civil Engineering Osijek has long recognized the role of fieldwork as a form of teaching that provides the students with a contemporary way of mastering the subject matter of their studies, which should be ensured in all study programs.

According to the *Regulations on Studies and Studying at Josip Juraj Strossmayer University in Osijek*, full-time students' load during the academic year is achieved through 30 weeks of teaching and 14 weeks provided for exam preparation and actual exam taking. Total liabilities of full-time students in undergraduate studies can be up to 26 hours a week, while for students in graduate studies these include up to 20 hours a week and for students in postgraduate studies up to 12 hours. Exceptionally, students' obligations may be more extensive if the study program specifies a greater number of hours of practical and field instruction. The share of practical / fieldwork is determined by ECTS credits. *Statute of the Faculty of Civil Engineering Osijek* similarly regulates student workload during the semester and academic year. The curriculum of full-time students is based on student workload of 40 hours per week, which includes lectures, seminars and practical fieldwork, including monitoring and control of acquired knowledge, assessment, practical exercises and other forms of teaching as well as the time required for preparation of the exam. The strategic development document of the Faculty, *Development Strategy of the Faculty of Civil Engineering Osijek for the Period from 2009 to 2013*, as one of the guidelines in defining its development, states that part of education has to be conducted at construction sites and manufacturing plants.

According to the Decision on amendments to the Development Strategy of the Faculty of Civil Engineering Osijek for the Period from 2009 to 2013, it is planned to increase the share of fieldwork by 20% in five years. Increasing the volume of fieldwork is planned based on the requirements for organization of teaching in accordance with modern principles (according to the Strategy), but also based on the students' desire for an increase in this form of teaching, which is something they are extremely supportive of. As a measure used to assess the achievement of strategic goals, one observes the ratio of the number of student field trips in relation to the total number of courses. The planned increase was achieved the following year. In order to monitor implementation of teaching, it is the obligation of each course teacher to write a brief report on fieldwork that was held, indicating the method of implementation, objectives, participants and results.

2.2. Fieldwork in documents of the Polytechnic of Zagreb

The importance of linking course content and the labour market is highlighted in the documents of the Polytechnic of Zagreb. The document *Strategic Objectives of the Polytechnic of Zagreb for the Period from 2014 to 2025* defines the development objectives that largely rely on cooperation of the education sector and the industry: "*The industry has brought the real-world problems to university classrooms and thus made a big step toward providing for continuing professional development of engineers throughout their career. The academic-industrial partnership has made it possible for formal education to keep pace with new technologies and rapidly change existing practices*." *Regulations on Studying at Polytechnic of Zagreb* defines the methods of implementation of fieldwork and refers to the *Rules of Carrying out Fieldwork and Professional Practical Work*

in the Study. At the undergraduate professional study in civil engineering, fieldwork is carried out as part of the Fieldwork course. The course is carried out in the fourth semester and it is compulsory for all students.

The objective of the course is to provide basic and practical knowledge about technological and organizational procedures involved in works and documents at the site. The conditions and methods of teaching the course are defined in the *Guidelines for the Execution of 4th Semester Course "Fieldwork" at the Professional Study of Civil Engineering at the Polytechnic of Zagreb*. During this course, students are introduced (through practical work) with the business operations of construction companies, as well as with the production processes at the site, in production plants, as well as in supporting facilities at the site. This way the students' theoretical knowledge gained in the study is complemented with new knowledge obtained by practical work, which will be useful for them in their further studying.

Fieldwork is carried out in two parts. In the first part, through lecture-style exercises, students are prepared for active participation in the processes on site. The other part of fieldwork is carried out as professional practice. Fieldwork lasts one month (180 work hours) during summer (July or August), when students are not burdened with lectures and exams. Students are required to attend and participate actively in the work on the construction site, which involves full-time work at the site. During the fieldwork, students are obligated to visit at least one manufacturing plant of the construction company.

During their practical work, students are required to keep a practical work diary. This diary consists of two parts. The first part deals with the daily site organization chart, temporary roads and fences, storage facilities and plants at the site, the organization chart of a production plant with a description of work and production organization, the scheme of site and company management and, the location and technical description of the facility, a description of construction, finishing and installation works on the building, use of machinery, transport solution during construction, method of keeping the construction site documentation and implementation of building regulations, the solutions of accommodation, food and life necessities of employees at the site as well as the method of implementation of safety measures at the construction site. The second part of the diary describes the works that the student has performed that day and the work observed by him/her in the production process. The student describes in detail the organization and technology of performing particular works that were performed that day at the construction site. In addition to these descriptions, the student has to enclose the necessary sketches, drawings of details on the facility or in production, and other similar documents.

3. Organizing and conducting of fieldwork

3.1. Fieldwork planning

Fieldwork at the Faculty of Civil Engineering Osijek is financed with own funds of the Faculty and consequently it requires continuous rationalization and control of costs. When planning fieldwork, it is important to take into account the possibilities of providing training at shorter distances and of combining multiple courses. It is also important to define the expected achievements and educational objectives in order to avoid ineffectiveness of fieldwork or reduction of students' participation to mere passive observation.

High-quality implementation of fieldwork requires the involvement of an increasing number of people - professionals who, apart from course teachers, are key for the realization of planned educational content. The quality of fieldwork thus largely relies on the relationship between the students and the "field teacher" – his/her professionalism and ability to create an atmosphere of learning, openness and support to students during fieldwork. For a positive environment in the implementation of fieldwork, it is important that the company also provide an open and positive atmosphere in which the student feels welcome, regardless of the known or potential causes of stress. In addition to learning the subject manner, this way the students also learn how to deal with situations that are far from ideal, how to deal with stressful working conditions, lack of equipment or people, deadlines and similar situations that are part of the daily routine and have become highly characteristic of the construction industry.

3.2. Conducting fieldwork

Fieldwork at the Faculty of Civil Engineering Osijek has a long and rich tradition. It is carried out in accordance with programs of courses that are conducted at the Faculty and in accordance with the adopted curriculum for the university and professional studies. Fieldwork is mandatory for all students taking the courses. Fieldwork is carried out in several forms: as a professional or study tour lasting for a few days, during which the teaching takes place throughout the day based on a preannounced schedule; as one-day courses; as field exercises with students working in small groups; as supplementary classes for individual course units or as students' independent field research. Most of the time, fieldwork is organized in combination with other courses

in the study (Construction Management, Railways, Pavement Structures, Quality Management, Project Management, Airports) in order to achieve comprehensive teaching objectives and introduce the students with the complex environment of the construction project.

After completion of fieldwork and return from the field comes data processing (reports, samples of material, photographs and the like) and joint review by students and teachers of their impressions and success of fieldwork. Using the collected materials and photographic documentation, a comprehensive report is drawn up and published on the website of the Faculty, http://www.gfos.unios.hr/portal/index.php/nastava/terenska-nastava.html.

Based on an analysis of the results of surveys conducted after the end of the academic year among the students in the course of study "Transportation Engineering" at the Faculty of Civil Engineering in Osijek, it is evident that they are satisfied with the volume of fieldwork and its contribution to the understanding of course subject matter, as well as with the inclusion of practicing professionals in the teaching process. For the assessment of the performance of fieldwork, students' feedback and comments are very valuable to teachers in terms of further improvement of fieldwork. Below are a few comments from students who participated in the survey at the end of classes in the academic years 2013/2014 and 2014/2015:

"This course has made me interested in transportation engineering more than I could ever have imagined. It clearly identified the issues involved in road bed construction. Videos about the railways that we watched in class were also very interesting and informative."
"I like that there are is lot of fieldwork and that there are visiting experts."
"There should be more fieldwork conducted simultaneously with the respective topic that is being covered in class."
"It helps us to understand the subject matter that we learned about in class."
"Fieldwork helps put the curriculum in a realistic environment and understand the processes explained in class. The volume of fieldwork is much greater than in other courses of study."

Overview of fieldwork conducted in the field of transportation engineering, construction management and technology in the academic year 2014/2015 is presented in Table 1.

Table 1. Overview of fieldwork conducted in academic year 2014/2015 at the Faculty of Civil Engineering Osijek

1 Reconstruction of pavement of state roads in the territory of Technical Unit Osijek, state road D46, bypass of Vinkovci; and visit to the asphalt plant Cestorad d.d. Vinkovci

Fieldwork in the courses *Maintenance and Rehabilitation of Roads* and *Application of Geosynthetic Material* for students of the 2nd year of graduate university studies – course of study Transportation Engineering, held on November 4, 2014

2 Visit to the construction site of southern bypass of Osijek – upgrade of southern carriageway

Fieldwork in the course *Characteristics of Asphalt Pavement* for students of the 2nd year of graduate university studies - course of study Transportation Engineering, held on November 5, 2014

3 Train station Osijek Donji Grad and the railway bridge over the river Drava on the line M301 Osijek - Beli Manastir - state border

Fieldwork in the course *Railways* for students of the 2nd year of graduate university studies - course of study Transportation Engineering, held on November 14, 2014

4 Visit to the construction site of the bridge over river Drava near Petrijevci

Fieldwork in the courses *Earthworks* and

5 Visit to the Centre for Highway Maintenance and Traffic Control (COKP) Čepin

Fieldwork in the courses *Maintenance and*

6 Visit to the Institute IGH Zagreb, geotechnical works on the highway Zagreb-Macelj

Fieldwork in the course *Application of*

Characteristics of Asphalt Pavement for students of graduate university studies held on November 19, 2014

7 Visit to the Vukovar City Museum – Castle Eltz

Fieldwork in the courses *Project Management* and *Revitalization of Architectural Heritage* for students of the 2nd year of graduate university studies, held on December 16, 2014

Rehabilitation of Roads and *Application of Geosynthetic Material* for students of the 2nd year of graduate university studies – course of study Transportation Engineering, held on November 24, 2014

8 Industrial track of the company Našicecement d.d. in Našice

Fieldwork in the course *Railways* for students of the 2nd year of graduate university studies, course of study Transportation Engineering, held on January 10, 2015

Geosynthetic Material held on December 8, 2014. Subject matter of fieldwork covers also the subject matter from the course *Geotechnical Engineering*.

9 Visit to the Department of Transport and Construction Machinery of the company Osijek-Koteks d.d. Osijek

Fieldwork in the course *Earthworks* for students of the 1st year of graduate university studies – course of study Transportation Engineering, held on January 14, 2015

10 Visit to the construction site of the state road D57 Vukovar-Orolik

Fieldwork in the course *Pavement Structures* for students of the 1st year of graduate university studies – course of study Transportation Engineering, held on April 14, 2015

11 Complex of Vina Belje in Karanac and biogas plant in Mitrovac

Fieldwork in the courses *Quality Management* and *Architecture of Industrial Buildings* for students of the 1st year of graduate university studies, held on April 17, 2015

12 Laboratories of Institute IGH d.d. Zagreb

Fieldwork in the courses *Pavement Structures* and *Geotechnics in Transportation Structures* for students of the 1st year of graduate university studies, held on April 24, 2015

13 Visit to the construction site of passenger terminal and transport areas of Zagreb Airport

Fieldwork in the courses *Pavement Structures*, *Quality Management*, *Geotechnics in Roads* and *Airports* for students of the 1st year of graduate university studies held on April 24, 2015. Fieldwork was organized in cooperation with the Polytechnic of Zagreb.

14 Visit to Croatian Standards Institute and Croatian Accreditation Agency

Fieldwork in the course *Quality Management* for students of the 1st year of graduate university studies held on April 24, 2015.

15 Visit to the concrete factory and reinforcement plant of Gradnja d.o.o. Osijek

Fieldwork in the course *Quality Management* for students of the 1st year of graduate university studies held on May 15, 2015.

16 Construction site of the new building of the Faculty of Civil Engineering in Osijek

Fieldwork in the course *Construction Management I* for students of the 3rd year

17 Asphalt plant of the company Gradnja d.o.o. in Petrijevci

Fieldwork in the course *Pavement Structures* for students of the 1st year of

18 Construction site of the southern bypass of Osijek: road section between junctions Čepinska and Vinkovačka

Fieldwork in the course *Pavement Structures* for students of the 1st year of

of graduate university studies held on May 22, 2015.	graduate university studies, held on June 11, 2015.	graduate university studies, held on June 11, 2015.

Fieldwork in the field of transportation engineering and construction management and technology at the undergraduate and graduate university studies in the academic year 2014/2015 was carried out in 13 courses, lasting for a total of 55 hours. The share of fieldwork in the teaching of individual courses is presented in Table 2.

The overview and analysis of the share of fieldwork in the performance of individual courses shows that fieldwork covers different parts of the curriculum, whereupon visits to construction sites, specialized laboratories and production facilities are predominant. It is also evident that fieldwork is usually carried out in a combination of several courses to ensure an integrated approach to a particular construction problem, but also to enable rational organization and implementation of teaching.

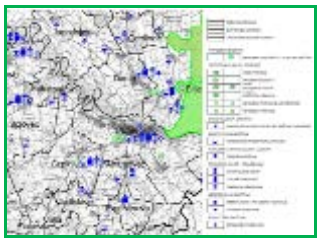
With the aim of better preparation of fieldwork, preparatory classes are organized whenever possible in collaboration with practicing experts involved in the implementation of projects that are the subject of fieldwork. Lectures given by guest experts are incorporated in the context of course content so that the theoretical part could be connected with the practical part in the best way possible. This ensures better preparedness of the field teachers, but also of the companies and construction sites where the fieldwork is to be carried out, in terms of their familiarization with the objectives, content and results of fieldwork.

Table 2. The share of fieldwork in the field of transportation engineering and construction management and technology at the university graduate studies

Year of studies	Course	Number of classes (lectures and exercises)	Number of hours of fieldwork	Share of fieldwork
1st year of graduate university studies	Earthworks	30+30	4	7.0%
	Pavement Structures	30+30	10	16.7%
	Geotechnics in Transportation Structures	30+30	4	7.0%
	Architecture of Industrial Buildings	30+30	2	3.3%
	Quality Management	30+30	8	13.3%
	Airports	30+30	2	3.3%
	Total number of hours of fieldwork:		30 hours	8.3%
2nd year of graduate university studies	Railways	30+30	4	7.0%
	Project Management	30+30	2	3.3%
	Application of Geosynthetic Material	30+30	4	7.0%
	Revitalization of Architectural Heritage	30+30	2	3.3%
	Maintenance and Rehabilitation of Roads	30+15	4	8.8%
	Characteristics of Asphalt Pavement	30+15	4	8.8%
	Total number of hours of fieldwork:		20 hours	6.1%

An overview of preparatory classes held as part of the courses in the field of transportation engineering and construction management and technology in the academic year 2014/2015 is presented in Table 3.

Table 3. Overview of expert lectures held in the academic year 2014/2015

1 What to do when you come across an archaeological site during excavation works?	2 Research, restoration and revitalization of cultural heritage Ilok-Vukovar-Vučedol	3 Human factor in traffic – the role of psychology
		
Lecture held on December 3, 2014 in cooperation with Slavica Filipović, BA, Senior Curator and Head of the Archaeological Department of the	Lecture held on December 12, 2014 in cooperation with Miroslav Pauzar, M. Eng. (CE) from the Institute IGH d.d. Business Centre Osijek and Zdenka Predrijevac, Head	Lecture held on January 21, 2015 in cooperation with Iva Anić, MA (Psych.), external associate of the Department of Psychology of the Faculty of Humanities

Museum of Slavonia in Osijek. of the Conservation Department in Vukovar. and Social Studies in Osijek.

Lecturers were able to explain the subject matter of the selected projects to the students, so that they could keep track of the fieldwork more easily. An anonymous survey and discussions with the students highlighted the importance of the choice of speakers and topics as particularly important. In the survey, the students expressed positive views on the participation of guest experts, just as they did when it came to organization of fieldwork. Below there are a few comments from students who attended the lectures in the academic year 2014/2015:

"Very good combination of different disciplines on the same topic - interesting and commendable."
"This way we were able to increase our knowledge and become familiar with situations related to our profession."
"I think it is interesting to hear the experiences of experts."
"I think that all the lectures were carried out very well. I only hope I will never meet any archaeologists in my own work."

4. Learning outcomes of fieldwork

Increased demands for applicability of acquired knowledge and easier adaptation to the workplace after one's graduation require further review of existing teaching practices and content of study programs. The process of reform of study programs based on learning outcomes needs to involve external associates and future employers and not just teachers and students. In the study program of the Faculty of Civil Engineering in Osijek, fieldwork is not represented as a separate course, but is rather implemented within the framework of individual courses or in combination of several courses as described in Section 3 of this paper. At the Polytechnic of Zagreb, fieldwork is implemented as a compulsory course lasting for 30 hours of practical work, with a teaching load of 2.0 ECTS. Course objective is for students to acquire the basic, practical knowledge of technological and organizational procedures involved in works and documents at the construction site. The following learning outcomes are defined for the course:

1. Draw an organization chart of the construction site.
2. Draw a layout of the manufacturing facility.
3. Distinguish between various constructions, finishing and installation works on the building.
4. Analyse the application of construction machinery on the site.
5. Draft appropriate construction site documents.
6. Analyse transport solutions during the construction process.
7. Distinguish between various safety measures at the construction site.

According to course content, during their fieldwork students solve certain problems at the site and prepare a research paper.

5. Conclusion

One of the important features of fieldwork is that it involves events that carry a high level of volatility and unpredictability - risk. Learning sometimes takes place based on short-lived events that are not repeatable, which represents an additional challenge in assessing the achievement of learning outcomes of fieldwork. To ensure the achievement of learning outcomes through this form of learning, one requires preparation, involvement of course teachers and field instructors, and good organization of teaching. This paper presents the performance of fieldwork in the field of transportation engineering and construction management at the Faculty of Civil Engineering in Osijek. The fieldwork lasts for 50 classes, which represents little over 14% of lecture hours in 12 courses. For a more precise evaluation of educational achievement acquired through fieldwork, one should evaluate the following elements:

- Description of the actual work in the field - field measurements, research, etc.
- Record of the experience gained, with indication of the contribution to educational achievements
- Discussion and exchange of experience gained through fieldwork.

Such holistic approach will ensure maximum performance of fieldwork for students and successful results in teaching.

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Integration of Multi-criteria Analysis into the Evaluation Process of Student Papers

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Abstract

Problems related to the management of projects, specifically priority ranking problems, can be found in all stages of projects' life cycles, mostly as the result of inadequate decision making. Such place where engineering students can be challenged both creatively and by knowledge in a complex project environment can be found in the graduate study programme under the course of Project Management at the Faculty of Civil Engineering in Rijeka. Priority ranking of student papers in faculty environment deals with complex decision making problems which is characterized by lots of participants, multidisciplinarity, huge quantities of information, different opinions as well as conflicting goals and criteria. In order to cope with such complexity and to help professors during evaluation process of student papers, the use of concept based on multi-criteria analysis for solving priority setting problem is proposed. The starting point of proposed concept is goal analysis and development of adequate criteria set. Evaluation of criteria importance is based on a set of experts' opinions processed by AHP method, while all data processing is done by PROMETHEE multi-criteria methods. The main outcome of proposed concept is a rank list of student papers. Structuring such complex problems and considering multiple-criteria explicitly leads to more informed and better decisions, at the same time involving students in the process of setting up the concept making them active subjects nor end objects. Integration of multi-criteria analysis into evaluation process of student papers contributes to higher consistency in their priority ranking, and at the same time innovating curriculum of the course as it is introduced into education process of construction management.

Keywords: Multi-criteria analysis; priority ranking; project management education; decision support

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1. Introduction

The tradition of higher education in the field of civil engineering in Rijeka began in 1969 with the founding of the College of Civil Engineering; in 1971 it started its programme in civil engineering as a part of the Faculty of Engineering in Rijeka, thus becoming the Faculty of Civil Engineering in 1976, an independent higher education and scientific research organization. The Faculty had its own development stages in the field civil engineering as well as teaching methods and methodologies.

In 1998 the shared view of four education ministers–in charge for France, Germany, Italy and United Kingdom–that the segmentation of the European higher education sector in Europe was outdated and harmful, and future higher education should have a "common frame of reference aimed at improving external recognition and facilitating student mobility as well as employability" (The Sorbonne Declaration, 1998). It resulted a year later in the establishment of the European Higher Education Area (EHEA)–a body for future development of higher education. At its inception (European Higher Education Area, 2015), the Bologna Process was meant to strengthen the competitiveness and attractiveness of European higher education and to foster student mobility and employability through the introduction of a system based on undergraduate and postgraduate studies with easily readable programmes and degrees.

The academic programme at the Faculty of Civil Engineering of the University of Rijeka has been reformed based on the principles of the Bologna Process which was applied for the first time in the academic year 2005/06 (Car-Pušić and Deluka-Tibljaš, 2009). Since then, courses performed in different study programmes (undergraduate, graduate, postgraduate, and vocational) are constantly creating and improving opportunities for students to learn and acquire knowledge from various scientific fields in a safe environment such as the University of Rijeka. One such place where engineering students can be challenged both creatively and by knowledge in a complex project environment can be found in the graduate study programme under the course of Project Management at the Faculty of Civil Engineering in Rijeka.

Construction project management is a difficult task when one takes into account the complexity, uncertainties, and large number of activities involved (Marović, Bošković and Car-Pušić, 2014; Marović and Jajac, 2014). Such complexity represents a shock to students as they lack both knowledge, business and field experience. In order to help students acquire desired project management knowledge, the real environment of construction projects is simulated by engaging with local public firms on their active projects. As these projects can be in various phases of their life cycle, the intention is either to find projects in their early stages and actively work on the project proposal or to make several alternative proposals based on the same known inputs and additional field research. In both cases, students were grouped into project teams. Such an environment allows them to express their accumulated knowledge, absorb new knowledge, and work in dynamic project surrounding is of great importance, especially for their future challenges as civil engineers. As future civil engineers, they have to be able to adapt (Rosa, 2013; Marović and Jajac, 2014) to new challenges and changes–synergetic effects of the economic and technological growth caused by various environmental, ecological and social problems at the local, regional and global levels.

The main objective is to present a decision support concept to the management of student papers (i.e. projects/project proposals) which is used in the course of Project Management at the Faculty of Civil Engineering in Rijeka. Special emphasis is put on the integration of multi-criteria analysis in the evaluation process of student papers.

Section 1, the Introduction, contextualizes the project management and teaching project management in a faculty environment; it also defines the objectives of the paper. Section 2 presents the literature review of group decision-making and the use of multi-criteria methods for selecting and ranking alternatives (i.e. papers, project proposals etc. in an academic environment). Section 3 shows the decision support concept to management of student papers with an emphasis on the structuring of the typical priority ranking problem. Section 4 shows the results of the study followed by the discussion. Finally, in Section 5, the Conclusions of the study are presented.

2. Literature review

Digital technologies radically transform project management and project delivery. Two decades ago, Morris described the evolution of project management as being closely related to developments in system engineering, modern management theory, and the evolution of the computer (Morris, 1997). Today, such technologies are adopted in project-based industries. Their use is breaking the framework of established approaches to project management, enabling more rapid and agile forms of organizing (Levitt, 2011; Whyte and Levitt, 2011), especially when it comes to the management of large complex projects (Whytte, Stasis and Lindkvist, 2015).

The top-down style of project management was formalized to plan and execute their projects in a book called PMBOK by the founders of the Project Management Institute in the beginning of 1970s. The PMBOK (PMI, 2013) provides guidelines for managing projects in a prescriptive way through nine managerial fields: integration, scope, time, cost, quality, human resource, communications, risk, and procurement management. It defines project management and related concepts in order to develop them in traditional plan-driven development processes with an emphasis on controlling and managing the scope of the project. How well the project goals will be reached and how the different requirements will be fulfilled depend on the decisions made during the projects.

The project management approach is based on detailed decision analysis because the decisions are crucial in reaching objectives of the project. Decisions are made based on assumptions, which are necessary because the outcome is in the future, and therefore uncertain at the present when decisions must made. Therefore, decision-making can be seen as a critical success factor in project management. The more complex the project environment is, the more complicated the decision-making process becomes. Since the complexity of the socio-economic environment of every project is constantly increasing, many decision-making processes take place in group settings. At the same time, it creates even more complex environment with the involvement of multiple stakeholders.

To deal with decision-making problems in such complex environments, various multi-criteria group decision-making (MGDM) methods have been developed. An overview of these methods within an organizational/business context was done by Alvarez-Carillo, Duarte and Leyva-Lopez (2010). The common feature is that the groups (i.e. stakeholders) are homogeneous even if different group members have opposite views. However, in the wider socio-economic context of decision-making problems, it is clear that the group is not homogeneous and the group members have different, and often conflicting, points of view (Marović and Jajac, 2014).

Munda (2004) defined social multi-criteria evaluation for decision problems within society as a whole and puts itself in the domain of public choice. In such context, problems are multidimensional and the evaluation of such projects has to be based on procedures that explicitly require the integration of broad set of various and conflicting points of view. Another MGDM method was developed by Macharis, Turcksin and Lebeau (2012) in which stakeholders are involved and their points of view are explicitly taken into account without being asked to converge directly to consensus–multi-actor multi-criteria analysis (MAMCA).

For purposes of priority ranking, different multi-criteria methods and concepts were used for decision-making. The Analytic Hierarchy Process (AHP) method is widely used since it was developed by Saaty (1980) and extended for group decision support (Saaty, 1989; Dyer and Forman, 1992; Ishizaka and Labib, 2011). While Saaty encourages the use of consensus voting in order to come to a common pairwise comparison matrix for the whole group or to aggregate the individual judgments, it is also possible to use the weighted arithmetic mean method where the average of the individual pairwise comparison is computed as presented by Marović (2013). The main disadvantage of AHP is the high number of pairwise comparisons required, which makes its use difficult for problems with a high number of criteria and/or alternatives (Ishizaka and Labib, 2009).

The other outranking method which is often used is Preference Ranking Organization Method for Enrichment Evaluation–PROMETHEE–developed by Brans, Mareschal and Vincke (1984). The main advantage of PROMETHEE is that it is easy to understand and does not include obscure technical parameters with no significance for the decision-maker. The evaluation of each criterion can be expressed in its own units and therefore the scaling effect

is completely eliminated. Thus, it has the advantage that a normalization of the scores is not required, which avoids the drawback that the ranking depends on the selected normalization method (Ishizaka and Nemery, 2011). In PROMETHEE group decision support, each individual ranking given by the net flows is considered as a criterion (Macharis et al. 1998; Jajac, 2010; Marović, 2013).

Strengths and weaknesses of AHP and PROMETHEE methods were discussed by Macharis et al. (2004) and the design of operational synergies in multi-criterial analysis is given. The synergy effect is most evident during decision-making hierarchy setup (setting up the goals, objectives and criteria), and is used for solving various multi-criteria problems.

Although multi-criteria methods are widely used for solving various problems of priority ranking and decision-making, the focus of this paper is on the academic environment. Certa, Enea and Hopps (2015) proposed a structured methodology to evaluate the results of an academic training course specific to postgraduate students. They used AHP method for group evaluations while the global judgement, derived from group evaluation, was performed by means of fuzzy numbers. On the other hand, Wu, Lin and Wang (2013) proposed a model based on the multi-criteria decision method that can offer counseling units in vocational high schools in Taiwan and devised a set of procedures for selecting assessment tools that can effectively identify students who are likely to leave education. Another model based on multi-criteria decision analysis is proposed (Bana e Costa and Oliveira, 2012) for faculty evaluation, while the group decision-making model which helps juries to attribute a scientific award was discussed by Colson (2000). Marović, Bošković and Car-Pušić (2014) presented a model based on AHP and PROMETHEE to make priority rank of student project proposals; the general settings of decision support concept to management of student project proposals were presented by Marović and Jajac (2014).

Learning Management System (LMS) technology provides a platform for an on-line learning environment by enabling the management of whole learning process as well as its users (both academic staff and students). Srđević et al. (2012) used AHP to support the evaluation of the most appropriate LMS system for students. In 2006 LMS and the tool Moodle were implemented in undergraduate courses at the Faculty of Civil Engineering in Rijeka. Informatics, a mandatory course in the freshman year, was the first course which implemented LMS and the hybrid (blended) learning model (Korin-Lustig and Lukarić, 2008), closely followed by several courses held at the Department of Construction Management, Technology and Architecture (Marović, Car-Pušić and Gudac, 2010). Their research about the implementation of e-learning tools in the teaching process provided the trigger to apply LMS and the hybrid learning model to all courses.

3. Methodology

3.1. Decision support concept to management of student papers

Proposed methodology for evaluating student papers is based on the priority ranking model PRIMO (Marović, Bošković and Car-Pušić, 2014) and the decision support concept to management of student projects (Marović and Jajac, 2014). Basically, it is a seven-step procedure continuously connected through three modules (data base, model base, and stakeholder involvement) as shown in Fig. 1.

The data base (or knowledge base) module consists of several sub-modules such as the archive, LMS and the local database. As the whole module is web-based, modules are in constant interaction. Interaction starts with inserting information about students from a local database (i.e. students administration) into LMS, which is scheduled at the beginning of the academic year and course kick-off (step 1). After presenting and assigning projects and project goals to students (step 2), students are grouped into project teams (step 3). From this point, students are teamed up (6 to 8 students per team) and work as a team on their papers (i.e. projects/project proposals), creating a highly competitive environment. In order to evaluate them and rank their outcomes in consistent and objective ways, taking into account lots of participants, multidisciplinarity, huge quantities of information, different opinions as well as conflicting goals and criteria, the use of multi-criteria analysis is appropriate.

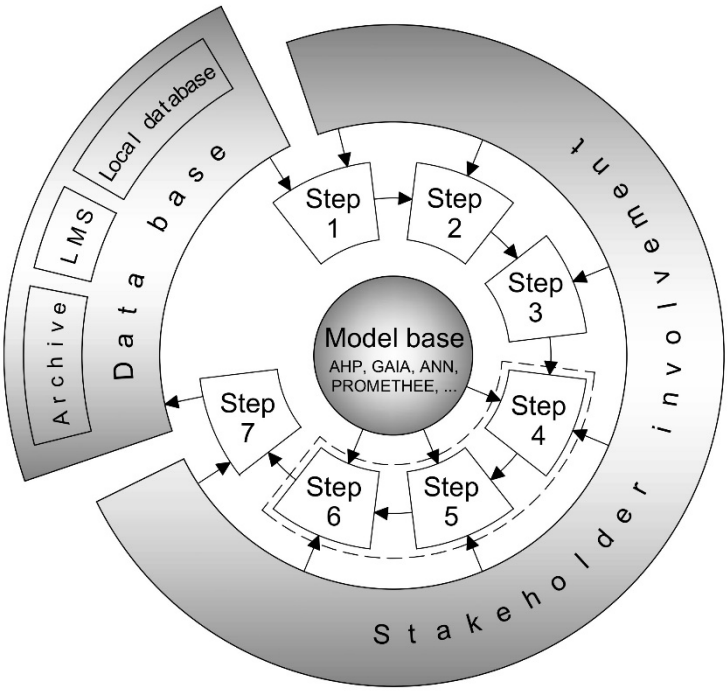

Fig. 1. Decision support concept to management of student papers (modified according to Marović and Jajac, (2014))

Multi-criteria analysis starts with goal analysis (step 4) (i.e. with determination of goals, objectives and criteria as well as their weights). It is a crucial step in priority setting problems where models and methods (from the model base module) and stakeholders (from the stakeholder involvement module) meet for the first time. It is of great importance to determine the goals, objectives and criteria in order to perform the comparison of alternatives (i.e. actions) and their final priority ranking. Such determination is done with the hierarchical goal structure procedure developed by Marović (2013) for multi-stakeholders based on AHP premises.

The procedure begins by defining the main goal (G) and breaking it down to the objective level (Oi) and the criteria level (Ci) which is done through multi-stakeholder (i.e. group consensus). At the point that objectives on certain levels of decomposition can be precisely described and measured (when they can be expressed quantitatively or qualitatively), they become criteria. Each stakeholder group has the opportunity to set its own hierarchical goal structure and present it in front of other stakeholder groups during the panel discussion. As they achieve consensus, the panel discussion ends, resulting in a final hierarchical goal structure. It is a hierarchical goal structure based on a compromise of all involved stakeholder groups. In such a manner, the group decision-making is implemented in a proposed decision support concept to the management of student papers at the beginning of multi-criteria analysis.

Assigning weights to criteria is a crucial part of this step for the future comparison of alternatives and is done once the hierarchical goal structure is made. As all criteria are not equally important to all stakeholder groups, each group weights its own goal structure where they are allowed to freely choose the scale for assigning the amount of importance. In order to compare the weights of different stakeholder groups, the assigned amounts need to be normalized (Marović, 2013). Final weights of the whole hierarchical goal structure is the arithmetic mean of the group weightings. The entire step 4, for the purpose of the evaluation of student papers, is presented in the next section.

Once the hierarchical goal structure is set, alternatives (i.e. papers) have to be analyzed and evaluated according to defined criteria (step 5). As alternatives are evaluated and the stakeholders' consensus toward the importance of each criterion is known (in the form of a decision matrix), it is possible to apply one of the multi-criteria methods from the model base in order to process data (i.e. compare alternatives) (step 6). The result of data processing is the

priority ranking of all alternatives (i.e. rank-list). Such rank-list gives the decision-maker adequate information to grade papers according to their performance and to select the best one (step 7). As the rank-list is translated into student grades and the final assessment list is uploaded on LMS, the course ends. From LMS, grades are synchronized the with active students' data in the local database of students' administration office and archived, as the concept is ready for the next academic year.

3.2. Determination of hierarchical goal structure and assigning weights

In the case of faculty environment, there are two major stakeholders–academic staff and students. According to the main goal, a scenario–hierarchical goal structure–per each stakeholder group was developed. As these two groups develop their scenarios during panel discussion, the consensus is achieved expeditiously.

The main goal of determined hierarchical goal structure for the evaluation of student papers consists of two objectives, each consisting of four criteria as shown in Fig. 2 and described in Table 1.

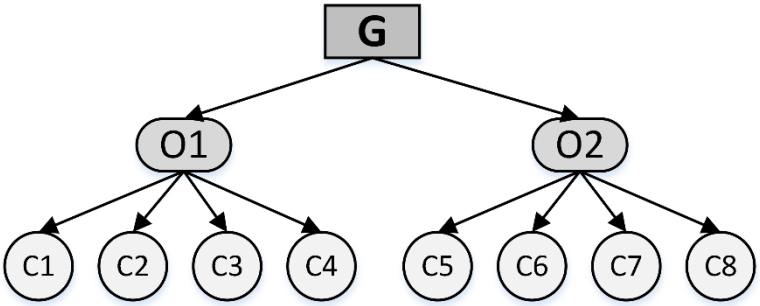

Fig. 2. Hierarchical goal structure for evaluation of student papers

For the purposes of this paper, the established hierarchical goal structure for priority ranking of student project proposals (Marović and Jajac, 2014) is adopted, modified and presented in Table 1.

Once the goal, objectives and criteria are known, there is a need to assign weight to each one. Since all objectives and criteria are not equally important, it is necessary to assign weight to each of them. Criteria weighting was performed by the same proposed procedure as hierarchical goal structure–through a group consensus. The group consensus of each criterion weight is shown in Table 1 as well.

Table 1. Code and description of goal, objectives, and criteria with assigned weight (modified according to Marović and Jajac (2014))

Code	Goal, objectives and criteria	Criteria description	Weight
G	Project team success	Project team success is based on evaluation of written paper as well as oral presentation.	1.0
O1	Evaluation of written paper	Evaluation of written paper is based on performance on criteria C1 to C4.	0.60
O2	Evaluation of oral presentation	Evaluation of oral presentation is based on performance on criteria C5 to C8.	0.40
C1	Organization and logic	Paper organization is clear, logical, mature, and thorough development of subtopics that support thesis with excellent transition between paragraphs. Thesis is clear, arguable, well developed, and a definitive statement.	0.15
C2	Clarity of text and figures	Paper is written in clear, logical, mature text and figures. Paper is concise with consistently proper grammar, spelling and paragraphing. Critical, relevant and consistent connections are made between evidence, subtopics, counterarguments, and thesis showing excellent analysis.	0.125
C3	Conclusion justified by results	Based on given results, emphasizes significance and implications of the study. Summary of topic, thesis and all subtopics are in proper order with concluding ideas that leave an impact on a reader.	0.175
C4	Significance and originality	Project proposal is exceptionally researched, extremely detailed and accurate with critical evidence from a wide variety of sources. Methods are appropriate and properly applied.	0.15
C5	Visual aids, legibility, and clarity	Audio-visual aids (if used) are well-prepared and appropriate.	0.10
C6	Effective use of time	Topical sequence logical, appropriate time given to sections of the presentation, keeps within allotted time.	0.075
C7	General style, liveliness and stage presence	Presenter is familiar with content, statements are clear, voice modulations appropriate, and maintains eye contact.	0.075
C8	Effectiveness in answering questions	Presenter has good grasp of study and related areas, and responds effectively and clearly to questions.	0.15

Assessed weights and criteria can be used in future evaluations without any changes, this has been done on the present course for the last three years. However, we strongly advise using the presented hierarchical goal structure as a draft for panel discussion so that it can be implemented in other courses. In spite of the possibility of changing the hierarchical goal structure, the whole concept remains stable and consistent.

4. Results and discussion

4.1. Setting up the model

Setting up the priority ranking model starts with analyzing the projects and evaluating each of them by predefined criteria (see Section 3). Following this, steps 4 to 6 of the decision support concept (i.e. the steps where multi-criteria analysis is implemented in the evaluation process of student papers) are presented. The results of such analysis for the academic year 2014/15 are shown in Table 2, thus creating a decision matrix needed for further comparison of projects.

Table 2. Decision matrix

Project teams	Criteria							
	C1	C2	C3	C4	C5	C6	C7	C8
PT 1	8.00	g	8.25	m	g	3.00	h	4.25
PT 2	8.50	g	8.00	h	g	4.00	vh	4.50
PT 3	8.25	g	9.50	vh	vg	1.00	vh	5.00
PT 4	8.50	vg	7.50	h	g	0.00	h	4.50
PT 5	9.00	vg	9.00	vh	vg	0.00	vh	5.00
PT 6	7.75	g	7.50	m	vg	1.00	vh	4.75
PT 7	7.75	a	8.00	h	g	2.00	m	4.00
PT 8	6.00	g	6.50	m	a	0.00	h	4.00

It is not necessary for criteria to be of the same characteristic–either quantitative or qualitative. Same table shows that some criteria are quantitative (C1, C3, C6 and C8) and other qualitative (C2, C4, C5, and C7). It is important to assign a value scale for each criterion; quantitative criteria were evaluated by two scales (1-10 and 1-5), while qualitative criteria were evaluated by two types of 5-level scale (from “very good” to “very bad” and from “very high” to “very low”).

The PROMETHEE methods (Brans, Mareschal and Vincke, 1984) are based on the pairwise comparison of the alternatives (i.e. actions it is necessary to input other basic parameters, such as setting up the direction of preference to minimum or maximum and associating a preference function to each criterion), and criteria weights into the decision matrix. One of six different types of preference function–available in Visual PROMETHEE–has to be associated to each criterion. Preference functions are generally characterized only by an indifference and preference threshold.

The essence of this step lies in the fact that the decision-maker must give priority to one of two alternatives based on the difference between the criteria values of the compared alternatives. In analyzing the projects, two types of preference functions emerged for future use: the V-shape and the U-shape preference function. V-shape preference function was used for those criteria (C1, C3, C6 and C8) in which the decision-makers considered that the differences in the values of the solution expressed through these criteria were very important. It is especially suitable to use for quantitative criteria. For other qualitative criteria (C2, C4, C5, and C7), the U-shape preference function was used as all the alternatives are indifferent. They are indifferent as long as the differences between their values do not exceed the threshold of indifference.

Once the priority ranking model is set up (both actions and criteria), the pairwise comparison of the alternatives can be made with the PROMETHEE II method for complete ranking of alternatives.

4.2. Results of the model

Results are obtained with the use of Visual PROMETHEE v.1.1.0. This is a multi-criteria decision aid software developed by VPSolutions under the supervision of Prof. Mareschal from the Universite Libre de Bruxelles. It is designed to help decision-makers to evaluate, identify and rank possible decisions or alternatives according to multiple and often conflicting criteria.

The PROMETHEE II complete ranking of all alternatives is based on the total or net flow Phi, which is shown in Fig. 3, where all alternatives are ranked from best to worst (+1.0 to -1.0 scale). The green half of the scale corresponds to positive Phi scores, while the red half to negative scores. As the alternative is higher on the scale (see Fig. 3) it becomes better than the others, equivalently as the alternative is lower on the scale.

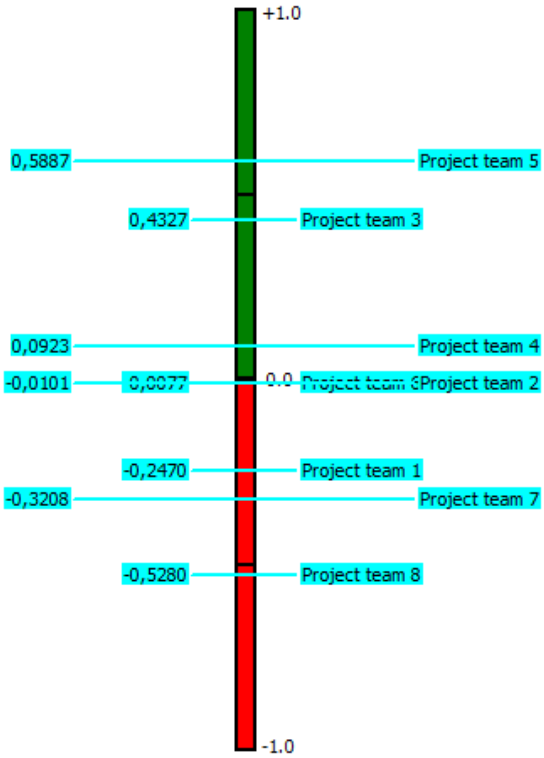

Fig. 3. PROMETHEE II complete ranking results

Sometimes such graphical presentations of results are not as “clean-sighted” as we want. In some cases, alternatives group very close to each other–meaning that there is a small difference between their rank–making it difficult for the decision-maker to determine their rank. As such, the numerical results of complete ranking gives the decision-maker true insight into the relationships of all alternatives both complete (absolute) and relative as is shown in Table 3. Such problems increase with the increasing number of alternatives and criteria.

Table 3. Numerical results of complete ranking

No.	Project teams	Phi	Phi+	Phi–
1st	PT 5	0.5887	0.5929	0.0042
2nd	PT 3	0.4327	0.4854	0.0527
3rd	PT 4	0.0923	0.2949	0.2027
4th	PT 6	-0.0077	0.2226	0.2304
5th	PT 2	-0.0101	0.2208	0.2310
6th	PT 1	-0.2470	0.1054	0.3524
7th	PT 7	-0.3208	0.1199	0.4408
8th	PT 8	-0.5280	0.0580	0.5860

Figure 3 and Table 3 clearly visualize the various alternatives (i.e. project team is the top ranked and which one is the worst ranked). The complete ranking (net flow Phi) and relative ranking (input values Phi– and output values Phi+) (i.e. the difference between alternatives) is also visible, which will be further discussed in next section.

4.3. Discussion

PROMETHEE rankings are based on computation of preference flows in order to consolidate the results of the pairwise comparisons of the alternatives and to rank them from the best to the worst one. Therefore, three different preference flows are computed:

- The positive (or leaving) flow (i.e. Phi+),

- The negative (or entering) flow (i.e. Phi–),
- The net flow (i.e. Phi).

The positive preference flow (Phi+) measures how much the underlying alternative is preferred to the other ones. It is a global measurement of the strength of that alternative (i.e. the larger Phi+ the better the action). In our case, the alternative with the largest Phi+ is Project Team 5 (PT 5) with a score of 0.5929, while the alternative with the smallest Phi+ is Project Team 8 (PT 8) with a score of 0.0580.

The negative preference flow (Phi–) measures how much the other alternatives are preferred to the underlying alternative. It is a global measurement of the weaknesses of that alternative (i.e. the smaller Phi– the better the action). In our case, the alternative with the smallest Phi– is Project Team 5 (PT 5) with a score of 0.0042, while the alternative with largest Phi– is Project Team 8 (PT 8) with a score of 0.5860.

Since the net preference flow (Phi) is the balance between the positive and negative preference flows, it thus takes into account and aggregates both the strengths and the weaknesses of the alternatives into a single score. The net preference flow of an alternative can be positive or negative, depending on its strengths and weaknesses difference.

Some alternatives group very closely to each other–especially PT 6 and PT2 in our case–causing the decision-maker some difficulty in identifying them and determining their rank when making the graphical presentation of the results. Numerical results give the decision-maker an opportunity to pragmatically determine relationships between alternatives. Without the use of multi-criteria decision methods, it would be impossible to do so, especially if there is a larger number of alternatives and criteria. In such situations–when one needs to be consistent and fair–it is hard to be without the use of some sort of multi-criteria decision methods, especially when the consistency is needed over more situations and during longer period of time.

The sensitivity analysis is essential when multi-criteria decision methods are used as the many parameters have to be set up in a multi-criteria model. With the PROMETHEE methods, this includes the choice of the preference functions and setting up their values, and the choice of the weights allocated to the criteria. Since the results of PROMETHEE II (i.e. final ranking of alternatives) are closely dependent on these parameters, it is important to check if a slight variation of parameters is influencing the analysis.

Since the preference flows are a linear function of the weights of the criteria, it is easy to perform sensitivity analyses with weight sensitivity analyses. Visual PROMETHEE software allows the end user to perform sensitivity analysis through visual stability intervals, making it possible to analyze how the net flow scores change as a function of the weight. It is important to make an analysis for each criterion at the time the weight is associated to each criterion; this is why sensitivity analysis with PROMETHEE methods can be performed and analyzed as weight sensitivity analysis.

Figure 4 shows a visual stability interval of criterion C1. While horizontal dimension corresponds with the weight of selected criterion (0% to 100%), the vertical dimension corresponds to the net preference flow score (+1.0 to -1.0 scale). For each alternative a line is drawn that shows the net flow score as a function of the weight of the criterion (green/red bar). According to Table 1 the weight of C1 is 15% and at that position the bar is set giving the insight to complete ranking of all alternatives (intersection of green/red bar and alternative lines).

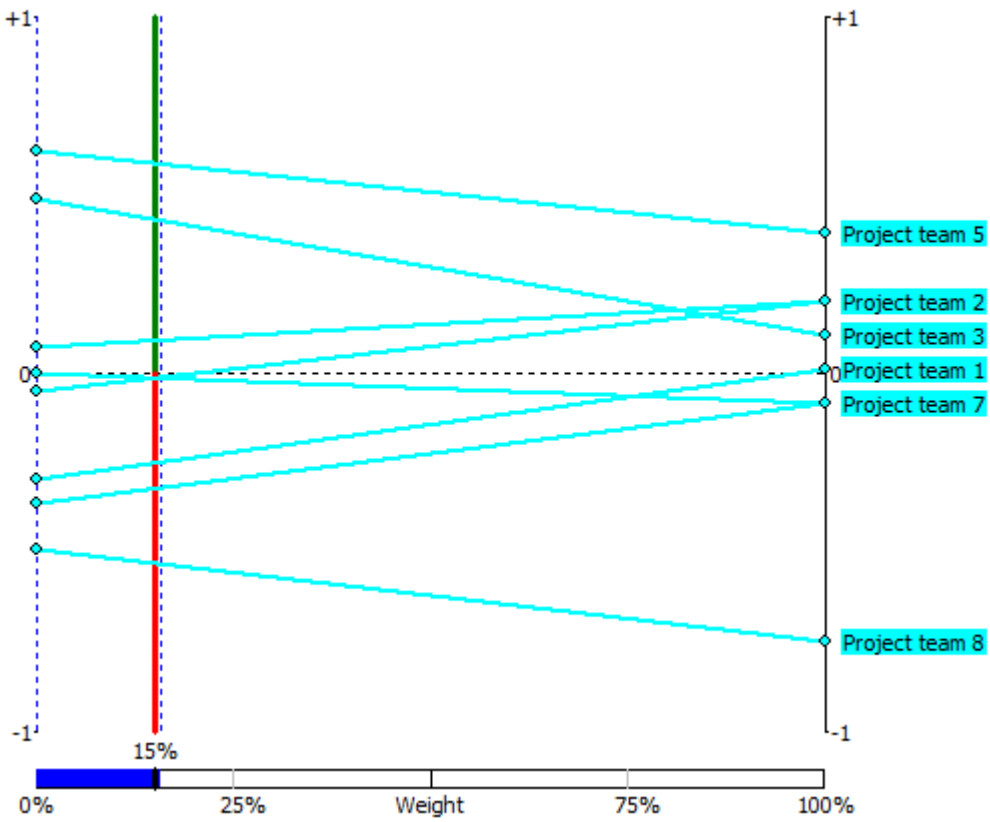

Fig. 4. Visual stability interval of criterion C1

The stability interval for the weight of the selected criterion is represented by the blue bar on the horizontal 0% to 100% bar and with two dotted vertical lines. Those dotted vertical lines show the weight interval within the PROMETHEE II complete ranking result remains unchanged. Such interval is called Weight Stability Interval–WSI and is shown in Table 4 for all criteria.

Table 4. Weight Stability Interval of all criteria

Ci	WSI min	WSI max
C1	0	15,7%
C2	4,26	29,53
C3	0	18,52
C4	3,77	15,24
C5	9,79	18,18
C6	7,24	26,49
C7	0	15,91
C8	14,29	37,04

The stability intervals indicate the range in which the weight of a criterion can be changed without affecting the ranking. If the weight of criterion C1 is changed over the maximum value of its WSI, the complete rank of all alternatives changes.

5. Conclusions

The main idea of this presentation is to develop a concept which will provide consistency in the evaluation of student papers for the course of Project Management at the Faculty of Civil Engineering in Rijeka on an ongoing basis, and be easy to be applied to different courses as

well. For such purposes, a decision support concept based on multi-criteria analysis and group decision-making is proposed.

The integration of multi-criteria analysis into the evaluation process of student papers is introduced into the educational process of construction management, thus innovating curriculum and making operational research methods more "popular" (according to student end-course questionnaires). Additionally, it allows students to be more active members of the process and gives them opportunities to learn new methods and processes by participating.

The presented concept is valuable because it improves consistency of decision-making in the group environment and gives all stakeholders the satisfaction that a final result is rationally, systematically and carefully analyzed, and it is based on group compromise. The advantage of such a concept is that it is easy to implement it into another course despite the new faculty environment and stakeholders. Even when such changes occur, the decision-making procedure itself remains consistent, giving the decision-maker a feeling of safety because he/she knows that if he/she follows the proposed procedure he/she will make a decision that is rational and pragmatically based on a group compromise.

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Weather Forecast as an Additional Dimension to BIM

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Abstract

Building information modelling has been proved as an efficient approach for solving global problems in construction projects. Researchers worldwide have pointed that the main direct benefits of BIM are for investors and final building users, while its benefits for construction companies in the construction phase are still matter of discussions. In daily work on construction site BIM is still considered as an unnecessary complication of the already established methodology. Therefore, authors in this paper have provided a literature overview and proposed a methodology for daily use of BIM in planning and monitoring on the construction site. Authors show that the weather forecast as additional dimension (as a statistical data) can be added to *nD* models as a platform for scenario simulation and risk evaluation. Just as well, they show that this is a valid point of intersection of the two orientations for modelling and simulation: BIM and process simulation. The results of this paper may contribute to a more realistic planning on site and thus positively influence on the projects overall performance.

Keywords: BIM; modelling; simulation; weather; forecast; construction site; nD

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1. Introduction

Building Information Modelling (BIM) concept has made an impact on construction project management, even on the entire industry, like none other in recent history. From its beginning as a logical response to the recognized and defined global problems in construction industry (e.g. project's fragmentations of the responsibilities and communication among stakeholders, constructability issues, unnecessary consumption and miss-timed allocation of resources, etc.), recently BIM has become a developing concept with hardly imaginable final form. Dimensions in *nD* project modelling are pilling as the AEC sector pushes the limits and due to its entry into the national legislations.

However, BIM is still not fully adopted by the practice as expected. One of the reasons could be the rather enthusiastic expectations of the theoretical circles neglecting the well-known fact that the industry reluctantly adopts new methods and techniques; and /or argument that BIM concept is still not fully adopted in project's construction phase noted by various authors van Berlo and Natrop, 2014; Azhar and Alex Behringer; 2013; Galic et al., 2014. The second argument could be précised with the following question: how does the construction site manager benefit from adopting BIM concept in his/hers daily routine? Authors Wang et al., 2012 have underlined that BIM has to be applied on construction site for reaching its full potentials and promises. Due to the mentioned, authors in this paper consider methodology for adding weather conditions and its possible negative combinations as a risk assessment to BIM model upon which site mangers could make their decision and adjust their site schedules. Site engineers usually are using the referent weather forecast available on meteorological web sites, but those information could be also used for making own stochastic predictions. In this paper authors are analysing the methodology when site engineers have to structure their own weather forecast using the Markov's chain method of event extrapolation as a simulation method of the weather forecast based on the collected data and add this information to BIM. Markov chain models have been already applied by the authors Carpinone et al., 2015 as a wind power forecasting method based on the use of discrete time models, which are very interesting for construction site managers when site efficiency is highly dependent on efficiency of high tower cranes.

Adding weather risk to BIM is certainly one of the paths for the concept's further development. This information, or dimension as often colloquially called, serves the model as an added value especially for construction companies and as well it enhances the site safety and quality of final product since the weather has been identified by Ahankoob et al., 2012 as the significant source factor of waste materials on construction sites.

2. Project planning by taking into account weather conditions

The usual project's life cycle consists of five interrelated phases: concept (studies), design, construction, maintenance and removal /conversion. As the project progresses from the conceptual phase to the construction phase time unit in plan tends to decrease: from the years, seasons, days, shifts to hours. Plan orientation also differs depending on plan's hierarchy level described by authors Radujković et al., 2012. With the acceptance of BIM concept it is usual that the lowest plan's hierarchy level is oriented towards construction objects. If the plan structuring goes from the lowest level upward it is necessary that risk assessment should also be oriented as the lowest hierarchy level: on objects/activities. Continuous constructability studies throughout the planning and design phase can help to anticipate potential problems involving the weather or delivery issues, unnecessary complexity, new or proprietary installation methods and long-term performance. However, it is usual that the contractor is entirely responsible for risks such as weather and similar unforeseen conditions elaborated by the author Bennett, 2003.Thus, thorough knowledge and

understanding the weather conditions on construction site are generally very important for the site engineer. This becomes even more important when the engineer is not from the local and climatic region of the construction site.

In the conceptual phase of the project's life cycle statistical data of the seasonal weather conditions (usually as a part of the feasibility studies) in which construction will take place should be gathered, filtered and added in form of the risk assessment to each phase and activity, which could be used as a baseplan for the daily update on the construction site. In most occasions engineers have to modify the construction plans to the unavoidable negative impacts in some climates like in tropical climates where is dominant heat stress which actually contains six negative impacts defined by the authors Rowlinson et al., 2014 (i.e. air temperature, humidity, radiant heat, wind speed, metabolic heat generated by physical activities, and the "clothing effect" on construction site performance). As well, in cold climates where the day activities are limited just on few hours, it is important that activities are planned extremely precisely. Especially for operations such as continuous concrete works, asphalt paving activities or excavations in soft soils which are highly dependent on weather conditions. Therefore, hourly planning of the daily activities is the most suitable. Authors Sacks et al., 2010 summarized it: the usual weekly planning doesn't fit the day-to-day site business. To each object it should be added information about its weather condition and combination sensibility, or as author in his book Weygant, 2011 has called it *weatherbility* and defined it as degree of resistance when exposed to certain negative weather condition. Law, 2011 pointed out that even though there are many online services for weather forecast they yet aren't readily integrated with the stand alone applications which would extend the applications functionalities. He proposed a workflow methodology (shown in figure 1) for including the weather conditions in project management.

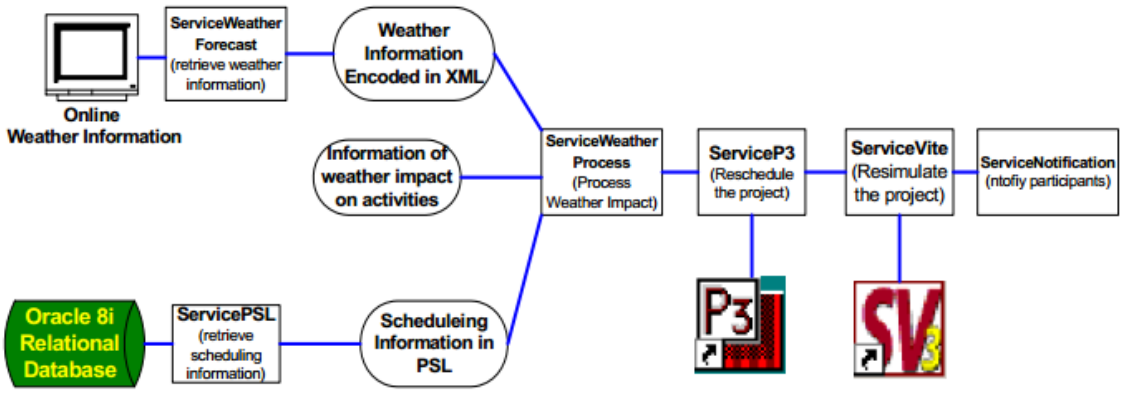

Fig1. Work flow for integrating weather condition to project management by Law, 2011

This methodology (figure 1) requires non-stop accessible internet connection which on construction sites is sometimes hard to establish. Thus, authors in this paper consider alternative methodology for including the weather condition forecast to BIM on construction site.

3. Markov's chain for weather forecast simulation

3.1. Markov's chain –mathematical background

The reason why this mathematical method is well known and popular among engineering disciplines lies in its relatively simple application. Subject of the Markov's chain represents a logical continuation from a basic course of probability occurrence of the random discrete–time or continuous–time processes defined by Suhov and Kelbert, 2008. In case of discrete processes the number of possible states is countable denoted as "I" (*state space*) while each state is denoted as "i" and the distribution of probability on "I" is denoted as "λ" (Equation 1):

$$\lambda_i \geq 0, \sum_{i \in I} \lambda_i = 1 \qquad (1)$$

The occurrence of the random change of states is described by the matrix "P" (transition matrix) with entries "p_{ij}" which are the conditional probability in which system will change from state "i" to state "j" in some time unite. Hence, being in any of the possible states all other are excluded in that moment, but they are potential states (Equation 2):

$$0 \leq p_{ij} \leq 1, \sum_{j \in I} p_{ij} = 1 \qquad (2)$$

Gained results are probabilities (transition matrix) of the state change from current or predicted to different, and if it remains the same, in some period of time. Thus, this mathematical model is suitable for scenario simulation for plan schedule analysis and adjustments in short-time weather forecast.

3.2. Weather forecast simulation on the basis of Markov's chain

3.2.1. Input parameters

Definition of the states (i.e. weather conditions or meteorological parameters) should be the first input. The second input is the transition matrix describing the probabilities of the state and parameters change, and as well definition of the time period. The states should be labelled and stored as database for later output.

Table1. Defined states and time period in relation to the object/activity oriented Gantt-chart

		day 1 - date								
		0 time	hour1	hour2	hour3	hour4	hour5	hour6	hour7	hour8
object 1	activity 11									
	activity 12									
	activity 13									
	activity 14									
	activity 15									
object 2	activity 21									
	activity 22									
	activity 23									
weather forecast	temperature [°C]	t0	t1	t2	t3	t4	t5	t6	t7	t8
	probability of occurence at time [%]	100%	pt1	pt2	pt3	pt4	pt5	pt6	pt7	pt8
	wind speed [km/h]	ws0	ws1	ws2	ws3	ws4	ws5	ws6	ws7	ws8
	probability of occurence at time [%]	100%	pws1	pws2	pws3	pws4	pws5	pws6	pws7	pws8
	wind direction	wd0	wd1	wd2	wd3	wd4	wd5	wd6	wd7	wd8
	probability of occurence at time [%]	100%	pwd1	pwd2	pwd3	pwd4	pwd5	pwd6	pwd7	pwd8
	rain [mm]	r0	r1	r2	r3	r4	r5	r6	r7	r8
	probability of occurence at time [%]	100%	pr1	pr2	pr3	pr4	pr5	pr6	pr7	pr8
	thonder storm [yes/no]	ts0	ts1	ts2	ts3	ts4	ts5	ts6	ts7	ts8
	probability of occurence at time [%]	100%	pts1	pts2	pts3	pts4	pts5	pts6	pts7	pts8
	humidity [%]	h0	h1	h2	h3	h4	h5	h6	h7	h8
	probability of occurence at time [%]	100%	ph1	ph2	ph3	ph4	ph5	ph6	ph7	ph8
	snow [mm]	s0	s1	s2	s3	s4	s5	s6	s7	s8
	probability of occurence at time [%]	100%	ps1	ps2	ps3	ps4	ps5	ps6	ps7	ps8

Of course, the subjects of engineer's attention are negative weather changes and thus they will be carefully analysed (e.g. high wind speed, extreme temperatures, snow and rain showers, etc.) showed in Table 1. The syntax in c-base programming language (ModL) for the simulation is described in the Table 2 for each section of the input based on the model in ExtendSim simulation software.

Table 2. Input and simulation programming code

Code	Explanation
real CumulativeRandom; real Hours;	Set the time model
If(Current_Weather < 1) Current_Weather = 1; CumulativeRandom = 0.; NextHour = 1;	Initializing the variables

while(RandomValue > CumulativeRandom)
{
NextHour++;
CumulativeRandom += DBDataGetAsNumber(DBIndex, Prob_Table, NextHour, Current_Weather);
}
NextHour --;
	Usage of the probability input (find in the database the next weather state)

Hours = DBDataGetAsNumber(DBIndex, WeatherTable, CountHours, NextHour) + 1; DBDataSetAsNumber(DBIndex, WeatherTable, CountHours, NextHour, Hours); DBDataSetAsNumber(DBIndex, WeatherTable, PercentHours, NextHour, Hours /(CurrentStep+1));	Result update (count of the hours and percentage of working time in each state)
if(AnimationOn && AnimationObjectExists(-1)){	Animation of the simulation and the

IconSetViewByPartialName(GetEnclosingHBlockNum(), DBDataGetAsString(DBIndex, Prob_Table, 1, NextHour)); AnimationTextTransparent(-1,DBDataGetAsString(DBIndex, Prob_Table, 1, NextHour)); AnimationTextTransparent(-2,EDHourToString(EDSimTimeToHour(CurrentTime, 0),1)); AnimationShow(-1); AnimationShow(-2); }	current state

It is important that the labels are exactly addressed in the database as in the code because otherwise the model will report an error as a feedback. So, if the input weather parameters are used from the referent weather institution web site it is crucial to uniform the labels.

3.2.2. Model structure and simulation interface

Authors in this research have used predefined codes and control panel given by the ExtendSim software which is structured of six controls panels (Figure 2). In the model there are two entities: input parameters and results (including the visual interpretation of the weather condition at certain time). In addition to the predefined model authors have added other weather condition parameters for simulation (listed in Table 1).

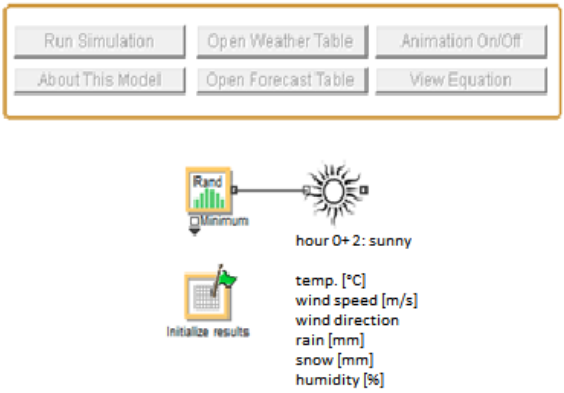

Fig.2. Model and simulation interface for weather simulation in ExtendSim simulation software

3.2.3. Results

When the simulation is set, the model will run and report the results (weather condition parameters and combinations) for 8 consecutive hours. For each hour there is a probability of transitioning from one weather state to the next as a result. Like showed in Figure 2 the first result is visual - an animation of the weather condition. The probability of the weather parameter change is an input parameter to the BIM, more precisely to the time schedule appointing to the certain object/activities.

4. Adding weather forecast to BIM

Construction phase is the testing point for BIM model. All of the added information

about the construction and other objects then come to the test. As well, they all become a baseline points for further modelling and planning. Therefore, its efficiency in solving or preventing some problems will be just as good as the continuous update. In earlier phases the exact location of the construction is usually defined by using the absolute coordinates (for the object orientation in relation to the sun's trajectory).

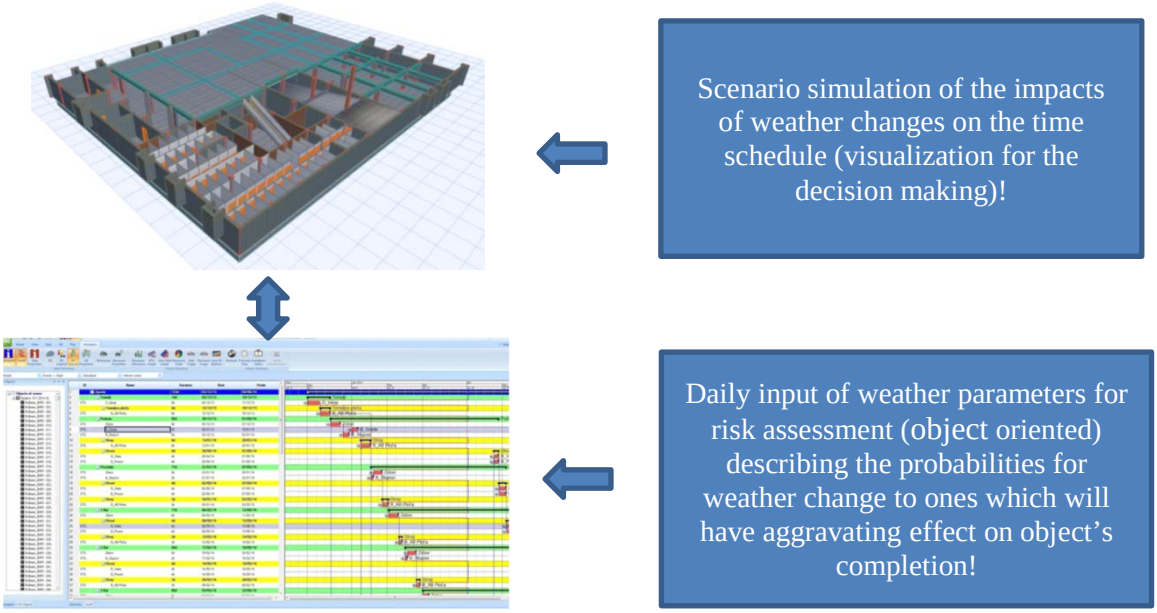

Fig.3. Methodology for adding weather forecast to BIM

In figure 3 it is shown how weather condition risk assessment should be added to BIM using already proved tools/software for 5D BIM (authors have figuratively showed schedule with added risk assessment in software Primavera and BIM model in ArchiCAD).To each object/activity user should add this info into the dynamic time schedule. The initial baseline path connecting the model and baseline time schedule defines the first scenario. By continuous input of the weather condition risk assessment, gained from the Markov chain transition matrix to each object/activity, user is generating scenarios. Each scenario is then ready for the simulation (visualization) which will help to detect possible clashes and for evaluation of each scenario.

Discussion

Stochastic environment manifested as a hardly modelled spectrum of impacts in construction projects has been argument at the same time pro and against implementation of the BIM concept. As an approach, modelling and simulation of complex's systems, which construction projects surely are, has been proved numerous times to be effective. However, like any other modelling technique BIM is highly dependent on input parameters and therefore the results are just as good as the input quality and consistency. If BIM model is not updated precisely and regularly during the construction phase it becomes useless for its application in later project phases (i.e. maintenance and removal/conversion). Therefore, if the objective is to fulfil BIM's potentials it has become a daily routine on the construction site. While it is a part of the daily business on construction site, site managers should benefit as much as they can from this concept. Except its continuous visual support for construction, BIM is an excellent platform for adding information on construction site which could be used

for updating schedules and simulation of the scenarios. Authors have used ExtendSim software and in further work will test another approach and simulation software. The alternative approach is to use a separate file for input parameters and calculation of the weather change probabilities which is linked to the BIM model and to the internet weather forecast web site. While alternative simulation software is one which supports this kind of input (e.g. Enterprise Dynamics software).

Conclusions and recommendations for further research

The methodology proposed by the authors in this paper describes the path for adding weather conditions and the belonging risk assessment to BIM. The proposed model is applicable in situations when the online internet connection is not a non-stop option and when it is necessary to make own quantitative analysis of the occurrence of negative weather conditions and their combinations. Thus the proposed methodology contributes to robust project execution by providing a concept that allows the involvement of risk related ancillary information for planning decisions on site.

Applying this methodology requires users' previous knowledge of programming language (c based language) and mathematical methodology of Markov chains. This is an area for further research and improvement of the proposed model in order to increase user friendliness. Weather change and assessment of its negative effects on completion of certain object's activities or temporary constructions is a solid link for connecting BIM with execution on construction site. In further research this methodology and model should be tested on case studies and further improved. There are available online weather forecasts which could be used for this model and contribute to a more effective application and inclusion in daily site routines.

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Diffusion of Building Information Modelling as an Innovation: A Conceptual Framework for Research

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Abstract

Despite the growing awareness of the benefits of using Building Information Modelling (BIM) throughout the life of a construction project, and even though the acceptance of BIM by organizations in Architecture, Engineering and Construction (AEC) industries has rapidly increased in recent years in fifteen of the world's leading economies, the general impression is that BIM is not being adopted as promptly as expected. Obstacles in adopting BIM are the topic of various studies, the latest of which indicate that this problem should be approached as an innovation management problem. This paper goes further in this approach by firstly defining BIM as innovation in construction, and then, on theoretical basis of the diffusion of innovation, provides a conceptual model of BIM diffusion as innovation at the level of AEC organization. The aim is to (1) identify the basic elements of the process of diffusion of that innovation and (2) specify the main groups of influential factors for the diffusion of BIM in the AEC organizations. According to the conceptual model proposed in this Paper, the initial phase of the BIM diffusion process preceding the decision on adopting the BIM, consists of „*Awareness of the need of BIM adoption*“ and „*Feasibility study and proposal to adopt*“, and its implementation phase consists of „*Adapting the organization to BIM*“, „*Training and user support for wider use*“, „*Sustainability of the continuous application*“ and „*Evaluation and improvements*“. The critical factors of success need to be defined within the following groups of factors: *social and business environmental factors, internal organizational factors, previous related knowledge, perceived properties of BIM,* and *communication channels*. The proposed research framework could lead further research in the direction of understanding the cause and effect relationships of diffusion elements for a successful implementation of BIM in the AEC organizations.

Keywords: Building information modelling (BIM); diffusion of innovations; AEC organization

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1. Introduction

Building Information Modelling (BIM) is defined in different ways in literature (Succar, 2010), (Eastman et al., 2011), (Buć, 2012), but all the definitions have several key elements in common: the process of creating a digital model, combination of "smart" elements containing both qualitative and quantitative data, interoperability of data, integration of processes based on a high level of mutual cooperation of all stakeholders with a joint goal - to manage the structure efficiently throughout its entire lifetime. The result of this process is a “building information model” – “a digital representation of physical and functional characteristics of a facility, a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle” (BuildingSmart, 2015).

In recent years, a significant increase of interest in BIM and its adoption in building construction, i.e. AEC sector (architecture, engineering and construction sector) has been noticed at the global level. The level of BIM adoption in North America soared from 28% (2007) to 71% over the course of 5 years, wherein the adoption of BIM by the contractors (74% of respondents adopted BIM) has recently exceeded the level of BIM adoption by architects (70%) (Bernstein, 2014). According to the survey conducted in Great Britain (NBS, 2014) in the British construction sector, the share of people who use BIM rose from the initial 13% (in 2010) within 3 years to 54% of them, wherein as much as 92% of respondents stated in the last year survey that their organization would use BIM. BIM use in the UK is being driven rapidly by the government mandate requiring BIM use by 2016. (NBS, 2014).

According to the research by McGraw-Hill-Construction (Bernstein, 2014), (data from 10 countries: Australia, Brazil, Canada, France, Germany, Japan, New Zealand, South Korea, UK and USA), the majority of construction companies spoke positively about the return on investment (ROI) in BIM (in Germany, France and Japan as much as 97% of the respondents). The respondents (contractors) recognized the following benefits of BIM: reduced errors and omissions, collaborating with owners/design firms, enhancing organization’s image, reducing rework, reduced construction cost, et al. (Bernstein, 2014). On the other hand, the investors (owners) see the greatest benefits of using BIM in the fact that BIM visualization enables a better understanding of the proposed design, there are fewer problems during construction related to design errors, coordination issues or construction errors, BIM analyses and simulation capabilities produce a more well-reasoned design, the use of BIM generates a beneficial impact on project schedule and the use of BIM generates a beneficial impact on control of construction costs (Bernstein, 2014).

However, despite its recognized advantages, BIM is still not used in the expected scope even in countries which adopted standards for work in BIM, and in which the use of BIM is a strategic orientation (NBS, 2015), not to mention the countries where neither the public nor the private sector require the realization of their projects in BIM. Therefore, different research has been performed lately in order to recognize the obstacles and critical risk factors for the adoption of BIM in companies. The research by the German AEC sector (Both & Kindsvater, 2012) showed that the main obstacles for the adoption of BIM at the technical level are - insufficiently supported implementation of IFC standards, at the level of standards - the need for higher quality standardization, and at the level of education - lack of new education and university (higher) education concepts. However, for the users of BIM, the financial aspect was neither an obstacle nor a problem for its adoption. The Malaysian research (Salleh & Fung, 2014) produced a similar conclusion, whose results show that the costs are not a key obstacle for BIM implementation, but the lack of expertise, training, and awareness about the need to introduce BIM. In the international research with leading BIM experts (Won, et al., 2013), the inter-organizational issues such as the willingness to share information, master BIM model team/managers, effective collaboration between project participants, and organizational structure to support BIM were recognized as critical factors for the adoption of BIM.

The question how to solve the problem of BIM implementation presents itself. According to Murphy (2014), this problem can be successfully solved if approached as implementation of innovation. Such approach was also supported by other authors, considering the factors of BIM diffusion (Singh, 2014), (Panuwatwanich & Peansupap, 2013).

A contribution to the development of research framework for the BIM diffusion model as an innovation is given in continuation. First the concept of BIM as an innovation will be substantiated, and then the important elements of the BIM diffusion process at the level of organization will be identified within the theoretical framework of diffusion of innovations set up by Rogers (2003), and primarily the individual phases of the very process of diffusion will be identified as well as impact factors of BIM diffusion at the level of organization in the AEC sector.

2. BIM - Innovation in Construction

In the Guidelines for collecting and interpreting innovation data, better known under the name „Oslo Manual“ from 2005, the following definition of innovation is given (OECD, 2005, p. 46): „*An innovation is the application of a new or significantly improved product (good or service) or process, a new marketing method or a new organizational method in business practices, workplace organization or external relation*.“

Such definition of innovation is completed by the definition according to the Directive 2014/24/EU of the European Parliament and the Council of the European Union (EU, 2014, p. 98): „*Innovation' means the implementation of a new or significantly improved product, service or process, including but not limited to production, building or construction processes, a new marketing method, or a new organizational method in business practices, workplace organization or external relations inter alia with the purpose of helping to solve societal challenges or to support the Europe 2020 strategy for smart, sustainable and inclusive growth*“

A widely accepted definition of construction innovation dates as early as 1998, which defines (Slaughter, 1998) innovation as the actual use of non-trivial change and improvement in the procedure, product or system, which is new for the institution developing this change. Slaughter (1998) introduces five kinds of innovations: incremental, modular, architectural, systemic and radical. The incremental innovation is here understood as a small change founded on previous knowledge and experience. Modular innovation is a significant change of concept of a certain component, wherein the links to other components and systems remain unchanged, unlike the architectural innovation, which involves a small change of a component, but a great change in links to other components and systems. A systemic innovation consists of integrated multiple innovations of components that are mutually complemented in order to achieve new functions or for overall improvement of building performance. A radical innovation is a step forward in science and technology, which often changes the character and nature of industry itself.

Other interpretations of the term innovation in construction are also found in literature, e.g. innovation is considered a process in which the life cycle of empirical learning and acceptance of technology contributes to creative thinking (Tangkar & Arditi, 2000). Innovation in construction mostly happens gradually, over a course of several years, so it often remains invisible. However, regardless of the conservative reputation, even though slow, the innovations appear and technological changes come to be accepted in construction industry.

The main feature of the construction sector is the focus on projects. Each new project gathers new stakeholders with their interests, but also their experiential knowledge, innovative tendencies etc. which can stimulate the creation and acceptance of innovations. The main characteristics of innovation in construction stem from there (Liu, et al., 2014):

- It is a collaborative innovation based on the project - collaboration is manifested at the project level, but this collaboration, which originated in the innovation process on a certain project, also continues outside the boundaries of this project, thus passing to the strategic level.
- Integrating innovation - not only as an integration of technological but also economic, managerial and other elements
- The possible source of innovation are numerous - since the realization of the construction project consists of different phases involving different organizations with their different professional background, and also their own supply chains that cross the boundaries of the construction industry.
- The presence of an "integration leader" is required in order to achieve full cooperation and integration of all resources for acceptance and management of technological innovation

- Complex, dynamic and non-linear innovation in construction can appear as a radical innovation, but incremental innovations are much more frequent.

According to the Oslo Manual, it follows that BIM is both a product innovation and a process innovation (OECD, 2005). According to Succar (2010), BIM is an integrated innovation model in which the data on the product and the data on the process are combined, stored, elaborated and distributed interactively to all relevant participants in construction. According to the classification model (Slaughter, 1998), BIM is a systemic innovation, since BIM requires changes in information and communication terms in different organizations, which leads to complex problems of interoperability, which depends on the interconnectedness and cooperation of stakeholders, and on cultural changes, all aimed at creating a unique system in order to raise the quality of execution. BIM also meets the criteria for innovation according to Murphy (2014) (Table 1.). Based on all the above mentioned, it can be concluded that BIM in fact is an innovation.

Table 1. BIM as an innovation, According to Murphy (2014)

Criteria for innovation	BIM as an innovation
Idea of something new and transformational	BIM is a catalyst for a significant transformation of the construction sector, reduction of fragmentation, increase in efficiency and effectiveness, reduction of the costs of inadequate interoperability, through collaboration of stakeholders and dramatic changes of the existing business practices
Ability to make a change	BIM is not the same as CAD, it goes further from the request to generate 2D and 3D drawings; as an integrated model, BIM is an efficient means of producing fully coordinated production information
Indirect (derived) benefits for all stakeholders	BIM lowers the overall risk for stakeholders and brings about better decision making; 3D coordination of different fields, dynamic cost estimate 4D planning and analyses of structure safety; more efficient processes, whole life costs are lower, increase in production quality and sustainability analysis, improved customer service.
Associated risk	The key risk is establishing the ownership of BIM data and protecting it through copyrights. It is necessary to define responsibility for the control of data input in the BIM model, and define risks before the use of BIM.

3. BIM diffusion in AEC organizations

3.1. Basic Theoretical Aspects of Diffusion of Innovations (DOI)

According to Rogers (2003), the author of DOI theory, the diffusion is "the process by which an innovation is communicated through certain channels over time among the members of a social system“ (Rogers, 2003, p. 5). The definition itself contains the four basic elements of diffusion of innovation: (1) innovation, (2) communication channels, (3) time, (4) social system. Therein, the innovation is "any idea, practice or object that is perceived as new by an individual or other unit of adoption. It matters little, so far as human behavior is concerned, whether or not an idea is objectively new as measured by the lapse of time since its first use or discovery.“ (Rogers 2003, p.12). It is important that the idea is perceived as new by the individual. A communication channel is a means by which the message passes from one person to the other. Different communication channels have a different role in individual phases of the innovation process. The social system is defined as a set of mutually connected

units that are dedicated to joint problem solving, in order to achieve a common goal. Members or units of the social system can be individuals, informal groups, organizations and/or subsystems. The social system represents boundaries within which the innovation diffuses.

Time dimension in diffusion of innovation is visible in (1) the innovation-decision process, (2) as innovativeness of the individual or unit of the adopter in comparison to other members of the system and (3) through the rate of innovation adoption in the system (Rogers, 2003). The innovation-decision process is a mental process, which the person or another unit for decision making undergoes from first knowledge of innovation until the confirmation of innovation adoption. Innovativeness is a degree at which the individual or another unit of adoption is relatively more advanced than other members of the social system in terms of acceptance of new ideas. It is possible to make the classification in five categories of adopters or members of the social system, based on their innovativeness: (1) innovators, (2) early adopters, (3) early majority, (4) late majority and (5) laggards, and they are distributed according to the Gauss curve. The rate of adoption is a relative speed by which the innovation is adopted by the members of the social system. The rate of adoption is measured by the number of members of the system that accept the innovation over a certain time period (S-shaped curve, depending on the type of innovation, and the type of social system).

Innovation process is one of the fundamental processes in all organizations, wherein the term "organization" for Rogers (2003, p. 404) assumes „a stable system of individuals that work together to achieve common goals through the hierarchy of ranks and division of labour“. In a certain organization, the innovation process consists of two main groups of activities: (1) initiation (introduction), starting from collection of all information, conceptualization and planning of innovation adoption until the decision on adoption is made, and (2) implementation, which consists of all events, activities and decisions related to the putting the innovation to use. The initiation phase starts when a general organizational problem has been recognized, which created the need for innovation or knowledge, i.e. awareness on the innovation, which is particularly the case in information technologies (IT). Searching the environment of the organization for innovation then follows. After it was found, or the awareness of the need for a certain innovation has been determined, the activities assessing the applicability of innovation for solving organizational problems follow (the benefits and problems of application) as the basis for reaching the decision on adoption or refusal of the innovation.

The implementation phase starts by reaching the decision on innovation adoption. First, it is necessary to perform the adjustment of innovation to the organizational needs, structure and vice versa, of the organizational structure to this innovation. Moreover, during the process of innovation in an organization, both the innovation and this organization normally undergo change. If the innovation is generated within the organization or from an external source, but it is precisely suited to the needs of this organization, its adoption is easier than implementation of this radical innovation, innovation with a high degree of uncertainty and harder implementation in the organization. Rogers (2003) calls the next phase of the process of diffusion clarifying. Clarifying occurs when the innovation is put into a wider use in a certain organization, so that the meaning of the new idea gradually becomes clearer to the members of the organization. The routine, as the final phase of the process of innovation in organizations, occurs when the innovation becomes incorporated in regular activities of such organization and loses its separate identity. The newer term for this phase is sustainability - degree at which the innovation is continuously used after the initial efforts for its adoption were completed.

Adoption or rejection of innovation always brings certain consequences. They mostly differ in three different dimensions: they are desirable or undesirable, direct or indirect and anticipated and unanticipated (Rogers, 2003). While the desirable consequences for the individual or the social system are the functional effects of the innovation, the undesirable consequence is dysfunctionality. Direct consequences for the individual or a social system are changes which occur as an indirect response to the adoption of innovation. Indirect consequences are, however, changes that occur as a result of direct consequences of a certain innovation; they are a consequence of consequences. Anticipated consequences are changes occurring due to innovations that have been recognized and intended unlike the unanticipated consequences that are not.

Wejnert (2002) differentiates public with respect to private consequences. Innovations that have public consequences include collective participants: countries, states, organizations and social happenings, and they mostly relate to the problems of social well-being and lead to historical reforms. Innovations with private consequences have an impact on the well-being of the adopter that are individual persons or smaller collectives such as organizations, age groups etc. They need to improve the quality of life of individuals or reform organizational and social structures. In innovations with public consequences, the transfer of information from innovation source to the adopter will be through institutionalization - standards, wherein the values or expectations become deeply integrated in the society. Transmission of information in innovations with private consequences assumes spatial and time proximity of the source and the potential source, mutual communication, institutional or individual coercion, as well as transmission owing to the pressure of the social networks. Considering the potential consequences of innovation implementation should be one of key activities in the process of decision making and adoption of this innovation.

The rate of innovation adoption is influenced by the perceived properties of innovation, type of innovation decision, communication channels, characteristics of the social system and action of the representatives of changes (Rogers, 2003). However, in previous research, the theories of diffusion of innovation were researched partially, mostly the perceived characteristics of the innovation itself, i.e. properties of the individual or organization that reaches a decision on the adoption of the innovation, characteristics of the environment and the time required for an individual to adopt innovation, which is one of the main deficiencies of DOI implementation. (Wejnert, 2002), (Panuwatwanich, 2008).

The research framework that is stated in continuation of this paper aims at avoiding the noticed weaknesses of previous DOI research, by incorporating both the social and communication structural variables in the research of diffusion, according to the recommendations of the author of the theory of the diffusion of innovations (Rogers, 2003).

3.2. Conceptual model of BIM diffusion

According to the conceptual model shown in Figure 1, process of BIM diffusion through AEC organization starts by raising awareness on the need to adopt BIM (Awareness of the need of BIM adoption). This need can follow from necessity, such as participation in a project where the work in BIM is required from the stakeholders. The initiative can be imposed by the public of private investor, or a leading partner at a certain phase of the project life cycle. The second key starter of gaining awareness about the need to adopt BIM is occupying or keeping the existing position on the market, i.e. conservation of competitiveness. The initiative for BIM adoption can also originate from employees, individuals who tend to adopt the innovation early.

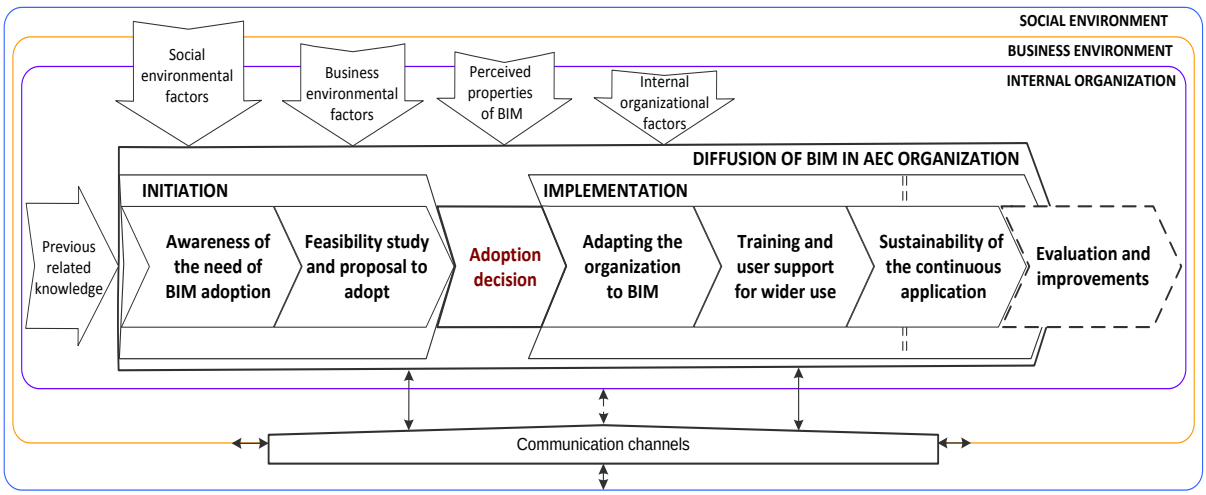

Fig. 1. Conceptual model of BIM diffusion in AEC organizations

In order for the management of the organization to be able to make a decision on BIM adoption, it is necessary to perform the analysis of business opportunities and risks that follow

after the decision on adoption or decision on non-adoption of BIM, as well as cost estimate, provide required resources (finances, people, space, information and communication equipment, required licenses etc.) The strategic plan for BIM adoption needs to reduce the risks and problems in the implementation phase. It shall enable clear understanding of organizational goals for the adoption of BIM within a certain time frame, efficient distribution of organizational resources for acquiring key BIM competences, define the criteria for the assessment of progress in plan implementation, and promote team work for planning and encompass different solutions within the organization (CICRP, 2013).

The team, work group for strategic planning, prepares the strategic plan for BIM adoption, and the top management of the organization adopts it and reaches a decision on moving on to the implementation phase. Therefore, the team shall include members of the organization with different authorities and responsibilities, from persons that have the possibility to lead this process throughout the organization, decision makers that are authorized to provide required resources, persons that will be able to monitor the progress of the process and manage the changes in the process, to persons that might be directly impacted by BIM adoption, motivated persons that might contribute to the process and which are inclined towards introduction of changes and the implementers who will work in BIM.

After reaching a decision on BIM adoption, it is necessary to prepare a detailed plan for BIM implementation. It shall include all required adjustments/changes of the existing work processes, starting from BIM implementation on a selected pilot project by the team designated for implementation, then training of the majority of employees that work on assignments in which some of the BIM software tools can be implemented, through continuous work in BIM in new projects, as a widely accepted method of work in organization, and the assessment of what was achieved and finding new ways and means to improve the entire work process in BIM (Figure 1).

Although the electronic sources of different manuals on planning implementation of BIM are available, e.g. at project level (CICRP, 2011), a comprehensive frame has not been elaborated so far, which would holistically consider the process of BIM implementation as the diffusion of innovation together with key factors that influence this process of diffusion, and having in mind the dynamic (time) characteristic of the process itself. The time dimension of BIM diffusion can be explained by the assessment of organizational innovativeness, which implies the level (time frame) at which the organization is ready to accept BIM.

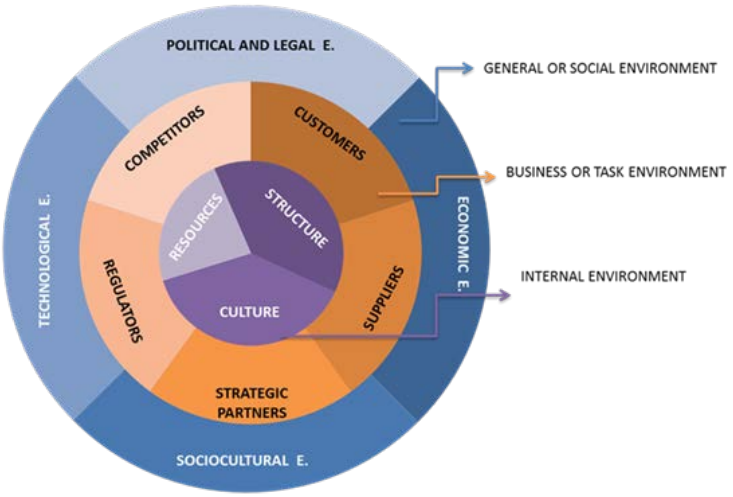

Fig. 2. Organization environment

The phases of diffusion process have been briefly outlined in this paper, and according to the conceptual model on Figure 1, it is necessary to explain the main groups of the influential factors on this process. The following main groups of influential factors have been identified: the social environment, the business environment, organizational factors, previous related knowledge, perceived properties of BIM and communication channels.

Each organization acts under the influence of the environment in which it conducts business (Figure 2). According to Buble (2000, p. 69), “the environment denotes the totality of participants that influence the business operation of a company, and which need to be respected by the management during decision making“. In doing so, he distinguishes external environment which is divided into general or social environment and business environment or the environment of the task and the internal environment. While the main characteristic of the general or social environment (macro environment) is the fact that is not under direct control of the company, business environment or task environment (microenvironment) is constituted by active participants in the immediate environment of the organization that have an influence on its capacity to service this environment. The internal environment represents „the part of the total company environment that is contained within itself" (Buble, 2000, p 81). It can be fully influenced and controlled.

Factors of the general or social environment of the organization that influence its capacity to accept and diffuse innovation, as well as BIM, could be explored further by examining for example its political and legal dimension (e.g. legislation, state incentive policies), economic (economic recession, accessibility of capital etc.), socio-cultural (e.g. fluctuation of highly educated human resources, accessibility of information regarding innovations) and technological dimension (such as the development of information and communication technology). The factors of the business environment of the organization that influence the process of diffusion of innovation should be viewed as the influence of competition, buyers, suppliers, regulators (e.g. regulatory agencies, professional associations and chambers), strategic partners and similar. The factors within the organization itself primarily refer to the existing organizational structure and method of management, then the culture of the organization (e.g. the culture of stimulating creativity and innovativeness, learning, mutual communication and sharing of information), and the availability of resources (material and financial, but also the availability of adequate human resources) (Figure 2).

Different models of technology adoption recognized the previous related knowledge as a significant factor of impact on its success. The level of knowledge and experience in the use of CAD is primarily considered, as well as the purpose of CAD model use (except for primary use - preparation of design drawings). BIM assumes mutual collaboration of different professions and organizations, so the knowledge for project management and experiences in team coordination are an important assumption for successful adoption of BIM.

According to the theory of diffusion of innovation, the dynamics of adoption of innovations is influenced by the perceived properties of innovations, which, according to the results of previous research, can be divided into five main groups: relative advantage, compatibility, complexity, trialability and observability (Rogers, 2003).

Rogers (2003) was aware of the importance of communication connections of the potential adopter of the innovation with persons that already adopted the new idea. Moreover, the degree of networking of a certain individual is a key factor for planning the success of innovation adoption. Therefore it follows that, in order to understand the process of diffusion, it is necessary to have knowledge about the nature of communication networks (Rogers, 2003, p. 331). Communication network consists of individuals that are mutually connected by the flow of information.

4. Conclusion and recommendations

This paper presents arguments for BIM as a systemic innovation, it is a product innovation and process innovation as well, and it also fulfils the criteria for innovation according to Murphy (2014). Furthermore, this paper proposes the conceptual framework for the research of diffusion of BIM as an innovation in AEC organization.

In compliance with the theory of diffusion of innovation, the process of BIM diffusion at the level of organization, according to the proposed conceptual model, takes place in two main phases: the initial and the implementation phase. The initial phase consists of two sub-phases: "Awareness of the need for BIM adoption" and "Feasibility study and proposal to adopt", after which the decision on BIM adoption is reached. If the decision is positive, the implementation phase follows, which consists of the following: „Adapting the organization to BIM“, „Training and user support for wider use“, „Sustainability of the continuous application“ and „Evaluation and improvements“. The proposed model also identifies the

following main groups of influential factors on the diffusion of innovation (BIM) in an AEC Organization: social and business environmental factors, internal organizational factors, previous related knowledge, perceived properties of BIM, and communication channels.

Unlike previous research, the proposed model considers the innovation diffusion process phases holistically, taking into account the key factors influencing this process. In addition, the proposed model complements the theoretical model of the innovation diffusion process by adding the final phase „Evaluation and improvements“, the phase in which the usefulness of the adopted innovation is assessed, and at the same time its improvements, i.e. starting of the new innovation cycle is made possible.

The future research should show which capacities an organization needs to have in order to successfully implement the BIM adoption for each of the main phases of the diffusion process, as well as to recognize and rank the key factors of the external and internal environment of the organization on the process of BIM adoption. The research conducted in Croatian organizations in construction could show to what extent the perceived properties of BIM, as well as previous related knowledge and the impact of communication networks influence the capacity of the organization to recognize and adopt BIM.

The model of BIM diffusion which would be created by consolidating the set up conceptual model described in this paper with the results of the proposed future research could contribute to better understanding of the problem of BIM adoption by AEC organization, and at the same time could provide a theoretical contribution to solving the noticed deficiencies of the theory of diffusion of innovation.

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Application of Planning Effort Parameters in Architectural Offices

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Abstract

For architectural offices an effort-based cost valuation/calculation of the costs for their services is vital. For this cost resp. effort approaches are essential. These planning effort parameters can be acquired e.g. from the evaluation and analysis of former, already completed projects within one architectural office as well as in a broader context for comparable offices or comparable projects. This research shows how many hours planners in architectural offices need for different services and on which factors the respective hours-effort depends. The planning effort parameters and benchmarks are developed on basis of empirical methods. With the aid of a standardized questionnaire all essential project characteristics as well as the relevant office structures are collected in 15 German architectural offices. The collected data from 78 building projects were analyzed on the basis of statistical evaluations such as regression analysis. From that, statistical parameters are deduced, which provide an effective instrument for cost-oriented calculation, planning and accounting of planning services. Moreover this basis of comparison for planning effort can serve as a benchmark: for internal benchmarking, i.e. comparison of different projects within one office, and also for external benchmarking, i.e. comparison of effort parameters of one architectural office with other offices. The aim of this research is to show how planning effort parameters can be acquired and used in architectural offices for cost valuation and benchmarking of planning effort.

Keywords: planning effort parameters; cost valuation; benchmarking; architectural services; fee

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1. Introduction

The calculation of costs and income is the elementary basis for any kind of economic action. Thus, for architectural offices an effort-based cost valuation/calculation of the costs for the performance of their services - planning of objects/projects - is vital. For this cost resp. effort approaches are essential.

These planning effort parameters can be acquired e.g. from the evaluation and analysis of former, already completed projects. This can be done within one architectural office as well as in a broader context for comparable offices or comparable projects.

This research shows how many hours planners need for different services and on which internal and external effort determining factors the respective hours-effort depends. Questions that can thus be answered for calculation and also for fee discussion with clients are:

- How many hours are objectively needed for a specific planning service (e.g. complete planning of an office building with 10,000 m² or only design stage of a logistics center with 15,000 m² etc.)?
- Which realistic target value (benchmark) can architectural offices of similar type reach for a specific planning service?
- Etc.

The planning effort parameters and benchmarks are developed on basis of empirical methods - data collection of real projects and statistical evaluations such as regression analysis.

From that, statistical parameters are deduced, which provide an effective instrument for cost-oriented calculation, planning and accounting of planning services. Moreover this basis of comparison for planning effort can serve as a benchmark: on the one hand for internal benchmarking, i.e. comparison of different projects within one office, and on the other hand for external benchmarking, i.e. comparison of effort parameters of one architectural office with other offices.

The aim of this research is to clarify the scope of application of planning effort parameters – cost valuation in the office, fee discussion with the client as well as benchmarking of planning effort –and therefore to underline their relevance.

2. Literature and experts survey

In a first step, potential influencing factors on planning effort were collected by means of different literature sources. The influencing factors gathered in this literature review are evaluated and supplemented with other relevant factors in the course of experts interviews with different professional experts from varying fields e.g. architects, clients, office management software producers, academics etc.

Summarizing, different factors can be identified through analysis of the above studies. Basically variables from following factor groups are examined: client, architectural office, project, technical planning, construction and authorities and politics and citizens. These

factors are listed in Table 1 and are used as a basis for the empirical study outlined in the following section.

Table 1. Influencing factors

Factor group	Factors (selection)
Client	type of client, experience, project definition, project management, user, decision process, modifications, consulting needs
Architectural office	Office structure (Office equipment, organization, efficiency) Appointed planning team (Project experience of the planning team, team factor, employee changes)
Project	Quality (building type, space, qualitative requirements) Cost (building costs, cost pressure, complexity of cost planning) Time (time objectives, timeframe, interruption in performance)
Technical planning	reliability of technical planners, coordination effort
Construction	tendering, awarding, reliability, coordination effort
Authorities, politics and citizens	authority procedures, resistance/acceptance from politics and citizens

3. Field survey

To investigate the relevant causal relationships, field survey data from 78 building projects in Germany was collected from 15 project partners.

The planning effort parameters and benchmarks are developed on basis of comparing real projects, which are gathered in planning offices with the aid of a standardized questionnaire. In this process not only the planning efforts but also all essential project characteristics as well as the relevant office structures (cf. table 1) are recorded. The results of the data collection are structured and entered in a data bank.

4. Model development

In this study, the term “planning effort” is defined according to the German Order of Fees for architects and engineers (HOAI), which provides information on all services of architects and engineers relating to new buildings, new facilities, rebuilds, extensions, conversions, modernization works, room-creating interior works, maintenance and repairs of architects and engineers. The services are summarized in nine service phases: establishing the basis of the project, preliminary design, final design, planning application, execution drawings, preparation for contract placement, assisting with contract placement, project supervision - supervision of construction and project management and documentation.

The empirical study on planning effort makes it possible to investigate the quantitative relationships between real-world observations and individual drivers/indicators and to develop the corresponding regression models. Statistical regression analysis (using minitab 17 software for Windows) is used to develop the models. In order to define the causal relationships, the stepwise-method of analysis (significance level 5 per cent) is employed.

The results of these statistical analyses are the relevant influencing factors on the planning effort, as defined above and measured in absolute hours. These factors are subsequently described:

- Consulting needs
  Amount of discussion effort, preparatory effort for decision making etc. [Rated on a scale of 0 to 10 pt.]
- Office equipment
  Level of technical office equipment [Rated on a scale of 0 to 10 pt.]
- Project experience of the planning team
  Project experience and qualification of the appointed planning team (qualification of project manager, specific project experience corresponding building type and project size etc.) [Rated on a scale of 0 to 10 pt.]
- Qualitative requirements
  Requirements in terms of integration with their surroundings (Rated on a scale of 0 to 6 pt.), range of functions (Rated on a scale of 0 to 9 pt.), design requirements (Rated on a scale of 0 to 9 pt.), construction requirements (Rated on a scale of 0 to 6 pt.), technical services (Rated on a scale of 0 to 6 pt.) and interior works (Rated on a scale of 0 to 6 pt.). [total points of rating]
- Building costs
  [Costs of cost group 300 “structure – construction works” and cost group 400 “structure – services” according to German DIN 276-1 (2008) (in €, excl. VAT)]
- Complexity of cost planning
  Complexity of cost planning, investigation of cost approaches and cost control, frequency of revision, quality of data base, level of detail of cost management, etc. [Rated on a scale of 0 to 10 pt.]
- Scope of services
  Scope of services, which are part of the project [%]

Moreover, the models also quantify the independent influences that exert by the variables on the overall planning effort. Figure 1 shows the contribution of the share of explanation of the different variables. Consequently the highest explanatory power contributes the variable “building costs” with 28%, followed by the variables “qualitative requirements” with 21% and “consulting needs” with 16%.

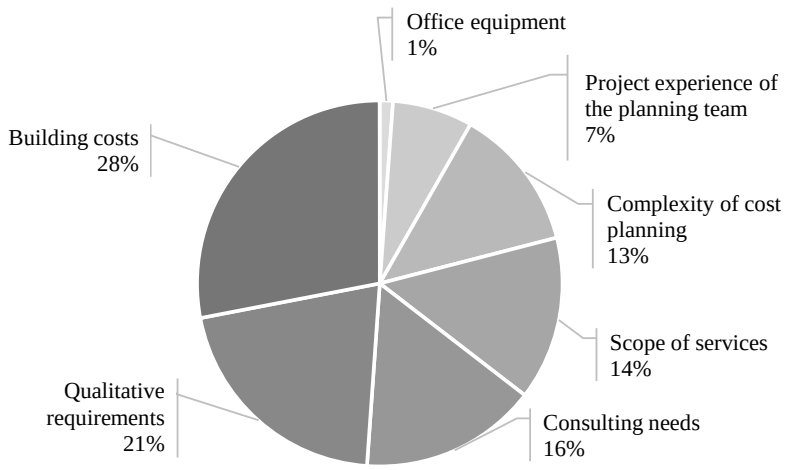


Fig. 1. Contribution of the share of explanation of the different variables

By way of example, the cause-and-effect relationships between planning effort in absolute hours [h] and relevant influencing factors are to be illustrated based on selected variables. By means of the sample it can be determined that for the planning effort the variables “building costs”, “qualitative requirements”, “consulting needs” and “complexity of cost planning” wield influence. The appraisal of the variable “building costs“ shows a positive relationship, e.g. the higher the costs, the higher the planning effort (cf. Fig. 2(a)). Additionally also the “qualitative requirements“ determinates the amount of hours spent on the project. It is readily identifiable, that the higher the rating is, the higher is also the planning effort in hours (cf. fig. 2 (b)). The same is shown for the variables “consulting needs” and “complexity of cost planning” in figure 2 (c) and (d).

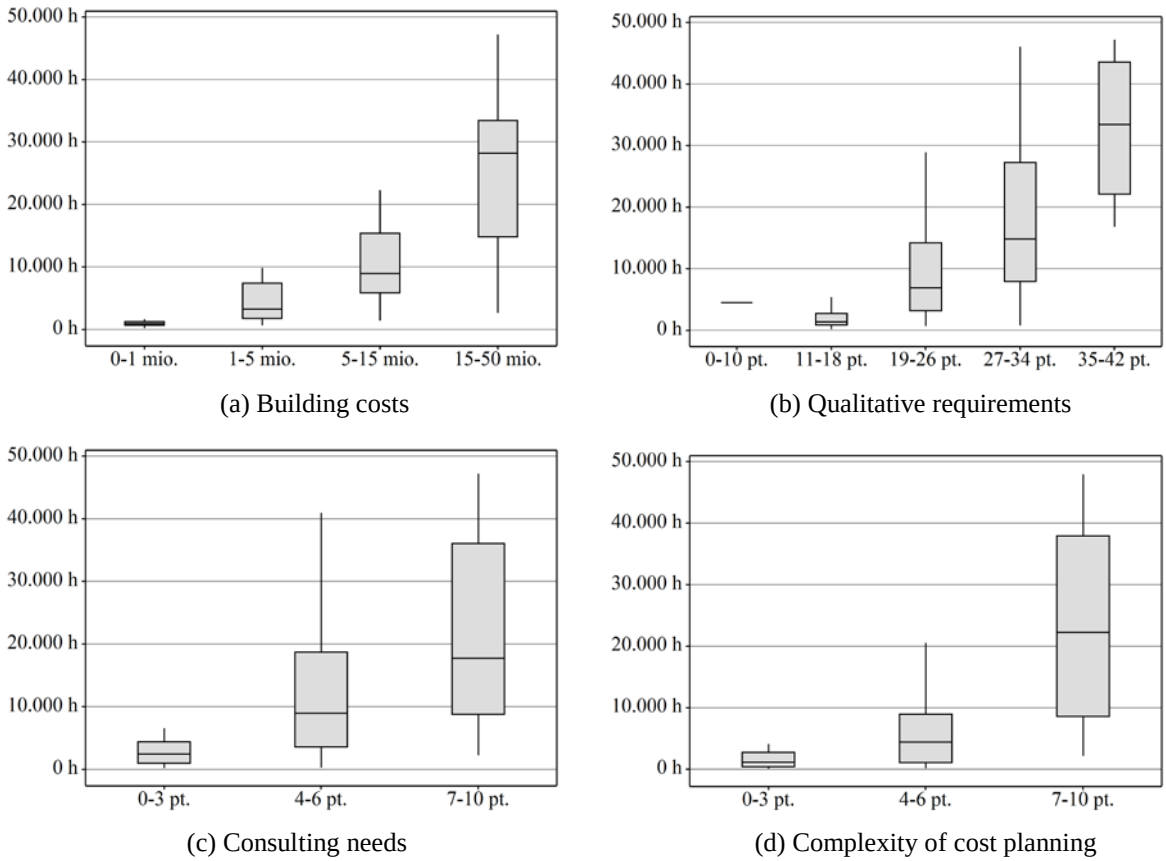


Fig. 2. Cause-and-effect relationships between planning effort [hours] and relevant factors (selection)

5. Application

The following section illustrates options of the application of planning effort parameters for architectural offices and clients based on an exemplary architectural office and an exemplary project.

5.1. Calculation of planning services based on effort parameters

Step 1: Investigation of the mean hourly rate in the architectural office

The model office with exemplary character has following employee structure: 2 owners, 30 technical employees (architects/engineers) and 1 commercial employee. For this office total costs in the amount of 2.300.000 € net resulted from cost-type accounting in the last year. The

directly in project planning hours relatable hours added up to 47.200 hours, 2500 of them worked by the owners and 44.700 hours worked by the technical employees.

The mean hourly rate can be calculated easily, if the total costs of the office and the overall hours of all employees including the owners, which accrued for the different projects within the previous year, are known. These so-called project hours can certainly only be reliably obtained if there were gathered within a narrow time frame und regularly updated by all employees. The cost-covering mean office hourly rate results by dividing of the total cost by the project hours: in the exemplary case 48,70 €/hour (2.300.000 € / 47.200 hours).

This hourly rate has to be at least achieved on an average across all projects to work without loss, because all overhead costs of the office (e.g. rents, office supplies, travel expenses, company vehicles, representation, acquisition etc.) are included. Not included are risk and profit. This is just a rough calculation for the exemplary office, which can and should be executed more detailed for each employee or planning team.

Step 2: Analysis of the scope of services

The next step is the analysis of the exact scope of service, which has to be provided for this project. In Germany the planning process of building project is regulated by the Order of Fees for architects and engineers (HOAI). According to §33 HOAI 2009 the services are summarized in nine service phases and are evaluated according to percentages of the fees as below:

- Service Phase 1 (establishing the basis of the project) 3 %,
- Service Phase 2 (preliminary design) 7 %,
- Service Phase 3 (final design) 11 %,
- Service Phase 4 (planning application) 6 %,
- Service Phase 5 (execution drawings) 25 %,
- Service Phase 6 (preparation for contract placement) 10 %,
- Service Phase 7 (assisting with contract placement) 4 %,
- Service Phase 8 (project supervision - supervision of construction) 31 % and
- Service Phase 9 (project management and documentation) 3 %.

For this example it can be assumed that the scope of services includes the service phase 1 to 7, which means the establishing of the basis of the project, preliminary design, final design, planning application, execution drawings, preparation for and assisting with contract placement and consequently 66 percent of the fees.

Step 3: Estimation of the planning effort parameters

On basis of the collected 78 projects and the statistical analyses described above to examine the relevant factors, planning effort parameters can be deduced. Table 2 shows exemplary the median-values differentiated by the factor levels of the two variables with the highest influence on the planning effort: building costs and qualitative requirements.

Table 2. Planning effort parameters

Factor level “building costs”	Factor level “qualitative requirements”	Median
0-1 mio.	very low 0-10 pt.	-
	low 011-18 pt.	897 h
	average 19-26 pt.	1.077 h
	over-average 27-34 pt.	759 h
	very high 35-42 pt.	-
1-5 mio.	very low 0-10 pt.	4.526 h
	low 011-18 pt.	2.603 h
	average 19-26 pt.	444 h
	over-average 27-34 pt.	-
	very high 35-42 pt.	-
5-15 mio.	very low 0-10 pt.	-
	low 011-18 pt.	3.402 h
	average 19-26 pt.	6.908 h
	over-average 27-34 pt.	10.875 h
	very high 35-42 pt.	17.979 h
15-50 mio.	very low 0-10 pt.	-
	low 011-18 pt.	5.205 h
	average 19-26 pt.	27.139 h
	over-average 27-34 pt.	28.219 h
	very high 35-42 pt.	36.923 h

With the assumption, that an exemplary building project has the characteristics “building costs” = 23.015.185 € and “qualitative requirements” = 25 pt., the planning effort measured in hours for this project can be estimated according to table 2 with 27.139 h.

Step 4: Calculation of the architect’s fee

The architect’s fee can thus be calculated by multiplication of the mean hourly rate in the architectural office with the planning effort in hours:

Service Phase 1 (establishing the basis of the project)	3 %	x	27.139 hours	x	48,7 €/hour	=	40.464 €
Service Phase 2 (preliminary design)	7 %	x	27.139 hours	x	48,7 €/hour	=	96.316 €
Service Phase 3 (final design)	11 %	x	27.139 hours	x	48,7 €/hour	=	154.339 €
Service Phase 4 (planning application)	6 %	x	27.139 hours	x	48,7 €/hour	=	85.814 €
Service Phase 5 (execution drawings)	25 %	x	27.139 hours	x	48,7 €/hour	=	364.341 €
Service Phase 6 (preparation for contract placement)	10 %	x	27.139 hours	x	48,7 €/hour	=	148.450 €
Service Phase 7 (assisting with contract placement)	4 %	x	22.434 hours	x	48,7 €/hour	=	60.466 €
Total fee	66 %	x	27.139 hours	x	48,7 €/hour	=	872.302 €

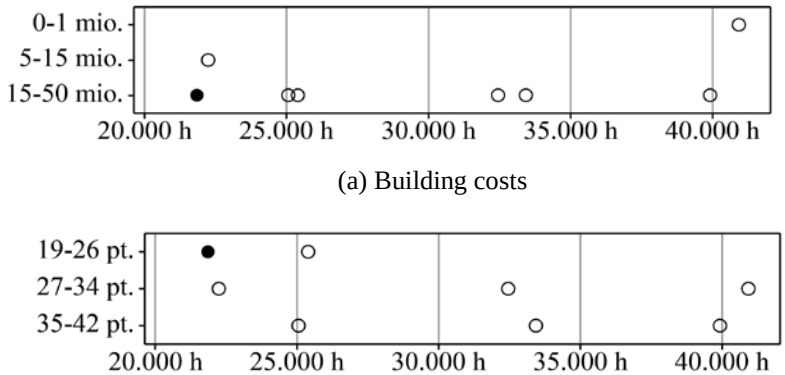
5.2. Benchmarking

Benchmarking is about comparing processes, practices or procedures. Performance benchmarking in particular is the comparison of performance measures for the purpose of determining how good an organization is in comparison to others. These may be compared within an organization against internal operation or with partners outside the organization. Transferred to architectural offices this means that the planning effort parameters can serve as

a benchmark: for internal benchmarking, i.e. comparison of different projects within one office, and also for external benchmarking, i.e. comparison of effort parameters of one architectural office with other offices. Both applications, the internal as well as the external benchmarking is to be illustrated by the exemplary project (After finishing the project the total amount of spent hours added up to around 22.300 hours.).

Internal benchmarking

For the internal benchmarking seven completed projects of the exemplary architectural office are shown in figure 3. The projects are clustered by the building costs (cf. fig. 3 (a)) resp. by the qualitative requirements (cf. fig. 3 (b)). The example project with a planning effort parameter from around 22.300 hours has the lowest amount of spent hours for planning services compared with the other projects, even in relation to the other project within the same group of building costs resp. qualitative requirements. Consequently this project can be assessed as very good concerning the planning effort.



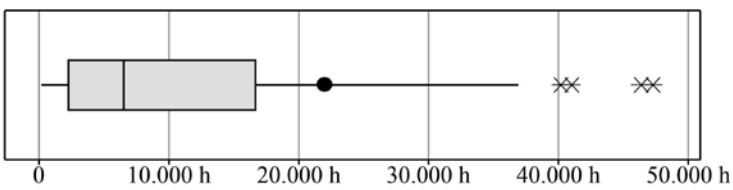
(a) Building costs

(b) Qualitative requirements

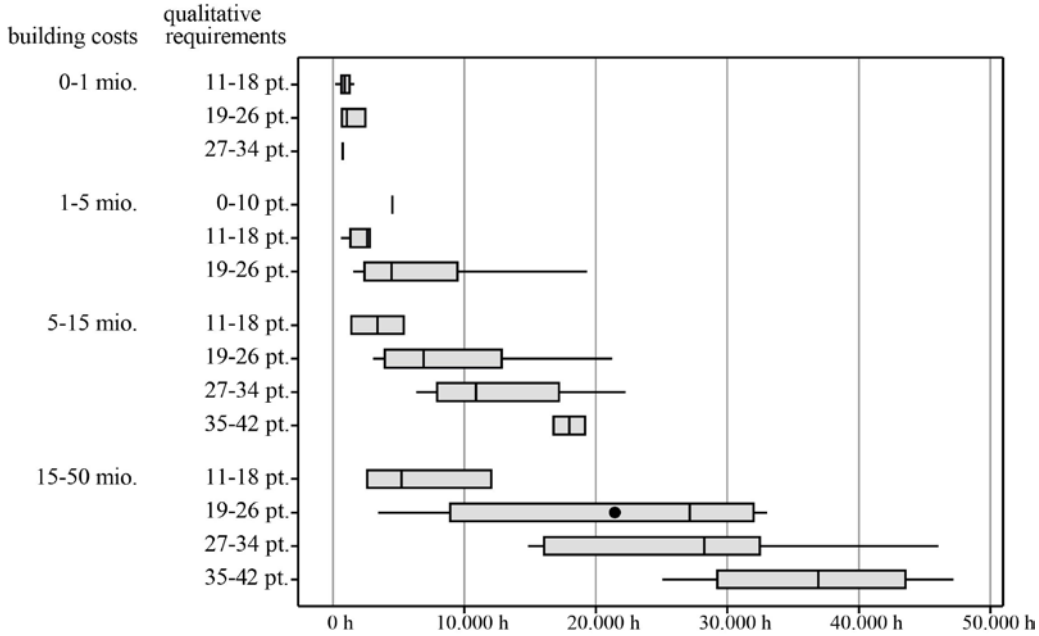
Fig. 3. Internal benchmarking

External benchmarking

For the external benchmarking in a broader context for different, comparable architectural offices all 78 project of the data sample were taken in account. Considering the exemplary project within the context of all projects, figure 4 (a) shows that the project has an higher amount of spent hours for planning services than 75% of all other projects (third quartile) and therefore can be assessed as an project with a high planning effort in comparison to other projects.



(a) External benchmarking – all projects



(b) External benchmarking – all projects with factor levels

Fig. 4. External benchmarking

When taking the highest influencing factors into account and grouping the total amount of projects by the factor levels of the variables with the highest influence on the planning effort – „building costs“ and „qualitative requirements“ – figure 4 (b) shows, that the exemplary project, is located below the median and so concerning the planning effort clearly below 50% of all other projects within the group of comparable projects. Which means a positive rating for this project concerning the planning effort.

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Application of Building Information Modeling in Education

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Abstract

Building Information Modeling (BIM) is a resource that is widely used around the world; however, in Croatia and in Eastern Europe it is still almost completely unknown, which prompted us to conduct this research. This article exploring the possibility of applying BIM in education of Master of Civil Engineers. The article describes a pilot project for the introduction of BIM at the master study in Construction Management at University of Zagreb, Faculty of Civil Engineering. The aim of the project was the introduction of BIM in the area of planning and cost calculation of construction. First was applied Autodesk Revit to overview their model and quantities, then GALA 2013 for the calculation of costs and creating a dynamic plan, and finally Autodesk Navisworks for simulation of the construction and the cost in time. In this way, students have designed a 5D model project of the space, time and cost, which was a completely new approach for them. At the beginning of the pilot project, initial surveys on knowledge of the basic concepts of BIM showed great ignorance in the area. At the end of the project students pointed out significant increase in the BIM perception and great interest for further training in this area. In order to education in this area of construction management become closer to global trends, implementation of information technology in teaching and introduction of access such as BIM represents a necessary condition.

Keywords: BIM, teaching, Gala, Navisworks, Revit, model

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1. Introduction

Building Information Modeling (BIM) content has become the most advanced approach to integrating information in construction projects from very earliest project phases onto the project ed. It combines professions such as architecture, civil engineering and other engineering disciplines. As such in the world has a wide application. However, in Croatia and in Eastern Europe it is still not as popular as in the most developed countries of the world. This situation was the reason to research BIM application by comparing the level of awareness and its application in Croatia with the rest of the world. Great Britain, Netherlands, Denmark Finland and Norway have set short term goals after which all of the procurement will be mandatory to comply with the BIM technology. In 2015 the European Parliament voted in favor of the directive according to which the next two years the member countries will stimulate the application of BIM technology in public works in order to reduce project costs, shorten construction times and modernize the procurement process, whereupon it will be mandatory (StudioARS, 2015).

Through available literature on the application of BIM we analyzed the current situation in world BIM education and how is the availability of the same connected with awareness of BIM in the countries around the world. Furthermore, as one of interest of our work is conduction of the BIM education on students, we analyzed the problems which we can achieve through this process and circumstances which we have to provide in order to better education.

All these facts were the reason for the methodology development of the BIM implementation in education which acquired basic BIM skills, but also knowledge about the proper work and thinking in a collaborative environment where they are left to everyone involved in the process of developing the project. Proper use of this developed methodology is illustrated with real project and the methodology itself is validated through education of students of Civil Engineering in Zagreb. If the developed methodology proved to be successful, methodology steps can be used to further practice in the stages of preparation and execution of the project, but also education.

Therefore, the main objective of this article is to develop a methodology for the better education of civil engineers, correct application of BIM in education and better understanding of the context of the construction process. For these reasons the article will be designed in a way that we will initially define the basic problems, hypotheses and objectives of the operation and furthermore we will show the literature review, development of the methodology and validation of the same on real example.

2. Problems, objectives and hypothesis of the research

The following research problems were identified that initiated this study:

- low awareness of Croatian civil engineering students of BIM issues
- lack of information on the proper application of BIM technology
- weakness of the proper and quality education
- glut on the market with new technological tools which causes confusion within students
- incompatibility of the software used in the same purpose

For the purposes of this study, we formulated the main hypothesis of work:

- By applying BIM methodologies in the education of civil engineers, the students can more efficiently and effectively understand the process of preparing, monitoring and control of construction.

The above problems and hypothesis of work opened to us the whole topic of research in which will prove them to achieve the following objectives:

- develop a methodology for the proper application of BIM applications in the technology and construction management
- prove justification developed methodology through its application in education

3. Application of BIM concept in education

3.1. World education and awareness about BIM

Below it will be shown state of BIM education and awareness about BIM in various countries around the world. For the preparation of the same we used research results which were published in 2013.

Most universities in Australia are starting to incorporate the topic of BIM into their undergraduate courses, although this is quite often at a very basic level of information, simply covering the concepts of BIM or the basics of using a particular BIM software package. Three universities are currently involved in a project supported by the Australian Government Office for Learning and Teaching (OLT) called CodeBIM (Collaborative Building Design Education using BIM). The project aims to examine whether collaborative design education can be improved using BIM technologies. The group identified that introducing BIM into academia would be a difficult change process and, like any major change process, would likely encounter resistance. Some of the reported difficulties included are: the difficulty of introducing new topics into an already crowded curriculum, unfamiliarity of lecturers with BIM and other fast-paced technologies and workflows, rapid changes and constant innovations in information technology which are favorable for traditional education.

In Canada is currently no incentive being provided from government to encourage BIM usage. On the contrary, George Brown College, Algonquin College and Institute for BIM (IBC) provide BIM certificate programs and courses. The results of the 2013 BIM Survey show that 96% of respondents were aware of BIM and 64% are currently using BIM.

In Finland, universities and polytechnics provide BIM education for their students. All current construction and architecture students study BIM to some extent. There are a number of initiatives, organizations and software companies taking place in Finland, which provide BIM education for their participants. Large firms such as Skanska use BIM for 100% of their own production.

In New Zealand BIM is taught by a few of the tertiary institutes and some software suppliers also provide training. A number of one-off industry presentations and seminars have also taken place. Although awareness of BIM is pretty high, a government – industry partnership is helping to raise awareness of BIM. The survey results show that 98% of respondents were aware of BIM and 57% are currently using BIM.

There are a number of postgraduate courses on BIM being provided by tertiary institutions around the UK. Many of these institutions also offer postgraduate certificates and other 'lesser' courses on BIM. There are also many events, conferences and website with lots of articles, videos and reports. This material is educational in a broad sense. The survey results show that 94% of respondents were aware of BIM and 39% are currently using BIM.

In USA usage of BIM has rapidly increase and 2012 was recorded at 71%. Users are reporting increased business benefits from BIM including better profits, more accurate documentation, less rework, reduced project duration, fewer claims and the ability to offer new services.

The China BIM Union has given many education presentations to hundreds of BIM professionals, presented by China Academy of Building Research. The China BIM Union and the development of BIM standards keep progressing. Current BIM objectives for China include: data sharing and interoperability in project life cycle, improve efficiency in industry, promotion of BIM, Combine BIM application with specific tasks of Architecture, Engineering and Construction (AEC) industry in the project life cycle.

The Czech BIM Council continually provide education through BIM seminars, workshops and presentations. There is a lack of impulse from government for the promotion of BIM use, partly due to elections taking place. There are a few BIM projects currently running (big projects) but 2D is still used for the majority of projects. Designers are still a bit skeptical of BIM, primarily due to the cost of software and education/training.

Some universities in Hong Kong are offering optional BIM courses in their degree programs. The Construction Industry Council (CIC) is collaborating with training institutes to increase BIM capability for the frontline workforce and professionals and to increase the

capacity of BIM model developers. BIM implementation in Hong Kong is still in the primary stage in terms of the scale of application, although the most participants use BIM in their business but on lower level of implementation. Some public sector clients have been using BIM and exploring the types of public construction projects to which BIM can be effectively applied.

The Netherlands construction industry as a whole is involved in the Concept Library project which has been initiated and agreement on collaboration with buildingSMART organisation. It will cover construction, civil works and geospatial environment, with new technology and new content being developed. The result will be a concept library with semantic structure and developed, validated and usable content.

BIM education in colleges and universities in Norway is driven by a few engaged teachers. Together with various client organizations, buildingSMART Norway are putting pressure on the faculties and on the new government in relation to BIM education. A new BIM standard for object libraries has recently been released by Standards Norway.

When BIM is used in South Africa, it is usually for larger or more technically complex projects. The most of documents are 2D CAD files which represents standard and BIM is eventually used for complex projects. (Rooney, 2013)

By analyzing the data, we conclude that the countries in which the BIM education is available to the general public and supported by public sector bodies, has greater awareness about BIM. Furthermore, higher percentage of companies are using and properly implementing BIM in their own business. In other words, access to education and the application of BIM are proportional in size.

3.2. Application of BIM concept in student education

In order to enter into consideration of this theme it is necessary to review which the proper application of BIM approaches in education is. This represents not only the knowledge of the individual BIM software, but also the adequate implementation of the same, then the ability to work in a collaborative virtual environment, interoperable cooperation with all those involved in the project. That can also be used in the education of all those who BIM apply. Here we come to the idea of BIM education which represents the application of BIM concept in education in order to acquire skills which are mentioned in the text above and as such are the basic of the correct implementation of BIM.

At many universities around the world and Croatia for quite some time students have been working on projects using 3D models, however, BIM technology is in its full sense rarely used as part of a college education. Most research on the proper application of BIM in education have been conducted on students of architecture. Conclusion is that creating and working with a 3D model is not as demanding work, on the contrary, quite intuitive job, and students who are computer literate, and it is today most of them, can be done within a few days to fully overcome (Friedrich, Kubečka, 2013). The term BIM education does not mean just creating and working with the 3D model, but how we can get the information we need for our particular profession in this model and then manage and properly use them. In addition, interdisciplinary environment is one students are not familiar with because within student education do not meet with it (Malachy, 2012).

To all of the above correctly transposed to the students we have to observed two things; a curriculum which teachers have to keep and the way that they represent it to the students. In addition, learning should stimulate an objective fact reasoning. The introduction of such an approach in education brings many benefits while more students can work on the same project, work together to solve problems from different fields and at the same time from different locations (Elinwa, Agboola, 2012). Furthermore, the introduction of BIM in classes students begin to look critically at their actions because they, in a complex environment, could see how some of their demands can cause various problems in other professions (Fonesca, Villagra, Marti, Redondo, Sanchez, 2012). It was also shown that students learn faster if they were given a realistic project that is taught in the classroom because such cases are better simulate real conditions and facilitate the idea of integration with other projects and optimizing project plans (Peterson, Hartmann, Fruchter, Fischer, 2010).

4. BIM software

Although BIM education does not represent only the knowledge of using BIM software, this knowledge is very important fact in BIM education, and as such represents framework of the same. Due to the complexity of collecting all relevant information when working with BIM on some project, on the market are developed software that are specially programmed for the BIM technology. While the basic CAD tools which are used for drafting differ from packages for 3D modeling in that they allow update of model with further information such as time, cost, sustainability, and so on. When you create such a model all the objects have a certain degree of 'intelligence', and the software does not perceive them as lines, but as objects with many features (Eastman, Teicholz, Sacks, Liston, 2011).

Through the work of many participants who are involved on the same project and use different BIM applications, it was important to do some form of standard model which will be compatible for all software, while preserving 'intelligence' facilities and all other information within the model. For the same reason it was developed IFC (Industry Foundation Classes) model by buildingSMART organization. IFC, as such, represents a neutral and open format for exchanging models through a variety of software applications (ISO 2015).

Below is an overview of BIM software which will be grouped by application in 6 groups. The first group is ‘Architecture BIM software’, therefore software for designing the buildings and, as such, represents an important component of BIM software, since where we create an initial model which is the base point of the work of other participants. The second group is ‘Structures BIM software’ which is consists of software for modeling, calculation and detailed structural analysis of structures. The third group is ‘MEP (mechanical, electrical and plumbing) Design BIM software’, another component in the construction supply chain. MEP design is crucial for deciding the design, accuracy of documentation, performance and cost estimates of construction, planning, administration and management of the final object. The fourth group is ‘Construction BIM software’, software essential for the organization of construction and building control. Fifth group is ‘Sustainability BIM software’ which has developed since architects and engineers are forced to design energy-efficient buildings, using recycled materials. Due to this, a detailed analysis of sustainability is necessary as well as software support for the same. A sixth group is ‘Facility Management BIM software’ which has become more important since facility management throughout the lifetime gets increasing importance. Therefore information on the current state of the object, the built environment and systems, represent the starting point for further facility management of the final object (Eastman, Teicholz, Sacks, Liston, 2011).

Table 1. BIM Software and Providers (Cad Addict, 2010)

Architecture	Structures	MEP Design	Construction	Sustainability	Facility Management
Autodesk Revit Architecture	Autodesk Revit Structure	Autodesk Revit MEP	Autodesk Navisworks	Autodesk Ecotect Analysis	Bentley Facilities
Graphisoft ArciCAD	Bentley RAM, STAAD and ProSteel	Bentley Hevacomp Mechanical Designer	Solibri Model Cheker	Autodesk Green Building Studio	FM:System FM:Interact
Nemetschek Allplan Architecture	Tekla Structures	4MSA FineHVAC + FineLIFT + FineELEC + FineSANI	Vico Office Suite	Graphisoft Eco Designer	Vintocon ArchiFM (For ArchiCAD)
Digital Project Designer	CypeCAD	Digital Project Extension	Vela Field BIM	IES Solutions Virtual Environmental VE-Pro	Onuma System
Nemetschek Vectorworks Architect	Graytec Advance Design	CADMEP (CADduct CADmech)	Bentley Construc Sim	Bentley Tas Simulator	EcoDomus
Bentley Architecture	StructureSoft Metal Wood Framer		Tekla BIMSight	Bentley Hevacomp	ARHIBUS
4MSA IDEA Architectual Design	Nemetshek Scia		Glue	DesignBuilder	
CADSoft Envisioneer	4MSA Strad and Steel		Syncro Professional		
RhinoBIM (BETA)	Autodesk Robot Structural Analysis		Innovaya		
			Digital Project Manager		
			Nevaris Nemetschek		
			Gala		

5. Development of methodology for the correct application of BIM

Through the work we developed a methodology that can be applied to basic education and the stages of preparation and implementation of projects, not only among students, but also among the participants who are involved in project development. All of them who apply the same need to acquire basic knowledge of BIM and use software so that they can get insight into: 3D models, 'intelligent' facility, collaborative environment, the way of thinking in a virtual environment and 5D projects. The study was started with knowledge of Excel and Microsoft Project, and a basic knowledge of Revit, Navisworks and Gala. The methodology was developed on the real project of building. In following section we will show 4 combination of BIM software we used when developing the methodology for BIM education.

5.1. Combinations

COMBINATION 1 - Revit + Excel + Gala

Creation process is as follows: making 3D model in Revit, exporting bill of quantities and IFC from Revit, making cost analyzes and estimation with Gala, calculating the activities duration using Excel, connecting the model and costs with plan and finally displaying construction simulation in Gala. In the figure 2 we can see steps of combination 1.

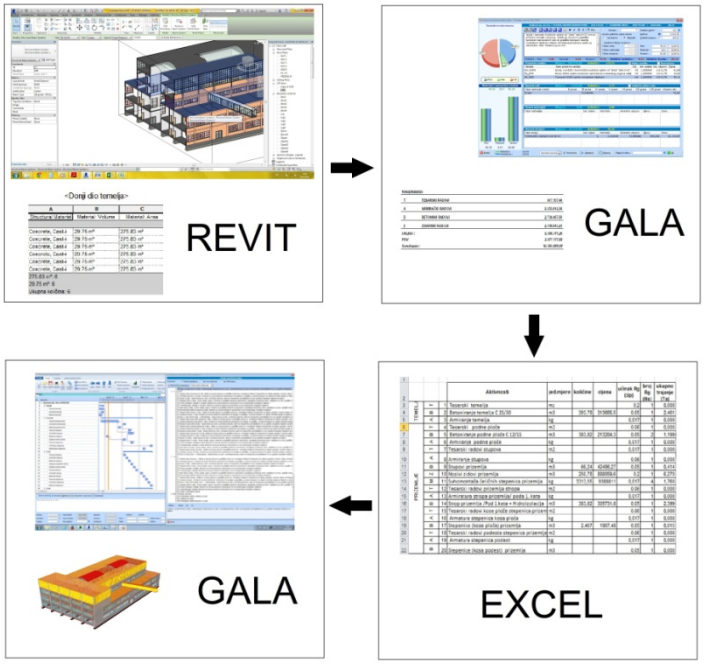

Figure 1. Combination 1

We conclude that Excel is in the process of time planning unnecessary as Gala independently calculates the duration of the activity and the required number of groups. The combination was rejected because of the unnecessary steps and unnecessary inclusion of additional software for calculations of duration.

COMBINATION 2 - Revit + Gala

Creation process was as follows: making 3D model in Revit, exporting IFC from Revit to Gala, making bill of cost, schedule and construction simulation uses Gala. In the figure 3 we can see steps of combination 2.

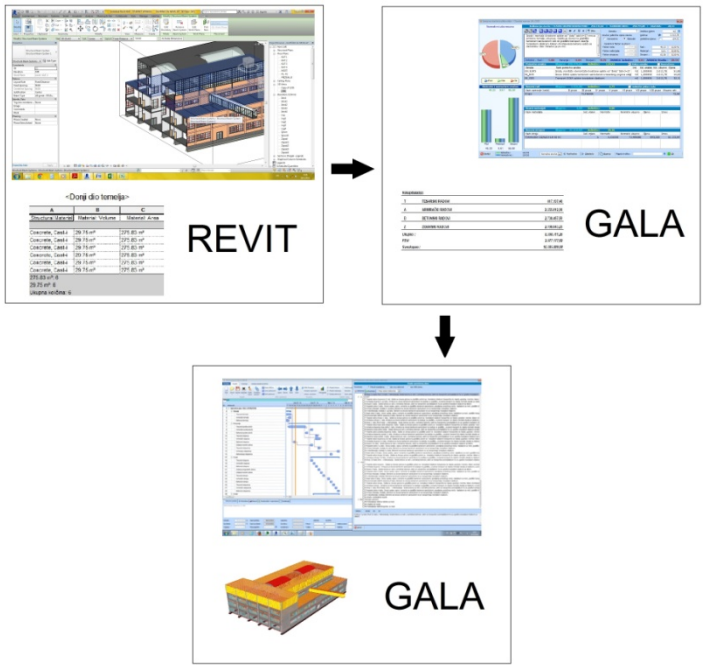

Figure 2. Combination 2

In order to use this combination of software required is extremely well-prepared 3D model and simplify it as much as possible. A combination as such is rejected for use in educating students, because our initial request is not achieved, concretely making 5D project.

COMBINATION 3 - Revit + Gala + Microsoft Project + Navisworks

Creation process is as follows: making 3D model and bill of quantities using Revit, making cost analysis and bill of cost with Gala, preparing schedule with Microsoft Project and finally connecting all these parts in Navisworks, in order to obtain the purpose of the construction simulation with cost display. In the figure 4 we can see steps of combination 3.

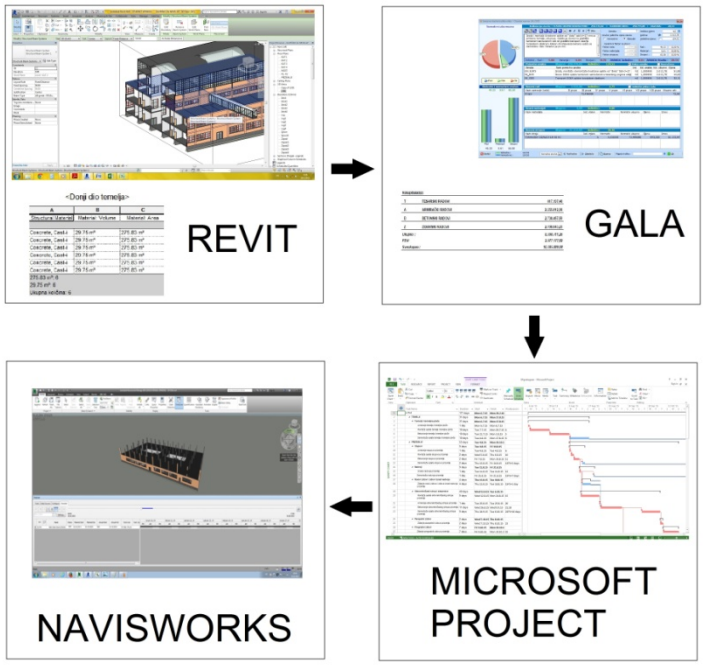

Figure 3. Combination 3

The combination was good because all the parts are accurately made, but the incompatibilities of software were observed. This is why we proceeded to the next combination in order to avoid the redundant software i.e. Microsoft Project.

COMBINATION 4 - Revit + Gala + Navisworks

Creation process is as follows: creating a 3D model and bill of quantities using Revit, making bill of cost and schedule using Gala, exporting plan to .mpp format and connecting plan with the model and costs to make a 5D construction simulation using Navisworks. In the figure 5 we can see steps of combination 4.

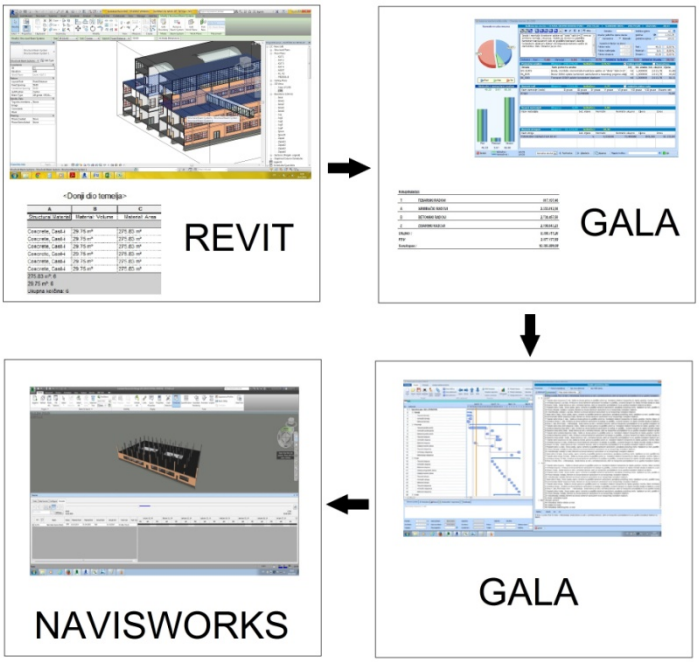

Figure 4. Combination 4

This combination worked well, showed the minimum of used software applications and the most effective results.

With listed combination we identified advantages and disadvantages of individual software together with identification of their performance and use. Furthermore, we examined the transmission of IFC forms within the software and conclude that combination (Revit + Gala + Navisworks) has proven to be the most appropriate for the application of BIM in education.

5.2. Correct usage of methodology on real example

To illustrate the proper application of developed methodology we applied the same in the case of the Civil Engineering faculty building in Zagreb. This example served as basic example for student assignments, but also as correct example of making 5D project for the participants who will eventually use them in practice.

3D model was made using Autodesk Revit software and is shown in figure 5. It was made as reinforced concrete structure that consists of the following elements: foundations, foundation slab, columns, lintels, ceiling and stairs while the walls are made of brick.

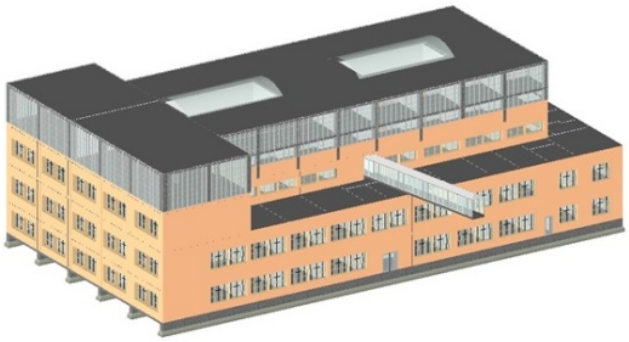

Figure 5. 3D model of Civil Engineering building in Zagreb

Bills of quantities were exported to .txt form also from Revit software. Its purpose is to show specific type of elements and their quantities and they are specially adapted to make cost analysis. Cost analysis and bill of cost were made using software Gala. After importing IFC model in Gala, we can mark the elements that will be used for a specific price analysis which automatically calculates the total amount of selected elements. The schedule was made with Gala calculating with working groups, their number, out-turn and material quantities. Simulation of construction was made using Navisworks Manage software where elements of object where linked to schedule activities. In addition, cost was entered to each activity, in order to obtain a 5D project. In the end, we exported a video simulation that showed a real planned construction simulation.

5.3. Models made for student case studies

For the purpose of testing the methodology in education we made 15 models (figure 6) in Revit so that students could work in pairs solving their case studies based on the example of the building of Civil engineering faculty that we made. Students followed this phases except for first step- drawing 3D model in Revit because they would not have enough time and education in that short time to make the same so we had to prepare them instead. Therefore, they can start from the second phase-exporting bill of quantities. Each model building construction had elements that required the application of different norms when making cost analysis (concrete ring beams, columns, beams, slabs, foundations, lintels, slanted board, basic boards, stairs, concrete walls, partition to load-bearing brick walls). In doing so, we did not want to get students to focus on the shortcomings of the software but to obtain basic BIM skills.

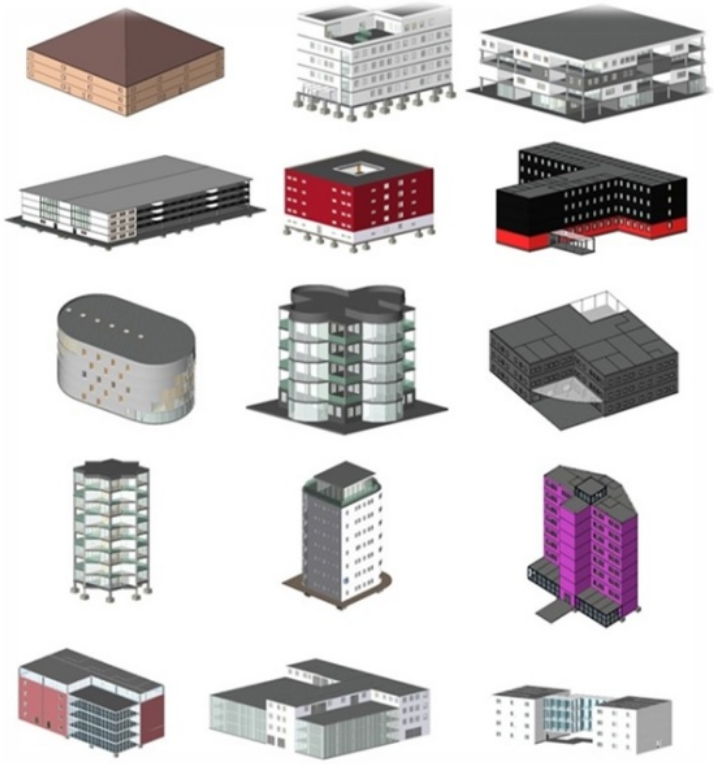

Figure 6. Models made in Revit for student education

6. Validation methodology through results student surveys

To validate the methodology we surveyed the students twice. First time before and second time after BIM education. Survey results indicate that most students before the education were not familiar (YES; 30%, NO: 70%) with the concept of BIM technology and after, with the help of adequate training that provided basic BIM knowledge, all the students gave a positive answer. In figure 10 the survey results also show that in the beginning students were not familiar with BIM software tools.

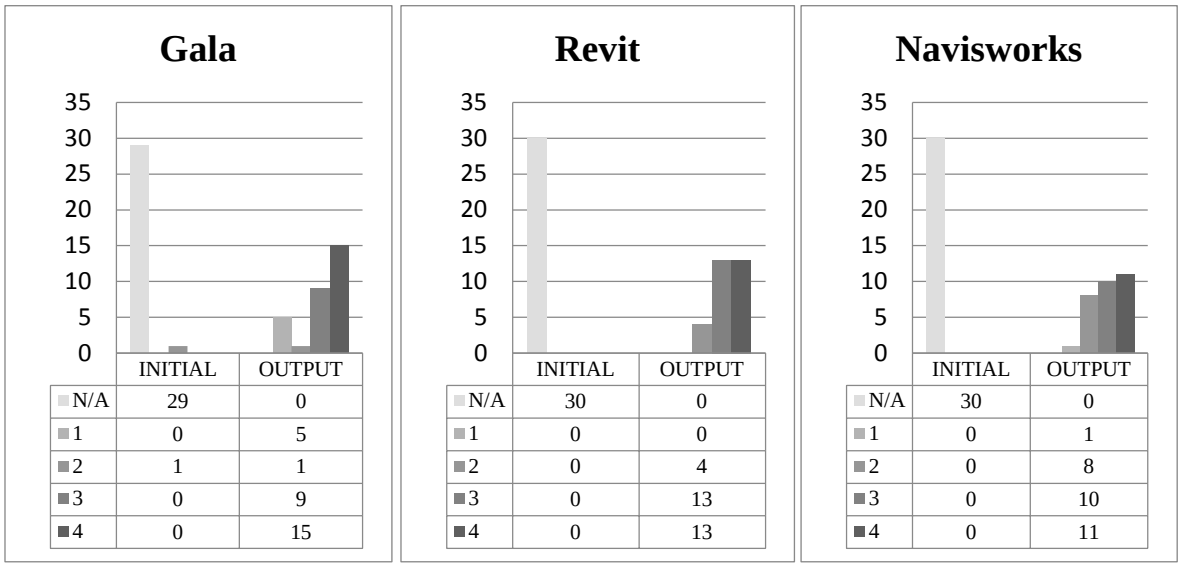

Figure 7. Graphical display of the initial and output survey responses on the question: 'Do you know this software? If yes, mark on scale 1 to 4 their performance (1 is bad performance, 4 is excellent performance).'

Only one student was familiar with Gala before making case study but after making their case studies, students were able to evaluate performance of Revit, Gala and Naviswork software. Generally, students were satisfied with the software which they applied for their case studies. Average evaluation of the same was following: Gala - grade 4, Revit - grade 3 and grade 4, Navisworks - grade 3 and grade 4, which means that students think that the performance of the software is quite satisfactory.

Furthermore the results have showed that Revit (software for creation 3D models and bills of quantities) had very good performance as evidenced by high survey scores. The ignorance was the reason for the occurrence of possible problems wherein the same can easily be solved with the help of vendors and professionals who use it. For Gala (software for cost analysis and schedule) we noticed lack of cooperation with elements after importing IFC model from Revit, therefore we had to insert quantities of some elements manually. Gala's original use was to calculate bill of costs the function where we could not have found. Furthermore, making the time schedule is not recommendable for more complex models, as it was in our case with the building construction. We can conclude that Gala's performance is not good enough for time planning and 4D simulation but it is excellent in cost estimation. Having a less complex projects, students could not make the same conclusion and the distinction but for less complex projects Revit and Gala were compatible. Student survey shows a very high grade for Gala. Then for Navisworks Manage (software for 3D model, schedule and cost connection) we noticed that schedule, cost estimations and 3D elements need to be well planned and well suited before start of their connection. If all those parts are not well prepared and incompatible it requires additional work and constantly returning to the first stage. Finally, the student survey showed a very high grade for Navisworks.

The results show that the methodology was successfully developed and applied to the education of students and as such can be applied in practice and the further stages of preparation and implementation of the project. Also it can be developed in education to a higher level on the required level of individual participants who will apply to the same.

7. Conclusion

In this article we have shown that:

- • the BIM education and its accessibility to the public is associated with greater awareness about BIM and a higher percentage of companies that use BIM and properly implement in their own operations
- the students who used developed methodology improved: communication skills, critical thinking, the ability to perceive potential problems, a way of creative thinking in solving problems in a collaborative virtual environment which in the end allowed them to observe the consequences of each decision
- the methodology that was developed and applied to the education of students has been proven as successful and as such can be used to further practice in the phases of preparation and execution of the project, and develop its use in education, depending on the required level of individual participants who will apply the same

Therefore the hypothesis of this article is confirmed.

So the developed steps (figure 8) that can be used in the preparation and execution of the project and thereby present BIM software are as follows:

1. preparation of 3D models using Autodesk Revit software,
2. preparation of bills of quantities using the software Autodesk Revit,
3. cost analysis using software Gala,
4. creation of schedule using software Gala,
5. preparation of the construction simulation with the display cost (5D project) using the software Navisworks.

The exchange model through the above software is done using a standard form of IFC model to achieve complete control of information, and the exchange of the schedule carries out as .mpp form.

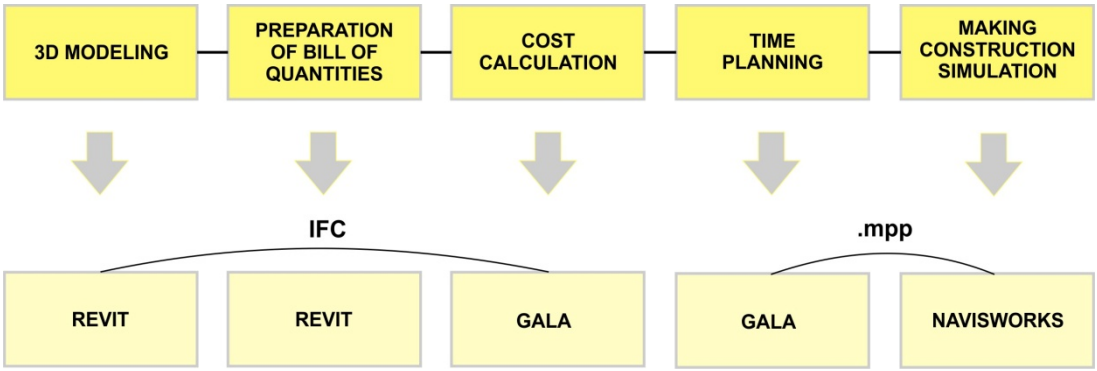

Figure 8. Schematic representation of the methodology steps and related BIM software

As discussed topics are just in their early development stage we propose the following research:

- inclusion of other BIM tools which would enable a development of a number of methodologies for the BIM implementation inclusion of additional resources (labour and equipment) in construction simulation
- extending the BIM approach to the other courses at the Construction Management education

We hope that the methodology developed in this study will help to better the education of Civil Engineering students. Furthermore, we hope that this methodology will serve the practice through the project phases of preparation and execution.

Acknowledgements

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- The students of the first year of graduate studies of Construction organization at Civil Engineering faculty in Zagreb for taken part in the student survey

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A Delphi Technique Approach of Identifying and Validating Subsidised Low-Income Housing Satisfaction Indicators

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Abstract

This paper reports on the practical experience of the researchers on the adoption of the inductive approach to knowledge diffusion through the use of the Delphi technique approach. The Delphi method is an essential technique of reaching consensus by experts on issues that cannot be resolved in a once off discussion. The research commenced with an extensive review of existing literature in order to identify the core and sub-variables which depicts housing satisfaction, to develop a Delphi questionnaire that was used in the Delphi study. A three iterative round Delphi technique was conducted to attain consensus of the identified housing satisfaction indicators. The experts used for this study were identified from different sources. The sources included the South African institutions of higher learning faculties, research institutes, the South Africa Department of Human Settlement, conference keynote speakers related to housing and human settlement issues in workshops, and individuals who have committed their lives working on the area of sustainable human settlement and housing related issues in South Africa. After three iterative Delphi rounds, consensus was achieved on the identified core-and sub-indicators identified from the literature and other added variables as suggested by the experts during the Delphi process. This study encourage the use of the Delphi technique as a method to achieve consensus in areas where consensus has not been reached such as in housing satisfaction studies to identify indicators for subsidised housing development in South Africa. The author argues that the Delphi method is a comprehensive method of attaining consensus on challenging issues of housing satisfaction; however, the technique requires proper communication management in order to achieve the required results.

Keywords: Delphi technique, experience, housing, housing satisfaction, indicators; inductive approach; methodology, qualitative

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1. Introduction

The common types of research questions being asked in housing satisfaction study's mostly seek to establish the current status quo. For most housing or residential satisfaction studies, the end result is an ordinary report of what determines and brings about satisfaction with the hope that solutions will be found for the stated reasons that determines housing satisfaction. However, since the study of housing satisfaction and human behaviour is progressive, there is now an increasing need to conduct housing satisfaction studies that offer a clarification on the core and sub-variables which determines housing satisfaction particularly in the low-income housing setting. Therefore the former requires that a different type of questions be asked and methodological approaches been used in order to obtain solutions for the problems which brings about dissatisfaction to low-income housing occupants. One such question that seeks a solution in housing satisfaction studies is one that asks the 'what-can-happen-if' a particular determinant influences housing satisfaction? Unfortunately, most housing satisfaction research questions are asking the 'what-are' type of questions which brings about residential satisfaction. Such type of questions only reports on the current status and determinants of housing satisfaction which are shallow in nature and does not respond to the need of the society to implement any programme(s) or changes to alleviate the problems of housing dissatisfaction.

One of the research methods ideal to generate a "what-can-happen-if" type of question is the Delphi technique. Logically, it is presume that the "what-can-happen-if" types of questions are difficult to measure except through experimental methods. Hence, most research does not ask such types of questions because experimental surveys in the human settlement psychological research domain are not realistic most of the time and are usually not appropriate. Moreover, there is no time for experimentation in the human settlement psychological research about housing occupants' dissatisfaction with their housing stocks. Therefore, this paper reports on the practical experience of the researchers on the adoption of the inductive approach to knowledge diffusion through the use of the Delphi technique approach. The Delphi method is an essential technique of reaching consensus by experts on issues that cannot be resolved in a once off discussion. The Delphi method will be discuss elaborately in the subsequent section of the paper and how it was applied to determine the core and sub-attributes that determines housing satisfaction.

2. Methodology

It was apparent from the literature review that the study of the determinants of residential satisfaction are a debatable subject in the human settlement psychological research domain as there are variants of determinants which are considered to influence satisfaction and others are less treated. Besides, residential satisfaction indicators (core and sub-attributes) differs from study to study. Hence, a research method that could generate and encourage the discussion of different opinions, in the attempt to ensure that all relevant indicators are validated, identified and explored was promoted for this study. Hence, this ruled out a one-off survey questionnaire method; and thus, favoured a method that could elicit experts' opinions. Hence, the Delphi method was preferred for the first phase of the research project. This perfectly aligned with the requirements of the research study, as one of the ideology of the study was to provoke debate and assist in reaching consensus on various indicators of housing satisfaction in the low-income housing sector.

The Delphi technique according to de Villiers et al. (2005) is derived from the constructivist approach to knowledge and it overlaps between quantitative and qualitative methods of data collection and analysis. These characteristics according to Stewart (2001) allows the research results and conclusions to represent a shared meaning based on interactive process drawn from a pool of experts. In addition, the Delphi method is considered to be a robust method for a rigorous query of experts. Unlike ordinary survey research, the Delphi's strength also lies in the iterative process (rounds of questioning) used which provide an opportunity for initial feedback, collation of feedback, and distribution of collated feedback to participants for further review. This unique process requiring group communication is central to the strength

of the Delphi (Stitt-Gohdes & Crews, 2004). Hence, a Delphi Study was conducted to determine and solicit expert's views on the influence (probability) and impact of residential satisfaction attributes on low-income housing beneficiaries, thus, identifying the determinant attributes (core and sub-) that bring about residential satisfaction in the South Africa low-income housing context. Three rounds of the Delphi process were conducted before experts could reach consensus on the questions that were posed to them.

3. Conducting the Delphi Study

The variance amongst the various group techniques and the definition of the Delphi Method as complied by various scholars and cognizance of the various criticisms forms the epistemological foundation for defining the approach towards a typical Delphi Study design. This is done by assuring that all expert feedback is anonymous.

According to Scheele (2002), the concreteness of the framework of the Delphi Design is vital in researching the overall objective of the study. The basic premises of the Delphi research design towards the identification and validation of residential satisfaction attributes for the low-income groups in South Africa; is entrenched in some form of general agreement and consensus regarding the core ingredients and components of the subsequent framework. Given the current status of low-income housing in South Africa and the absence of a general agreed upon residential satisfaction attributes, the search for consensus and a point of departure in attributes that determine residential satisfaction in other low-income housing issues is therefore justified. Hence, the objective of the Delphi Design was to obtain the most reliable consensus of opinion of a group of experts in the field being studied. Therefore, given the nature of the current research, it was evident that the Delphi Technique was well-suited to obtain credible inputs from experts in industry, academics, government and NGOs to serve as key input in the identification and validation of residential satisfaction attributes for low-income housing. The next section provides an overview of how the Delphi Technique was used in this study.

3.1 Designing, Constructing and Executing the Delphi Study

Given the rationale behind the Delphi Technique and the main features explained above, the design, construction and execution of the Delphi Study for the current research followed a sequential process as suggested by Loo (2002). According to Loo (2002), four vital planning and execution activities should be followed, which are:

- Problem definition;
- Panel selection;
- Determining the panel size; and
- Conduction the Delphi iterations.

Supporting Loo's (2002) approach, Delbecq et al. (1975) suggested a basic Delphi Methodology that includes distinct stages such as, Delphi Question Development (objective), expert panel selection, sample size, first questionnaire, first questionnaire analysis and follow-up questionnaires. This methodology forms the basis of the current Delphi research study and is explained in the subsequent sections.

3.2 Phase 1 – Delphi Question Development

The formulation of the Delphi question is vital to the whole process. It is paramount that the panel of experts understands the broad context within which the questionnaire is designed, especially with the current research where the concept of what determines housing satisfaction has different connotations; hence the concept had to be broadly clarified. For the Delphi Study to achieve the objectives, key questions were asked. The basis of constructing the questions for this current study was based on the guidelines given in Table 1, with corresponding wording and phrasing given for this study.

3.3 Phase 2 – Delphi Expert Panel Selection / Determining the panel size

A critical part of conducting a Delphi interview technique is selecting the right experts (also known as panellists, participants or respondents) and their role is crucial to the success of the research (Hasson et al., 2000). Experts to be selected must be sufficiently interested and involved in the subject being examined to ensure a high commitment response rate. According to Hasson et al. (2000), controversial debate occurs when a professional becomes an 'expert'. The claim that one group represents valid expert opinion has been criticized as scientifically untenable and overstated (Hasson et al., 2000).

For the purpose of this research McKenna's (1994) definition of 'expert' as being a panel of informed individuals (otherwise called experts hereafter is used). McKenna's (1994) definition was further supported by Goodman (1987) stating that the Delphi technique "tends not to advocate a random sample of panellist … instead the use of experts or at least of informed advocates is recommended". Likewise, Helmer (1977) argues that since a "Delphi inquiry is not an opinion poll, relying on drawing a random sample from the population of experts is not the best approach, rather, once a set of experts has been selected (regardless of how – but following a predetermined qualifying criteria), it provides a communicative device for them that uses the conductor of the exercise as a filter in order to preserve anonymity of responses', which is the core of the Delphi Technique. Therefore, Linstone & Turoff (2002) states that the most significant danger in selecting the panel of experts lies in the path of 'least resistance' through the selection of a group of cosy friends and / or like-minded individuals, which thus negates the strength of the process.

Table 1. Delphi question formulation

Key Delphi Questions	Phrasing for this study
Why are you interested in this study?	This study was initiated because of the belief that not all beneficiaries who received government low-income houses are satisfied with what was allocated to them. Therefore, this assumption is concrete because there is lack of understanding of the diverse attributes that determine housing satisfaction.
What do you need to know that you do not know now?	Despite the knowledge about the attributes that bring about residential satisfaction; there has not been a consensus amongst experts in order to inform policy and predict housing satisfaction in the low-income groups in South Africa.
How will the results from the Delphi Study influence residential satisfaction?	The result of the Delphi Study will enable us to know the attributes which collectively predict and establish housing satisfaction in South.

Since panellists form the cornerstone of the Delphi technique, clear inclusion criteria was applied and outlined as a means of evaluating the results and establishing the study's potential relevance to other settings and populations. The selection of panellists for the study was based on criterion sampling. Panellists were selected for a purpose to apply their knowledge to the concept raised in the objective based on the criteria that was developed. This was necessitated because the technique does not depend on a statistical sample that attempts to be representative of any population. It is a group decision mechanism requiring qualified experts who have deep understanding of the issues (Okoli and Pawlowski, 2004). Hence, one of the most critical requirements is the selection of qualified experts as it is the most important step in the entire Delphi process because it directly relates to the quality of the results generated (Hsu and Sandford, 2007). The careful selection of the panel of experts is a keystone to a successful Delphi study.

In choosing panellists for this study, each expert were required to meet at least five of the following minimum criteria of: 1) residency- have lived or is living in one of the South Africa Metropolitan or District Municipalities cities; 2) has knowledge of the low-income housing

situation in South Africa; 3) academic Qualification, has been presented an earned degree; 4) experience related to the low-income or other sustainable development or human settlement context; 5) employment in a professional or voluntary capacity; 6) influence and Recognition; 7) authorship of peer-reviewed publications in the field of housing with emphasis on South Africa; 8) research, has received research funds that support housing development studies for the low-income group or other human settlement related issues; 9) teaching, has served as an individual or as a collaborative instructor in the teaching of one or more college or university courses focusing on the sustainable development or related field; 10) membership of a professional body so that their opinions may be adaptable or transferable to the population and k) willingness to fully participate in the entire Delphi studies.

The adoption of five criteria was considered more robust than the suggested number of at least two criteria by Rodgers and Lopez (2002). The five minimum criteria were framed after the four recommendations made by Adler and Ziglio (1996), with the inclusion of experts' residency status, which was considered to be compulsory for all selected experts. This was considered significant because experts were required to have a wide-ranging understanding of the low-income housing context in South Africa. Also, a minimum number of five criteria were set because the technique may be undermined if panellists are recruited who lack specialist knowledge, qualifications and proven track records in their respective field (Keeney et al., 2001) amongst others.

Panel members were identified from four sources. The first source was from the South Africa institutions of higher learning faculties, departments, research institutes amongst others. The second source was the Department of Human Settlement. This is because they are the entity vested with the responsibility for the initiation and development of subsidised low-income housing in the country. Hence their involvement in the Delphi process was a key consideration. The third source was from various conference proceedings such as the annually held Built Environment Research Conference hosted by the Association of Construction Schools of Southern African, Construction Industry Development Board biannual post graduate research conference amongst others. Individuals who had frequently appeared as authors or key speakers related to housing and human settlement issues in these proceedings were identified as potential experts on the study. The fourth source was references of individuals who had committed their lives working in the area of sustainable human settlement and housing related issues in Southern Africa.

With regard to the recruitment process, panellists were recruited via e-mail, with a brief overview of the study objective. Thereafter, those that consented to the preliminary invitation were sent a detailed description of the Delphi study; and were requested to send their curriculum vitae in order to confirm their areas of expertise and to ascertain whether they met the qualifying criteria. Hence all experts selected for the current study met a minimum of five criteria's set for the study.

From all the sources mentioned above, 55 invitations were sent out. Out of 55 invitations, 17 responded to the invitation; 17 completed the first round and 15 were retained throughout the study as one panellist could not meet with the demand of the study while the other was deceased during the course of the study, but had sent through his opinions for the first round. Therefore, the Delphi study retained 15 active members during the iterative round. This number of panellists was considered adequate based on literature recommendations from scholars which have employed the technique previously (Okoli and Pawlowski, 2004; Hallowell and Gambatese, 2010). Based on the above and the fact that the Delphi method does not depend on the statistical power, but rather on group dynamics for arriving at consensus among experts, the panel of 15 experts was considered adequate.

3.4 Phase 4 – Conducting the Delphi iterations

Data collection through Delphi

Sequences of questionnaire rounds are used to obtain iterative responses to issues in a Delphi Study. For instance, Woudenberg (1991) proposes two or ten rounds as appropriate numbers of rounds supporting that accuracy is expected to increase over rounds, because of the repetition of judgment and group pressure for conformity. Likewise, Critcher and Gladstone (1998) suggest between two and five rounds. The Delphi method used in this study

involved three rounds of iterative process, with the view of achieving consensus between the panel members on the determinants of residential satisfaction of low-income housing. A Delphi questionnaire was sent out electronically to all panel members who were then asked to take the time and respond to the questions, according to their ability and expertise. The Delphi Questionnaire was developed based on the findings from the literature review and was specifically designed to address and achieve the Delphi specific objectives defined for the study.

On average, each round took about a month to complete. A questionnaire was designed for each round based on the responses to the previous one. The Round One Questionnaire was designed, based on a summary of the comprehensive review of literature highlighting sets of attributes and sub attributes that are potentially relevant to residential satisfaction decisions by the occupants of low-income housing. Round One of the Delphi Study was intended to be a brainstorming exercise used to produce a list of empirical attributes that determine residential satisfaction in South Africa. Closed and Open-ended questions were used in this round. Thereafter, these were analysed and formed the basis of Round Two and Round Three of the study respectively. Frequencies were obtained to measure the degree of consensus reached amongst participants regarding the attributes that determine residential satisfaction in South African low-income housing. Also, a content analysis methodology was adopted to analyse responses to the open-ended questions to "minimize redundancy" (Rubin et al., 1998).

The purpose of the second round of the study was to allow experts to review and comment on the attributes that determine residential satisfaction and other issues relating to low-income housing in South Africa, which were proposed by the expert participants in Round One. Closed questions were used in this round to investigate participant comments expressing agreement, disagreement or clarification concerning proposed attributes that determine residential satisfaction in South Africa. The specific nature of the closed-ended questions stimulated participants' reactions. Frequencies were likewise obtained to measure the degree of consensus reached amongst participants regarding the attributes that determine residential satisfaction and for other related questions. Also, a content analysis approach was adopted to analyse responses to the open-ended questions.

The Round Three Questionnaire was designed based on the findings of content analysis and measures of frequency responses to the questionnaire of Round Two. The final Round Three, was specifically aimed at:

- informing the experts of the findings of the analysis of responses to the questionnaire of Round Two; and
- requesting their final affirmation / comments on attributes and issues that did not receive any consensus in Round Two.

Upon receipt of responses from the first round, group medians were computed for each question. In the second round, the same questionnaire is sent back to panellists individually with their own responses from the first round with the group median responses included so that responses in the second round could be made taking into account the group median. In the second round expert panel members are asked to either maintain their original responses made in the first round, or they could change their initial response to either be in agreement with the group median or make a new rating altogether. The panellists, who have ratings of two units either above or below the group median on any one particular question, are requested to state the reasons for their dissenting opinion if at all they opted to stick to their rating. The stated reasons are sent to all panellists so that together with the calculated group medians in the second round, panellists could take cognisance of those comments in making their new ratings in the third round. Panellists are specifically requested to consider reasons from the outliers made in the second round in making their decisions in the third round.

After the third round, group medians and the absolute deviations are again computed for the third round. If calculations for the third round of the Delphi process indicate the desired level of consensus, then there is no need to proceed to the fourth round as there is no further value that could possibly be added to the degree of consensus that has been attained. Throughout the Delphi process, anonymity of panel members was maintained to avoid undue influence on other members. The aspect of anonymity is crucial to the credibility of the Delphi process.

Over the three round Delphi Survey, consensus was reached regarding most of the attributes that determine residential satisfaction in South Africa. Based on the findings of the analyses of

responses to the Delphi rounds, a list of attributes that determine residential satisfaction was prepared, which informs the conceptual framework for another broader study. The Delphi Survey was conducted via electronic mail, and follow-up emails were used to encourage prompt responses to the questionnaires. Using email provides a free and faster means of communication.

Computation of Data from Delphi Study

Computation of data from the Delphi Study was conducted using Microsoft Office Excel, a spreadsheet software programme. The first stage involved analysis to determine consensus on responses to the predetermined criteria. This involved determining the group median responses for each question. After the third round of the Delphi, absolute deviations of the group medians of each rating for the relevant questions as pre-determined.

A computation of each and every question element was completed for the likelihood and impact of the attributes in predicting residents' satisfaction South Africa low-income housing. Additionally, for every round of responses from the experts, besides the group median value computation, their respective interquartile deviation (IQD) were also computed as a measure of the central tendencies to determine consensus. The median value was adopted as a measure of central tendency because of its effect to minimize the effects of potentially biased individuals. While the IQD scores were used to summarize the variability in the data. The IQD helped to identify which measure were most appropriate to influence residents' satisfaction. Also, through the use of the IQD, a clearer picture of the overall dataset was provided as the IQD removes / ignores outlying values. The inter-quartile range is a measure that indicates the extent to which the central 50% of values within the dataset are dispersed.

Determination of Consensus from the Delphi Process

It is a general notion that consensus forming is the quintessence of the Delphi technique.Unlike questionnaire surveys which requests for the opinion of non-experts on a matter, the Delphi technique seeks to establish the opinion of experts on a particular matter. Hence it is imperative in a Delphi study that consensus is reached on all questions asked. However, measuring or determining consensus is a highly contended subject in literature. Consensus is difficulty to measure in Delphi Studies. The foregoing has been established from literature, that actually there is no consensus on how to determine consensus regarding a set of opinions. Holey et al. (2007) suggested that consensus is the same as agreement and that agreement can be determined by the following: the aggregate of judgments; a move to a subjective level of central tendency; or alternatively by confirming stability in responses with the consistency of answers between successive rounds of the study.

Other researchers have used frequency distribution to assess agreement and the criterion of at least 51% responding to any given response category being used to determine consensus (McKenna, 1994). Other studies, such as the study of Rayens and Hahn (2000), have used means and standard deviations with a decrease in standard deviations between rounds indicating an increase in agreement. Likewise, inter-quartile deviation (IQD) has also been used to determine consensus (Rayens & Hahn, 2000), which was also adopted for the present study. Furthermore, Holey et al. (2007) used the following criteria to determine consensus: percentage response; percentages for each level of agreement for each question to compensate for varying response rates; computation of median, standard deviation and their associated group rankings; computation of the means, standard deviation and their associated group rankings using the importance ratings; and computation of the Weighted Kappa (k) values to compare the chance eliminated agreement between rounds.

According to Holey et al. (2007), consensus is reached when the following is present: an increase in percentage agreements; convergence of importance rakings; increase in Kappa values; a decrease in comments as rounds progressed; a smaller range of responses; and smaller values of standard deviations. The studies above suggest that there is little agreement on how to measure consensus in a Delphi Study. It is however agreeable that for consensus to have been achieved, there has to be a convergence of ideas and reasoning towards a subjective central tendency measure. Hence, in the current study, consensus was determined to have been reached if the following was achieved: more than 60% of responses are generally positive or

negative with certain questions; the average of the absolute deviation was not more than one unit; the absolute deviation is calculated; the IQD was less than 1.00., meaning that items with IQD = 0.00 were considered to have reflected high consensus. Therefore the scales of consensus adapted for this research are:

- Strong consensus - median 9-10, mean 8-10, interquartile deviation (IQD) ≤1 and ≥80% (8-10);
- Good consensus - median 7-8.99, mean 6-7.99, IQD≥1.1≤2 and ≥60%≤79% (6-7.99); and
- Weak consensus - median ≤ 6.99, mean ≤5.99 and IQD≥2.1≤3 and ≤ 59% (5.99).

4. Findings- experience on conducting the study

In the study presented in this paper, the Delphi Technique formed the initial stage of the study whose objective was to develop a residential satisfaction models for subsidised low-income group in South Africa. The Delphi study was therefore useful in developing the conceptual models which were later validated using structural equation modelling through the EQS software.

The Delphi technique was found to be an invaluable tool to validate what literature offered in formulating a theory. It was also found to be a necessary step in conducting a rigorous investigation to human settlement psychosomatic issues.

Though, conducting a Delphi study requires a careful administration of both the received data and the panel members. Hence, the Delphi study is demanding for the researcher compared to other methods of primary data collection such as the questionnaire survey. For instance, in the survey questionnaire, data is only input once while for the Delphi data may be input at least three times. Depending on the number of rounds scheduled for the study. Likewise, the analysis is also undertaken at least three times. Together with the above, a careful scrutiny of comments by the experts must be undertaken. With the enormous amount of data and communication, it is possible to mix up the email communication resulting in sending emails to panellists who were not intended to receive them; hence, the process is can be ruined if not well managed.

Regardless of the difficulties and demands on both the researcher and the experts, the research found the Delphi study to be an essential tool in seeking solutions to the problems that the human settlement body of knowledge faces in the study of issues where there has been no consensus. It is not enough to simply report on the determinants of housing satisfaction, but what is required is to objectively determine the causative of the construct being studied as was found in this study. It was also found that the researcher must spend a considerable amount of time communicating with the participants and keeping them motivated to continue with the study. This is however not an easy task. But, in this study, out of the 55 invitations sent out, 17 experts responded. These 17 experts completed the first round; but 15 were retained for the study as one panellist could not meet with the demand of the study while the other was deceased during the course of the study, but had sent through his opinions for the first round. Therefore, the Delphi study retained 15 active members during the iterative rounds.

5. Conclusion

The study investigated the practical experience of the researchers on the adoption of the inductive approach to knowledge diffusion through the use of the Delphi technique approach. The study found that the criteria set for identifying the experts for the study was successful as out of the 55 experts invited to participate, the 15 experts who finally complete the study qualified as experts for the study. The Delphi method also proved to be a success despite the challenges and time consuming aspect of the technique as the experts responded on time with their opinions. It was also found in this study that the criteria set for reaching consensus using multiple parameters to decide on consensus is vital as only one or two parameters could be flawed and not giving the correct results. Also the choice of the experts and the topic of discussion was a success, this is revealed through the high consensus rate achieved for the study bearing in mind that the study adopted three successive rounds of Delphi.

Based on the challenges encountered by the research during the course of this study, the following suggestion are thus recommended: researchers proposing to use the Delphi technique should be predetermine the approach they would like to adopt in the first round; either an open ended or closed-ended structured questionnaire as this will dictate and determine the output from the study. Also, researchers should be mindful of the feedback process and the type of questions to be asked in the subsequent iterative rounds before the commencement of the Delphi study. Also, the instructions of the questionnaire to be sent to the experts should be concisely stated and be specific without any ambiguity in order to achieve the desire results. Furthermore, in order to improve on the response rate from the experts, it is recommended that constant reminder to the experts shortly before the closing date and after the closing date of returning the questionnaire responses should be done. Also, the experts should be allowed some extra time if the experts are not able to respond on the proposed date of return of the questionnaire. In conclusion, this study encourage the use of the Delphi technique as a method to achieve consensus in areas where consensus has not been reached such as in housing satisfaction studies to identify indicators for subsidised housing development.

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Analysis of the Information Flow from BIM to Energy Simulation Programs

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Abstract

Buildings account for 40% of EU final energy demand and thus hold the biggest opportunities for energy saving. In this context, regulations have been promulgated over the past decade for energy saving through energy modelling in new and existing buildings. Energy modelling is a well established area in the AEC industry and several energy simulation programs are currently in use. On the other hand, Building Information Modelling (BIM), which is a process involving the generation and management of digital representations of physical and functional characteristics of buildings, is spreading widely in the AEC industry as well. Automated transfer of information from BIM models to energy simulation programs as an input is possible; however, there are serious interoperability issues. In this paper, most commonly used energy simulation programs, namely Ecotect, Green Building Studio (GBS), Integrated Environmental Solutions (IES) and Quick Energy Simulation Tool (eQUEST) are analyzed in terms of the functions offered, required inputs and outputs when used together with BIM. Information flow has been modelled for each energy simulation program and problem areas regarding interoperability with BIM are identified.

Keywords: AEC industry, BIM, energy simulation, information flow, sustainability

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1. Introduction

Scarcity of resources, environmental degradation, and increasing competition deeply effect architecture, engineering and construction (AEC) industry. To survive in the strictly competitive environment, companies have to follow the most recent technological improvements and develop new products, services and methods. As a result, Building Information Modelling (BIM) and green/sustainable buildings have emerged as the two prevailing trends (Krygiel and Nies, 2008).

Building Information Modelling (BIM) is an IT enabled approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project life cycle in the form of a data repository, including geometric and non-geometric data like spatial relationships, geographic data, building components, manufacturer details, construction schedules, fabrication processes (Gu and London, 2010). BIM has been getting increasingly essential in the AEC industry and being widely projected to be the technology of the future (Harding et al., 2014). BIM prevents the problems and faults resulting from the lack of coordination between project participants, allows clash and maintainability checks, provides automated updates in project documents after design revisions, and elicit simulations of design alternatives in the early stages, aiming to minimize time and money losses through the life cycle of a building. (Zhao, 2011; Ilter and Ergen, 2015).

On the other hand, sustainable design approach also aims for improving efficiency in buildings, looking for solutions to decrease negative effects of buildings on environment, while improving building performance, and consequently health and comfort of building residents. Fundamental method of sustainability is to decrease consumption of non-renewable resources and to minimize waste products (GSA, 2015). Employing a sustainable design philosophy encourages decisions at each phase of the design process that will reduce negative impacts on the environment and the health of the occupants, without limiting the quality of life. Such an integrated approach positively impacts all phases of a building's life-cycle, including design, construction, operation and decommissioning. Studies show that buildings consume average 40% of total energy consumption and thus the most essential factor for sustainable buildings is energy (Wu and Issa, 2011). Accordingly, green building certification criteria and specifications clearly show that the most substantial part in scoring is energy consumption. The widespread practice of decreasing energy consumption is energy simulation in early design phases. With the help of energy simulation, energy performance of alternative design solutions can be seen at the concept and detailed design stages and according to these results variables can be changed for energy saving (Wu and Issa, 2012). In order to design more energy efficient buildings, energy simulation programs, such as Ecotect, IES<VE>, eQuest, GBS, Energy Plus, Design Builder etc. are widely used to analyse and improve the energy performance of buildings. These programs may range from simple tools to sophisticated programs and offer a range of applications including simulations, load calculations and thermal, solar, lighting, acoustic, ventilation etc analysis. Most of these programs support 3-D modelling functions and importing drawings from CAD or other drawing formats (Kumar, 2008).

Researchers and practitioners are well aware of the opportunities that raise using BIM and energy simulation programs together in the design of energy efficient buildings, which has been recently called Green BIM (Krygiel and Nies, 2008). Green BIM can be expressed as the application of BIM to design and construction of green/sustainable buildings and integrating energy simulation with building models designed with BIM (SmartMarket Report, 2010). The synergies between green and BIM can improve project outcomes and higher sustainability

goals can be accomplished (Wu and Issa, 2015). The chaos resulting from the big and self-interacting data produced during the design of a green/sustainable building makes the conventional methods ineffective. Taking the advantages of BIM in information management into consideration, BIM makes management of various variables of energy performance, time, cost and work flow easier and more effective (Azhar et al., 2011). Nevertheless, the full potential of green Green BIM is yet to be explored (Wu and Issa, 2015) and although necessary standards exist for both BIM and sustainable buildings separately, methods and standards for applying BIM to construct sustainable buildings are not mature enough and thus pose risks and barriers for their integrated use. For the realization of the potential that Green BIM offers, the interoperability of BIM and energy simulation programs needs to be established so that a change in building design applied to the BIM model can be reflected in the building's predicted energy performance through the simulation programs and updated automatically (Kumar, 2008). Surveys among practitioners show that lack of tools, tools being too complicated or not having required functionalities in current programs hinder the use of BIM for green projects and most users are 'frustrated' by the lack of a fully integrated approach (SmartMarket Report, 2010). It has also been reported that almost 3% of the projects costs are related to the lack of software interoperability (Kumar, 2008). Another important problem with non standard approach in Green BIM that is one can find very different results with different simulation tools using the same building model (Kumar, 2008). Thus, the next generation of BIM tools and energy simulation programs are required to have robust translation of large quantities of data from each other.

The aim of this paper is to model the data flow from BIM to energy simulation programs and determine the interoperability problems. For this purpose, previous literature on energy simulation programs was reviewed and most widely used programs were selected. Revit was chosen as the BIM tool in this study, as it offers best interoperability with energy simulation programs (Kumar, 2008). Investigating the interoperability of BIM and energy simulation programs, analysing the input requirements and comparing the benefits offered by the programs is expected to help AEC industry find more efficient ways to construct energy-efficient buildings, using BIM as a method.

2. Analysis of Energy Simulation Programs

There are many energy simulation programs working together with BIM programs. These programs can be classified according to various features and energy analysis capacity. Statistical data in the studies of Attia et al. (2009), Azhar et al. (2009) and Azhar and Brown (2009) list the most widely used programs as GBS, Ecotect, IES<VE>, Energy Plus, Delight, Radiance, HEED, Homer, Virtual DOE, Bentley HEVACOMP, Bentley TAS, Climate Consultant and show programs' advantages, disadvantages and analysis capacities. A more recent survey shows that there are five more energy simulation programs in use, namely Graphisoft, EcoDesigner, eQuest, DesignBuilder and Energy-10 (Reeves et al., 2012). In this study programs are compared for interoperability, user friendliness, available outputs, available and inputs (Figure 1). It can be seen from this figure that interoperability score is highly correlated with the overall score of the programs. The programs taking highest four ranks in Reeves et al. (2012), namely IES<VE>, Ecotect, GBS and eQUEST respectively, were investigated for their inputs, outputs and data flow in this study.

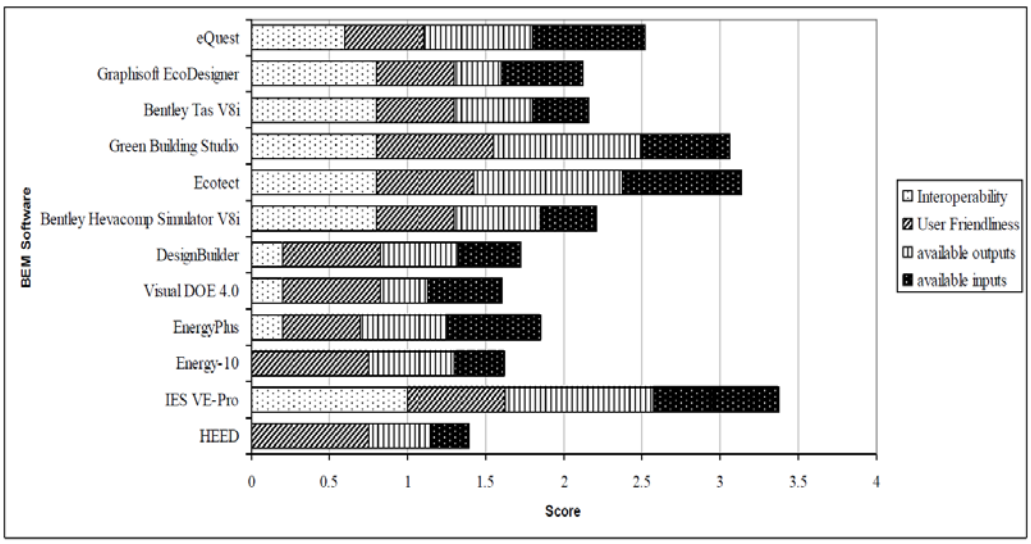

Fig. 1. Comparison of energy analysis programs (Reeves et al., 2012)

2.1. IES - Virtual Environment (VE)

IES<VE> has been ranked as one of the most powerful tools by researchers for high interoperability capacity and having vast array of available inputs and outputs (Azhar et al., 2009; Reeves et al., 2012). 3D model can be directly imported to IES<VE> in "green building extensible markup language" (gbXML) format (also in "IFC", "DXF" file extensions), thus does not require re-modeling for energy simulation. If required, a new model can be created in the program as well. Location, building type, space, surface, opening information can also be transferred to IES<VE> from Revit or Sketch-up through a gbXML file. On the other hand, information regarding material density, conductivity, lighting, furniture, floors and roof has to be fed to the program by the user. Available outputs include lighting, airflow, HVAC, value/cost, data for certification (LEED), energy, carbon and solar analyses. Information flow from BIM to IES<VE> can be seen in Figure 2.

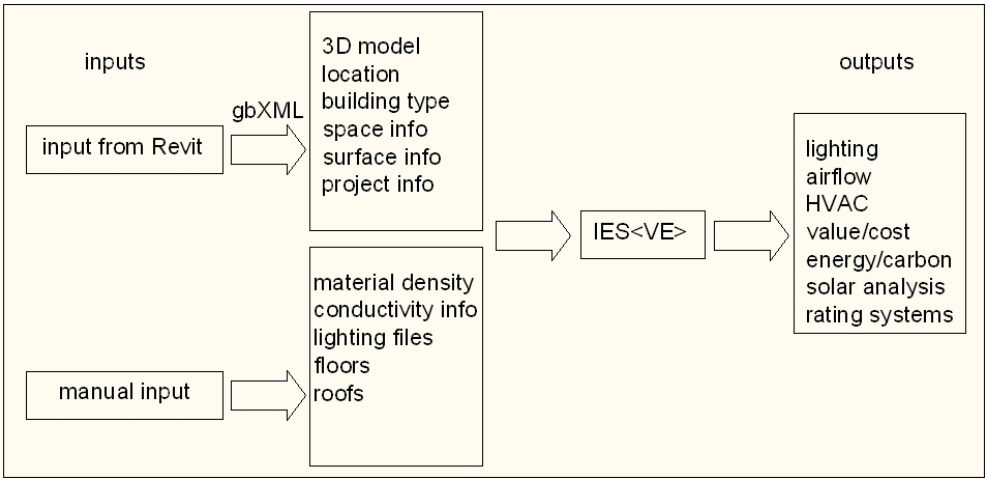

Fig. 2. Information flow from BIM to IES<VE>

2.2. Ecotect

Ecotect has been ranked lower for interoperability compared to IES-VE but is as powerful in terms of user friendliness, and available input-outputs (Reeves et al., 2012). Ecotect gives both analytical and visual results to users about energy, shadow, passive gains, radiation,

sunlight rights, acoustical, thermal and water use analysis. Ecotect can be used together with BIM software (Revit). Designers working on the same draft can analyze different model alternatives and they can see the factors which affect building energy performance. The transfer format is gbXML. Important properties of Ecotect are given below:

- The effects of peripheral factors on the building performance can be seen on simulations and 3D model.
- Solar radiation, shading, reflection and visual effects work in the program.
- For different design alternatives, water, energy and carbon emission analysis are made by Ecotect.
- Provides analysis for Energy Star and LEED solar credits.

Information flow from BIM to Ecotect can be seen in Figure 3.

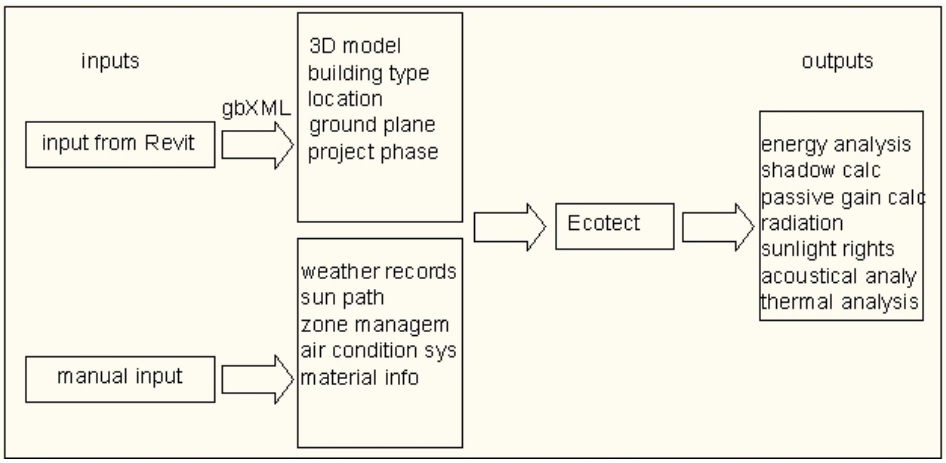

Fig. 2. Information flow from Ecotect

2.3. Green Building Studio (GBS)

Autodesk GBS is ranked lower in terms of interoperability however is perceived as the most user friendly energy simulation tool (Reeves et al., 2012). GBS has a narrow range of available inputs, which renders the program faster but less suitable for advanced level use. GBS provides cloud-based service and also can be used as a standalone web service. It also powers Autodesk Revit's whole building energy analysis tools. Azhar and Brown (2009) explain the advantages of GBS as automated online process, little preparation requirement, easy transformation from Revit to gbXML, automated fault check in gbXML, user friendly interface and applicability to LEED. Disadvantages on the other hand are listed as lack of reliability in bigger file sizes and possibility to determine the analysis type, requirement for internet connection and password to access the file and the results. Workflow of GBS is shown in the figure 4 (Autodesk).

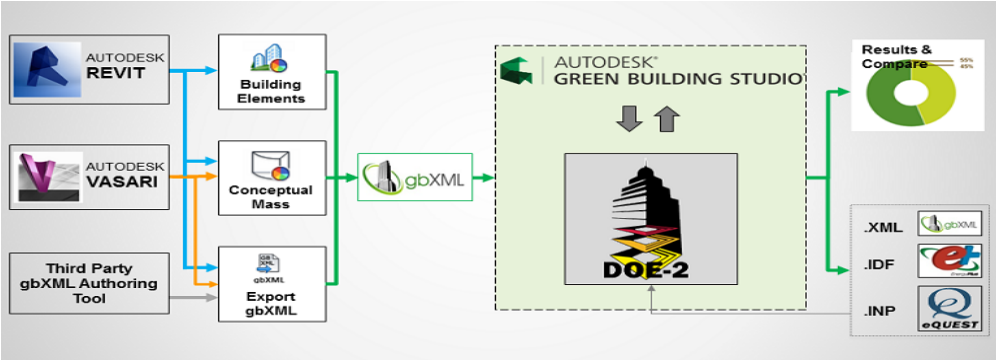

Fig. 4. Information flow from BIM to GBS (Autodesk)

2.4. Quick Energy Simulation Tool (eQuest)

Among the four programs analyzed, eQUEST has been ranked lowest in general as well as in terms of interoperability and available outputs (Reeves et al., 2012). eQuest is a freeware program and it can be freely used by any user, not encountering any limitation, such as trial version or student version. Schematic Design choice for small-scale works and Design Development for detailed works is present. It can work on the files with gbXML and dwg extensions, however eQUEST cannot import gbXML format directly from Revit or Revit MEP. The transfer becomes possible making the use of GBS program. Dwg files created in AutoCAD, on the other hand, can be directly imported to eQUEST (Figure 5, Moon et al., 2011). eQUEST has the ability to create its own model and provide results for LEED.

The information such as lighting, heating, cooling, the time lots in which the building will be used, is entered to eQUEST. It provides simulations for shadowing, windows layout, in-door mass, covering mass, HVAC properties. eQUEST also includes a dynamic sunlight model to use daylighting effect. Information about location, weather, geometry, building type, types of spaces, usage timetables and HVAC components are main inputs of eQUEST (Maile et al.2007).

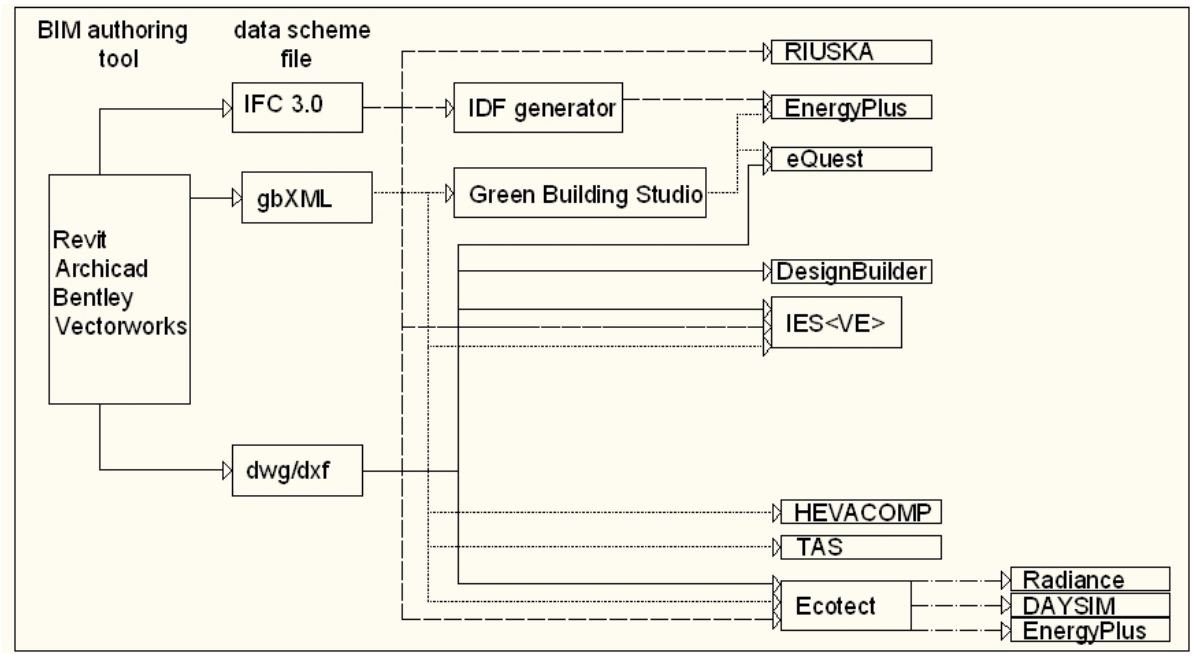

Fig. 5. Information flow from BIM to eQuest and other programs (Moon et al., 2011)

3. Comparison of Energy Simulation Programs

Modeling the information flow from BIM to the most widely used energy simulation programs allow for comparison of the programs in different aspects. There are various interoperable file formats such as rvt, rfa, dwg, dxf, gbXML, IFC, ODBC with different capabilities to transfer information form BIM to energy simulation programs. Figure 6 shows supporting file extensions after 3D BIM model prepared in Revit architecture.

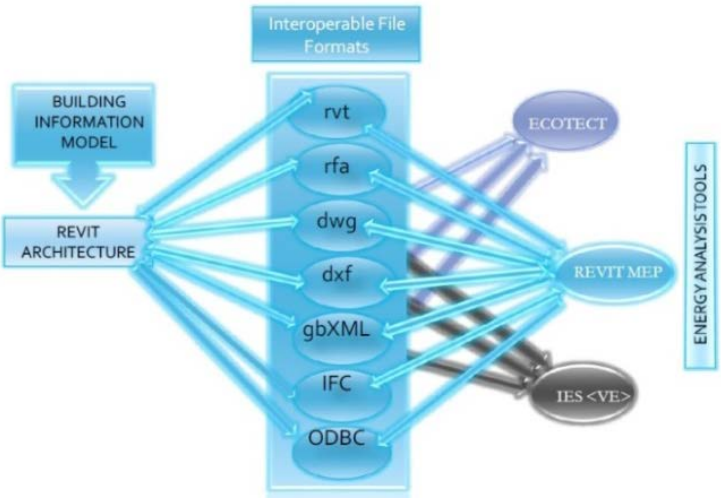

Fig. 6. Interoperable file formats (Kumar, 2008)

Lack of standardization in Green BIM and the fact that different firms are using different BIM tools and energy simulation programs makes collaboration of different stakeholders even more difficult. As the most important aspect of BIM is improving collaboration and standardization of the information, the interoperability issue has to be solved taking the requirements of the users into account. In due process, users have to choose among different energy simulation programs according to benefits offered and limitations. These benefits and limitations, achieved as a result of the analyses presented in the previous section, are listed below.

- While Ecotect and IES<VE> allows the user to analyze the desired coordinates, GBS does not have such a property.
- IES<VE> and GBS can analyze carbon emissions, but Ecotect and eQuest cannot.
- Ecotect and IES<VE> can be used to examine the effects of solar radiation on buildings. However, GBS and eQuest do not have this property.
- IES <VE> and GBS can help the users to make analysis for LEED Daylight Credit 8.1 while Ecotect and eQuest cannot.
- “Life Cycle Assessment” and “Life Cycle Cost” properties are available in IES<VE> and GBS whereas Ecotect and eQuest do not have these capabilities.
- Ecotect and IES<VE> programs can make thermodynamic analysis depending on thermodynamic loads. On the other hand, GBS and eQuest cannot.
- Only Ecotect and IES<VE> programs can be used to design lightening/shadowing units.
- Only Ecotect, in addition to the comparison criteria, can be used to make acoustic analysis.
- GBS completes the analyses faster than the other programs.
- GBS has the simplest and IES<VE> has the most complex user interface.
- eQuest and GBS are freeware software whereas Ecotect and IES<VE> demand high fees.

- Interoperability with Revit is the best for IES<VE>. Because eQuest is dependent on GBS for data transfer, its interoperability with Revit is the worst.

Table 1 summarizes the interoperability and analyses offered by the energy simulation programs investigated in this study.

Table 1. Comparison of energy analysis programs

Analysis offered and interoperability	Ecotect	IES <VE>	GBS	eQuest
Interoperability (gbXML, IFC, DXF, DWG)	gbXML	gbXML, IFC, DXF, DWG	gbXML	gbXML (together with GBS) and DWG
HVAC System		✓	✓	✓
Building Area Use	✓	✓	✓	✓
Daylighting and Shadowing	✓	✓		
Water Consumption			✓	✓
Carbon Emission Calculations		✓	✓	
Thermal Analysis	✓	✓	✓	
Daylight Affects	✓	✓		
Lightening Units	✓	✓		
LEED Daylighting Credit 8.1		✓	✓	

4. Conclusions

BIM has stemmed from the needs of AEC sector to manage building projects in a cheaper, faster, and more effective way. Sustainable design has resulted from the need to find solutions to minimize harms of buildings on environment, to improve building performance, and health/comfort of building residents and also to make the growth of the industry sustainable, with the limited resources. Green BIM is the integration of BIM and sustainable design, and it can be defined as the application of BIM to design/construct sustainable/green buildings. This integration is currently hindered by interoperability issues, which leads to a non standard approach and redundant work (Kumar, 2008).

The data flow from BIM to energy simulation programs and their interoperability have been analyzed in this study comparing the available analyses and benefits offered by the programs. The study has been limited to the most widely used energy simulation programs (Ecotect, IES<VE> GBS, and eQuest) and BIM tool (Revit). It has been shown on the information flow schemes that in Ecotect, IES<VE> and GBS the data are imported directly from Revit; however, in eQuest transfer is only possible through GBS. Data inputs and calculations that are available have been presented. Comparisons between energy simulation programs have showed that:

- Evaluating the programs for interoperability and scope of analysis capabilities, IES<VE> and Ecotect was found to offer more benefits to users.
- GBS has a narrow range of available inputs, which renders the program faster but it is less suitable for advanced level. Use of GBS is preferable when a user friendly interface and fast analysis are required.
- GBS and eQUEST are preferable if a freeware tool is sought.
- In eQUEST interoperability with BIM is only possible through GBS.

By improving the issues raised, the exchange of information back and forth across BIM tools and energy simulation programs is expected to become more robust. The integration of energy simulation functions within BIM tools also needs further research so that a change in the building model can be automatically reflected in the energy simulation.

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Understanding Building Information Modelling in the South Africa Construction Industry

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Abstract

Building Information Modelling (BIM) is a concept that has been defined as a technology that digitally constructs an accurate virtual model of a building. BIM can be defined as an IT enabled approach that involves the application and maintenance of a fundamental digital representation of a building and all its information throughout the different stages of the project. The model of the building, which will be in 3D, will depict the exact dimensions of the building. The study assesses the barriers to the adoption and implementation of BIM within the South African construction industry, and suggests ways of overcoming the identified barriers to the full adoption and implementation of BIM in the South African construction industry. The data used in this paper was derived from primary and secondary sources. The primary data being questionnaires, was designed based on the related literature that was reviewed. The questionnaire was distributed to construction professionals such as Construction Project Managers, Architects, Quantity Surveyors, Construction Managers, Facility Managers, or academics who have previously done research on BIM in the South African construction industry. The questionnaires were analysed using descriptive statistical procedures. The findings revealed that a lack of skills, education, and knowledge on BIM are the biggest barriers to the full implementation of BIM in South Africa. Furthermore, the results also show that educational and skill development initiatives are widely considered to being the answer to the existing barriers to BIM adoption. As well as, establishing feasible ways of moving away from the common practice into using BIM on all construction projects.

Keywords: Building Information Modelling, BIM adoption, BIM barriers, South Africa construction industry

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1. Introduction

BIM produces a model known as the building information model, which according to Ahazar (2011) and Bryde et al., (2012), can be used throughout all the project stages to, and including the operation and maintenance of the facility. According to Riddel (n.d.), BIM represents the design of the building as objects that carry their geometry and full attributes. This is achieved because the model will depict how the building will look once all the components have been inserted or built into the data. According to Ashraf and Esquire (2008), some of the other possible uses for BIM in construction industry include it being used solely for design purposes, for coordination and clash detection, estimating material prices, construction simulation, and the creation of shop drawing and for review of submittals, amongst others. Although BIM is perceived to being able to eradicate almost all the inadequacies that arise in the process of construction, it is not the solution to all the problems in construction (Davidson, 2009). Eastman et al., (2008) further states that BIM is a modeling technology, which has an associated set of process that produce, communicate and analyze building models. The authors further identify the characteristics of these models by the building components that are digitally represented, the different components of the data, and the data, which produces the different views of the model. This derived model is further used in the maintenance and operations of the building post its construction phase, which also counts as an advantage of using the technology in construction. From, the existing knowledge of BIM in the South African construction industry, the researcher opted to fill the knowledge gap on BIM to optimize its awareness, and eventual adoption within the relevant practices in the South African construction industry. This research project was undertaken with the intention of educating practicing professionals such as Quantity Surveyors, Architects, Engineers, MEP Engineers, Construction Managers, Project Managers, and the clients (Both private and public), on BIM as a full model, and its capabilities and role in the technologically advance world we live in today. Therefore, this study assesses the barriers to the adoption and implementation of BIM within the South African construction industry, and suggests ways of overcoming the identified barriers to the full adoption and implementation of BIM in the South African construction industry.

2. Advantages of Using BIM

The initial feeling towards BIM and its usage was not one that was easily welcomed into the construction industries. Though it had been used extensively in the United States of America (USA) by 2010, it has taken a lot of time, research and persuasion on the part of the pioneers of this phenomenon in the construction industries of other countries. A good example of this is how Hobbs (2008) explained that after much research and initiating, BIM was finally gaining momentum and acceptance amongst construction stakeholders in the United Kingdom (UK).

Davidson (2009), listed some of the driving forces behind the adoption and implementation of BIM in the UK. He mentions accuracy and consistency of data. This is in regard to all the information that will be used will be derived from the model, thus guaranteeing the accuracy and consistency of the data. This may include, amongst other things, drawings and dimensions that will be accessible to all interested parties due to the 3D model that BIM provides. This is in agreement with what Tse et al. (2005) and Azhar (2011) said in their respective definitions of BIM. A second advantage was Design visualization. Due to this advantage, 3D representations of different parts of the project can be generated from the building model at any given stage. These representations can range from basic structure drawings to complex photorealistic renders of how the proposed building will look like; and all this will be consistent with the 2D drawings that will already be in existence.

Furthermore, the Ease of quantity take-off for the quantity surveyor was one of the driving forces to adoption and implementation of the BIM technology in the UK. As a result of BIM's ability to extract quantities for elements such as floor areas, material volumes, amongst others., it makes it very easy and quick for cost estimates, material scheduling and procurement to be carried out as all data is readily available from the model at all times. These sentiments are shared by Riddell (n.d.) who also speaks about the ease of which the cost of the

building can be attained, while also adding BIM's contribution to the overall energy usage and organizational performance of the entire project team. The multi-user collaboration attributed to BIM is also one of the motivating factors to BIM adoption. The usage of BIM makes it possible for all project team members to be able to use different spheres of the same model in order to effectively share and distribute information amongst each other. This is a big bonus as manual/physical information sharing has previously had its own disadvantages.

For a more fluid and sufficient system of working, the project team may agree to bring someone on board who will oversee the operation of the model as a whole. This may forge new BIM-specific job opportunities such as a BIM-modeller or a BIM model manager as identified by Brewer et al. (2012). Davidson (2009) goes on to further conclude and reiterate that the usage of BIM in the construction industry contribute immensely in reducing cost directly and indirectly through better designs, reduced usage of building materials and efficiency gains. It should also therefore be pointed out that the usage of BIM will not automatically constitute a cheaper project for the interested parties

BIM tools are elements which form part of the BIM database, which will help the project team in achieving their BIM objectives of the project. These are the elements that make it possible for the model to function in its full capacity and produce its deliverables. According to (The Associated General Contractors of America, n.d.), these tools are advantageous towards the project. The characteristics of these BIM tools should include the following:

- Simplicity: The software that will be used needs to be easy to learn and understand. It should also be easily teachable and accessible to all stakeholders.
- Functionality: The tool should be able to meet the requirements of the model.
- Collaborative: The tool should be able to intertwine with other software to make it possible for them to share information in a model.
- Longevity: The tool should be technologically advanced enough to withstand incoming technologies over the project period or even beyond.
- Support: The tool should provide tutorials and support systems to ensure that the software adequately understood and utilized.

Advantages of using BIM in the South African construction industry throughout all the project stages are discussed by Kaber (2010). In the early design and planning stages, the planners and designers are afforded the opportunity of using BIM tools such as ArchiCAD and Revit in conjunction to aid their objectives of producing the best possible design which is in line with the relevant statutes of its intended location. For the QS, the relative ease of taking off the combining tools such as Innovaya and Autodesk QTO from the data extracted from the tools that were used by the designers of the structure.

Moreover, Kaber (2010) has identified the main advantages as improved visualization, improved productivity due to accessibility of data, and increased coordination of documents. This is mainly due to the multi-user collaboration abilities as discussed by Davidson (2009). When each of the professionals have done work on their preferred programs (BIM tools), they then add it to the database of the project. And because all of this is done electronically, it then makes it readily available at all times for the other professionals. Another benefit as identified by Kaber (2010) is BIM's ability of embedding and linking of vital data such as specified materials, location of details, and all the quantities required for tendering and estimating purposes. The general reduction of costs has also been identified as a benefit. All this is in the form of time spent on the designing and co-ordination of the documentation, as well as on the duplication of hard copies, and the printing and copying of documentation as it will be electronically accessible. From the above it can clearly be concluded that the use of BIM offers numerous benefits and advantages to the different users. The benefits of BIM range throughout the various stages of a project, from the planning through to maintenance of the completed project.

3. Methodology

The data used for this paper was derived from both primary, and secondary sources. The primary data was obtained through a structured close-ended questionnaire, and the secondary data was obtained from the relevant literature that was reviewed by the researcher. A total

number of 65 structured questionnaires were sent to individuals in the municipalities of Tshwane, City of Johannesburg, and Ekhuruleni (all in Gauteng, South Africa) who are practicing as Quantity Surveyors, Construction Managers, Architects, Facility Managers, Project Managers, or Academics.

The questionnaire was designed based on the information that was gathered during the literature review. A 5-point likert type scale was used for the questionnaires. This scale measured the extent to which the respondents agreed or disagreed with the factors presented to them. A random sampling method was adopted for the purposes of this research. This method was preferred due to the fact that it gave all the targeted respondents an equal chance and opportunity of being selected.

From all the questionnaires that were sent out; 50 usable questionnaires were returned. This meant that the response rate was at 77%. The data were then analyzed using the Statistical Package for the Social Sciences (SPSS); with the frequencies and mean item scores (MIS), and the standard deviations (SD) of the rated factors being considered. This research was conducted between the months of May and September 2014; with the data collection being carried out between June and August 2014.

The Likert scales were transformed to an MIS for each of the research objectives as applicable. The indices were then further used to determine the rank of each item according the results obtained from the respondents. These rankings made it possible to cross compare the importance of each item to the respondents. The MIS was based on previous studies as conducted by Mukuka et al., (2013) where the 'MIS' rating was used. This method was also used for this study to analyze the data collected through the distributed questionnaire. The MIS was calculated from the total of all weighted responses and then it was related to the total responses on a particular option/item on the questionnaire. This was based on the principle that respondents' scores on all the selected options, considered together, are indices of the relative importance of each of the options. The index of MIS of a particular factor is the sum of the scores that were received from the respondents (on the particular Likert scale of that question) as just a proportion the overall score that all respondents could give to that factor (one to five), which, for the two main questions for this study, mean "Not a barrier (NB)-Extreme barrier (EB)" and "Strongly Disagree (SD)-Strongly Agree (SA)". The relative index for each item was calculated for each item as follows, after Aigbavboa et al (2013).

Following the mathematical computations, the criteria are then ranked in descending order of their relative importance index (from the highest to the lowest). The next section of the article presents the findings of the survey and some discussions.

4. Findings and discussions

4.1. Biographical data results

Findings from the respondents revealed that 64% of the 50 respondents were male; while 36% were female. Furthermore, 36% were between 20 and 25 years of age, 28% were between 26 and 30 years of age, 18% were between 31 and 35 years of age, 10% were between 36 and 40 years of age, 4% were between 41 and 45 years of age, and 4% were between 46 and 50 years old. Results also showed that none of the respondents above the age of 55 years old. The results further showed that 42% of the respondents had obtained a Bachelor's Degree, 38% had a Diploma, 14% had a Master's Degree, and only 6% had a Matric certificate as their highest educational qualification, 32% were working as Quantity Surveyors, 32% were Architects, 18% were Construction Managers, 12% were Project Managers, 4% were Construction Project Managers, and only 2% were working as Facility Managers. When asked about their years of experience in their field of work, 52% had between 1 and 5 years, 30% had between 6 and 7 years, 12% had between 11 and 15 years, 4% had between 16 and 20 years, and only 2% had above 20 years of experience; while 32.7% worked for contractors, 28.6% worked for/as consultants, 20.4% represented a client in the private sector, 12.2% represented the government as a client, 2% worked for higher learning institutes, and 4.1% worked for organisations that weren't listed as one of the available options. All these biographical information were obtained within the three main municipalities of Gauteng known as Ekurhuleni, Tshwane, and the City of Johannesburg.

4.2. Awareness, Usage, and Benefits of BIM

The researchers asked the respondents to compare their organisation's ICT levels relative to their competitors. The results showed that 62% of the respondents said that their companies ICT levels were either somewhat better or much better than their completion, and only 24% said theirs were either somewhat worse or much worse than their competition (Fig. 1). Of these companies, most of them used AutoCAD (27%) and Revit (16.6%). Furthermore, when researching the respondents' knowledge of BIM, findings showed that 70% of them had an average-to-excellent knowledge of what BIM is.

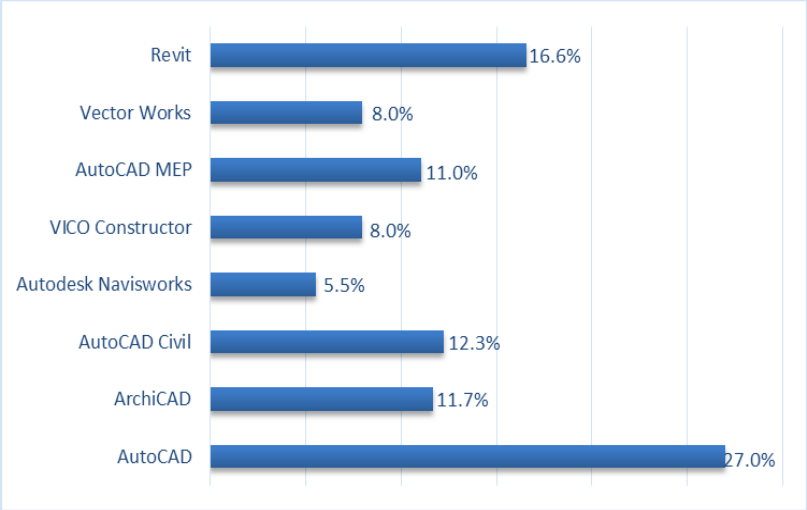

Fig. 1. BIM-related tools mostly used in the respondents' organisations

However, when it came to their actual experience and interest in BIM as a tool that they use/can use in their projects; 34% of them had no BIM experience, while 30% of them had between 1-3 years of experience. Furthermore, of the 34% with no experience, 72% of them were either interested or highly interested in BIM, while only 38% of the 66% that had some experience with BIM use it often or always. From these set of results, the researchers found that although the South African construction industry was technologically aware, the usage of BIM was very low, and this can be attributed to the unwillingness to change the traditional ways of practice (MIS=3.00, SD=0.904, R=9). This is in agreement with what Ahmad et al (2010) about companies resisting change due to a lack of flexibility and versatility. Furthermore, the researcher found that this could be as a result of the fact that 78% (Figure 3.2.2) of the respondents said the people who use BIM in their organisations are either in management positions, or are employedas designers. This is negative as it limits the exposure of the rest of the employees in the organisations who aren't in top management positions or employed as designers.

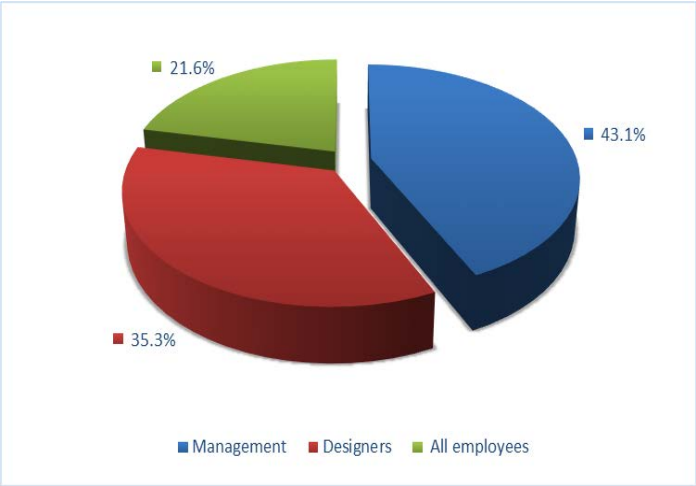

Fig. 2. BIM usage in the respondents' organisations

From the 80% of the respondents that said BIM is used in their organisations, 25% of them indicated that BIM was used for cost management purposes, while 22.8% used it for construction management, 20.7% used it for project management (Fig. 2). This showed that although BIM is scarcely used in the South African construction industry, it was mainly used for management purposes on the project which it is used on, thus validating why it was mostly used by the management (43%) in the organisations that employed the respondents'.

Table 1: Shows the motivating factors/benefits of using BIM

Motivating factors/benefits of using BIM	MIS	SD	RANK
Improves the project management process	4.35	0.855	1
Improves the design visualization	4.27	0.811	2
Provides better visualization of projects	4.26	0.828	3
Ease of taking-off quantities	4.14	0.842	4
Enhances the accuracy of data	4.12	0.918	5
Improves the cost modelling	4.06	0. 876	6
Enhances the consistency of data	4.06	0. 966	6
It is an interactive tool (Collaborative tool)	4.02	0.958	7
Improves the time management	4.02	0.979	7
Helps with the value Engineering	4.02	1.020	7
It's more efficient than normal practice	3.98	0.946	8
To increase capacity of design reviews	3.96	0. 880	9
Reduction in project variations	3.96	0. 947	9
Helps in the updating of details	3.94	1.038	10
Provides a competitive edge	3.92	0.853	11
Improves the cost management	3.88	1.062	12
Improves the management of data	3.82	0. 962	13
It minimizes collisions in the construction phase	3.82	0. 983	13
Helps with the Life Cycle Costing analysis	3.76	1.061	14
Competitors use it	3.76	1.135	14
It minimizes conflicts	3.50	0.995	15
Creates more job opportunities	3.49	1.227	16
It is a requirement of most clients	3.16	1.299	17

The respondents were further asked to rank what they thought the major benefits of using BIM were, they ranked the fact that it improves the project management process in first place (MIS=4.35, SD=0.855), secondly, the fact that BIM improves the design visualization was ranked second (MIS=4.27, SD=0.811), thirdly, BIM's ability to provide better visualisation of projects (MIS=4.26, SD=0.828), and the fact that BIM provides ease of taking-off quantities (MIS=4.14, SD=0.842) was ranked fourth (Table 4.1). These major benefits, except the fact that it improves project management, are in agreement with what Hergunsel (2011) said about them being the simplest, and most obvious benefits of using BIM. And the four least factors were the fact that competitors use it (MIS=3.76, SD=1.135, R=14), that it minimizes conflicts (MIS=3.50, SD=0.995, R=15), that it creates more job opportunities (MIS=3.49, SD=1.227, R=16), and the fact that it is a requirement of most clients (MIS=3.16, SD=1.299, R=17). The next question set out to find out what BIM was used for in the South African construction industry, the results revealed that project management (MIS=4.38, SD=0.945, R=1), constructability analysis (MIS=4.36, SD=0.776, R=2), cost scheduling (MIS=4.20, SD=0.926, R=3), and virtual mock-ups for design evaluations (MIS=4.18, SD=0.869, R=4). The importance of BIM for the fluency of project management has also been highlighted by Aranda-Mena et al (2009) in their investigation carried out in Australia and China, and He (2012) in the Hong Kong construction industry.

5. Conclusions

The study has assessed the levels of awareness, usage, and advocated benefits of using BIM by stakeholders in the South African construction industry. This objective was met as the research findings revealed the ICT levels of the respondents' organisations, their knowledge of BIM, their experience and interest in BIM, their frequency of use of the BIM technology, as well as the benefits of using BIM in the South African construction industry. The findings have shown that although most of the respondents had minimal BIM exposure (64%), their general exposure to ICT was good. Research has also found that although the ICT levels were satisfactory, and the usage of BIM is at 80%; the main reason for the low BIM experience of respondents was due to the fact that it was mostly used by management and designers in construction organisations (78%).

Furthermore, the researcher found that the respondents indicated that their organisations used BIM mostly for cost, construction, and project management purposes. Moreover, the results also revealed that respondents thought the major benefits of using BIM in the South African construction industry were because it improves the project management purposes, the design visualization, it provides better visualization of projects, and it makes provision for easier taking-off for the QS.

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SUSTAINABILITY IN THE BUILT ENVIRONMENT

Construction Managers' Perception of Sustainability Implementation in Building Processes

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Abstract

Construction fosters the economic development of the country, but as well it can have a negative impact regarding sustainable development. One of the reasons for poor implementation of sustainability is the opinion that it could increase the construction costs. Construction managers can have a significant contribution in the implementation of sustainability in construction, especially in the building process.

Familiarity with sustainability in construction and perceived implementation of three main aspects of sustainability in the building process – economic, environmental and social, were investigated among 108 construction managers employed in construction companies in Republic of Macedonia. Participants were asked to fill out a questionnaire in order to assess the studied variables contributing to sustainable construction.

Data analyses using MANOVA revealed that the way respondents perceived implementation of sustainability practices in building process, highly depends on familiarity with sustainability concept, information on sustainability aspects in building process and type of organization where respondents were employed. Follow up ANOVA showed that: a) construction managers who were more familiar with sustainability concept rated economic and social aspect of sustainability at higher level, b) participants who were informed about sustainability characteristics of structures, highly evaluated environmental and social aspects of sustainability, c) construction managers employed in organizations with up to 20 employees reported higher degree of implementation of environmental dimension compared to their colleagues from companies with more than 20 employees.

In general, findings demonstrated that construction managers need more information on sustainability, that they perceive these issues subordinated to costs and that sustainability practices should be focused more on human resources.

Keywords: sustainability; construction managers; perception; building process

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1. Introduction

Construction industry enables investments for corporate objectives, satisfaction and changes in people's lifestyle by making structures that fulfill their social needs (Zakaria et al., 2013). By balancing the society's demand and the economic and environmental sphere (FIDIC, 2012 as cited in Rafandadi et al, 2014), the construction industry should create conditions for sustainable development – fulfilling the needs of the present in respect with the needs of the future (UNWCED, 1987).

Meeting the increasing needs of sustainability leaves the construction industry under pressure. Although the sustainable buildings cost more than the unsustainable ones (Katz, 2003), the participants in construction projects have to support the sustainability (Chendo, 2013, Zakaria et al., 2013). They should put an emphasize on integrating the social, economic and environmental aspects/pillars (Halliday, 2008, Rafandadi et. al, 2014, Smith and Rootman, 2013), that make the "Triple Bottom Line"-TBL (Elkington, 1999) of sustainability. For Hill and Bowen, 1997 political, institutional and technical pillars should also be taken into consideration.

Additionally, the project participants are in race with the time in order to finish the project in the frame of planned project costs and quality (Zakaria et al., 2013, Walker 1995, Abd El-Razek et. al, 2008). Thus, negative impacts may appear regarding sustainability (Shen et al., 2007). Creating conditions for introducing the sustainability concept have become a construction companies' challenge. Construction managers can give a big contribution, so their perceptions of sustainability aspects of the building process are of crucial importance.

Considering the mentioned above, the aim of this study is to investigate the familiarity with the sustainability concept, information on sustainability characteristics of structures and perceived implementation of three main aspects of sustainability – economic, environmental and social, in building processes among construction managers in Macedonia.

The paper is organized as follows; in section 2 an introduction of the literature review on aspects of sustainable construction and the construction managers' perception on this issue is given followed by the research methodology in the third section. The results are presented in the fourth section. In the final, fifth section, findings are discussed and conclusion is given.

2. Literature Review

As the society's awareness and demands for sustainability increases, the sustainable construction is seen as an important approach in mitigating the environmental issues, social and economic demands (Majdalani et al., 2006). Namely, improving the environment's health should be priority in construction processes considering that the buildings are the largest pollutants and consumers of resources (Smith 2013).

Incorporating the economic aspects is also a key element considering that the construction industry usually has one of the largest shares in the production of the Gross Domestic Product in the countries (Smith, 2013).

As Valdes-Vasquez and Klotz, 2013 stated, social aspect of construction sustainability should not be referred only to final users and nearby community, but to construction workers involved in building projects, i.e. their safety, health, training and interpersonal relations. With other words, conception of social sustainability incorporates engagement among employees, communities, clients and supply chain and denoted different processes aimed to improve health, safety and well-being of current and future generations (Herd-Smith and Fewings, 2008 as cited in Valdes-Vasquez and Klotz, 2013). According to the same authors, social sustainability is differently interpreted due to stakeholders' perspective and project's phase.

Project Management Institute (PMI) Standards Committee (as cited in Bal et. al., 2013), describes project stakeholders as individuals and organizations who are involved in the project or whose interests may be affected by the completing of the project. There are various stakeholders in construction projects; contractors, construction workers, engineers, architects, subcontractors, clients, materials suppliers, local administration, managers, etc. All of them have specific responsibilities and important role in successful completion of the projects. Their interests, attitudes toward construction project and perception of its different aspects

could be significant for the project's performance and introduction of sustainability procedures in construction.

Implementation of sustainability procedures in construction is a slow process. This delay could be explained through prevailed opinion that sustainable procedures are more expensive compared to traditional procedures or that their cost is excessively high to justify the use in building projects (Dobson et. al., 2013).

Chendo's, 2013 study showed that managers had negative perception towards the environment, as well as that they had poor perceptions about disposal of waste and the environment hygienic maintenance.

Rafindadi et al., 2014 reported that significant differences in perceptions of sustainable project risks among different stakeholders were not found.

Perception regarding organizational sustainability was investigated by Smith and Rootman, 2013. Precisely, they found positive and significant relationship between perceived environmental protection and perceived sustainability outcomes.

Facilities managers' perceptions of sustainability activities performance in their organizations are given in BIFM, 2009. The findings demonstrated that managers employed in organizations with the highest annual turnover have more positive perceptions than managers employed in organizations with lower annual turnover regarding perceptions of their management of sustainability.

Miller et al., 2009 proposed a perception-influence model for the management of technology implementation in project-based engineering firms. Their model contributes in understanding the influence of participants' perceptions at the project site on technological innovations implementation.

Sustainability perception of real estate valuers was appraised by Babawale and Oyalowo, 2011. It was found that the valuers have to increase their knowledge about sustainability in order to effectively value the properties, taking into account the three aspects of sustainability (environmental, social and economic).

Warren-Myers, 2012, found that owners perceive the sustainability as very important for their portfolio.

Other investigations about managers' perceptions are also worthy of attention.

Enshassi et al., 2007 investigated the perception of construction managers for i) characteristics of local industry that affect construction safety and ii) factors that cause accidents at site.

Project success factors from the perspective of project managers were investigated by Pankratz and Loebbecke, 2011.

Dobson et. al., 2013 analyzed the sustainable construction within industry from the aspects of costs and benefits. They found that the perceptions of high capital costs can be an obstacle for sustainable construction.

The findings of Bowen et al., 2002 showed that there is misperception about project team participants' perception on cost, time and quality management of building project and that those misperceptions may influence the project team ability for achieving clients' objectives.

As was stated above, in the focus of this paper are managers in construction projects, their awareness on sustainability in construction and the way in which they perceive/assess implementation of sustainability procedures during building processes.

3. Methodology

3.1. Sample and procedure

The 108 participants in this study were construction managers. Most of them, 32,4% had work tenure of more than 20 years and 25,9% had work tenure between 11 and 20 years. Work tenure between 6 and 10 years had 14,8% of the surveyed construction managers, from 2 to 5 years tenure reported 12,1% and less than 2 years tenure indicated 14,8% of the respondents.

All participants had university education in architecture or in civil engineering. Fifty seven surveyed construction managers were employed in construction organizations with employees

in range from 5 to 20, while 51 of the respondents were employed in construction companies with more than 20 workers.

Data were collected during the second half of 2014 on building sites in R. of Macedonia. Participants were informed that their participation is voluntary and anonymous and that obtained data will be used in research purposes only.

3.2. Measures

In order to assess study variables, a questionnaire with total of 13 statements (3 statements for economic aspect, 6 items for environmental aspect and 4 items for social aspect of construction sustainability) was administered to participants. They gave their answers on a 5-point Likert scale from 1-strongly disagree to 5-strongly agree. Higher score denoted that respondents evaluated implementation of environmental aspect (e.g. water protection, use of ecological materials), social aspect (e.g. work safety, training, and employees' relations) and economic aspect (e.g. priority on ecological characteristics of building materials ahead of lower costs/prize) at higher level.

Two single item measures were used to assess familiarity with sustainability concept as well as information on sustainability characteristics of structures. Participants were asked to choose between two alternatives Yes/No. Also, they needed to indicate their level of education, work tenure and size of the employing organization.

3.3. Statistical analysis

MANOVA (Multivariate Analysis of Variance) was used to analyze obtained data. Specifically, it was estimated the role of familiarity with sustainability concept, information on sustainability characteristics of structures and size of the employing organization on linear combination of perceived implementation of economic, environmental and social aspects of sustainability during construction process. In the next step, follow up ANOVA was performed to assess contribution of the first three variables on perception of economic, environmental and social sustainability facets separately.

4. Results

Descriptive statistics showed that construction managers who participated in this survey had highly positive perception of social aspect of sustainability in building processes. The lowest level of implementation according to their evaluations had economic aspect of sustainability. More precisely, social aspect was assessed as relatively highly implemented compared to the midpoint of the ranking scale from 1 to 5, which is 3 ($M=3.78$, $SD=.87$). Surveyed construction managers rated implementation of environmental aspect slightly above the theoretical mean ($M=3.33$, $SD=.86$) and evaluated implementation of economic aspect under the scale's midpoint ($M=2.84$, $SD=.92$) (Table 1).

Results from conducted MANOVA revealed that linear combination of three aspects of sustainability during building process was differently perceived by construction managers who were familiar and those who were not familiar with sustainability concept ($\lambda=.90$, $F(3, 104)=3.65$, $p<.05$, $\eta^2=.095$). According to the follow up ANOVA results, two groups of respondents differ in assessment of economic and social aspects of sustainability in building processes analysed separately ($F(1, 106)=6.99$, $p<.01$, $\eta^2=.078$ and $F(1, 106)=3.22$, $p<.05$, $\eta^2=.04$, respectively). Respondents who were familiar with sustainability concept perceived implementation of these aspects as higher.

Table 1. Perceived level of implementation of sustainability aspects in building processes among construction managers who are familiar and who are not familiar with sustainability concept

Variables	Familiarity with sustainability concept	Mean	Std. Deviation	N
Economic aspect of sustainability in building processes	Not familiar	2.33	.72	22
	Familiar	2.96	.92	86
	Total	2.84	.92	108
Environmental aspect of sustainability in building processes	Not familiar	3.17	.84	22
	Familiar	3.38	.86	86
	Total	3.33	.86	108
Social aspect of sustainability in building processes	Not familiar	3.44	.74	22
	Familiar	3.87	.88	86
	Total	3.78	.87	108

MANOVA demonstrated that linear combination of three aspects of sustainability during building process was differently perceived by construction managers who were informed and those who were not informed about sustainability characteristics of structures (λ=.85, F(3, 104)=6.15, p<.01, η^2=.151). Follow up ANOVA showed that information on sustainability characteristics of structures contributed to differences in assessment of environmental and social aspects of sustainability in building processes separately (F(1, 106)=9.27, p<.001, η^2=.12 and F(1, 106)=7.67, p<.01, η^2=.10, respectively). Precisely, respondents who were informed about sustainability characteristics of structures rated implementation of these aspects at higher level (Table 2).

Table 2. Perceived level of implementation of sustainability aspects in building processes among construction managers who are informed and who are not informed on sustainability characteristics of structures

Variables	Information on sustainability characteristics of structures	Mean	Std. Deviation	N
Economic aspect of sustainability in building processes	No	2.78	.84	63
	Yes	2.91	1.02	45
	Total	2.84	.92	108
Environmental aspect of sustainability in building processes	No	3.09	.76	63
	Yes	3.68	.87	45
	Total	3.33	.86	108
Social aspect of sustainability in building processes	No	3.56	.89	63
	Yes	4.10	.74	45
	Total	3.78	.87	108

Conducted MANOVA showed that linear combination of three facets of sustainability during building process was differently perceived by construction managers from different sized construction firms (λ=.91, F(3, 104)=3.33, p<.05, η^2=.088). Follow up ANOVA revealed that size of the employed construction firm contributed to differences in perception only of environmental aspect of sustainability in construction projects (F(1, 106)=4.30, p<.05, η^2=.04). Respondents who were employed in firms with less than 20 employees evaluated implementation of environmental aspect of sustainability at higher level in comparison to their colleagues from firms with more than 20 employees (Table 3).

Table 3. Perceived level of implementation of sustainability aspects in building processes among construction managers from companies with less and more than 20 employees

Variables	Size of the employing company	Mean	Std. Deviation	N
Economic aspect of sustainability in building processes	Less than 20 employees	2.85	.86	57
	More than 20 employees	2.82	.98	51
	Total	2.84	.92	108
Environmental aspect of sustainability in building processes	Less than 20 employees	3.49	.86	57
	More than 20 employees	3.16	.82	51
	Total	3.33	.86	108
Social aspect of sustainability in building processes	Less than 20 employees	3.71	.84	57
	More than 20 employees	3.86	.89	51
	Total	3.78	.87	108

5. Discussion

This study examined the relationship of construction mangers' familiarity with sustainability concept and information on sustainability characteristics of structures to their perception of implementation of three main aspects of sustainability in building processes.

Taking into consideration that the stakeholders in construction projects may have important role in projects' success through their attitudes, interests and perceptions (Bal et al., 2013), this research was focused, specifically, on construction managers.

As it was found, most of the surveyed construction managers in Macedonia were familiar with the concept of sustainability, but not informed about sustainability characteristics of structures. Conducted MANOVA revealed that these variables, as well as, the size of the employing organization lead to differences in perception of main aspects of sustainability in building processes – economic, environmental and social. Follow up ANOVA showed that respondents who were more familiar with sustainability and more informed on sustainability characteristics assessed at higher level the implementation of social aspect, i.e. employee relations, their safety in the workplace and training. Familiarity with the concept of sustainability was related to indication that lower costs of the project had priority over environment protection and usage of ecological materials. More informed construction managers about sustainability characteristics of structures reported that energy savings, water protection, selection of building location, eco-materials usage are well implemented practices in construction projects.

Consequently, these relationships could have an impact on managers' involvement in sustainability procedures incorporation, in particular and in timely completion and quality of building project, in general. These study findings could be seen as an extension of Chendo's, 2013, Smith and Rootman's, 2013, and Babawale and Oyalowa's, 2011, results on managers' perceptions of sustainability. In the frame of Dobson et al., 2013 findings, results in this research about evaluation of economic aspect of sustainability in building processes can be explained with previously created (wrong) opinion that sustainability is expensive and does not approve high costs. On the other hand, these analyses revealed that information on sustainable construction is very important to overcome misperceptions in this filed.

It could be concluded that the assessment of sustainability practices in construction on the base of self-scoring statements/questionnaire enables to see stakeholders' (in this study – managers) perspective on this vital issue. Inclusion of stakeholders in assessment of sustainability in the projects is recognized as key requirement to achieve quality in building (Kaatz et al., 2005).

6. Conclusion

In a contemporary buildings' construction it is a challenge to incorporate the sustainability aspects in the building process. At this point, construction managers can play a crucial role and their knowledge about building process sustainability is of essential importance.

This paper presents the findings of the research for construction managers' familiarity with the concept of sustainability, information on sustainability characteristics of structures and implementation of different aspects of sustainability in building processes in Macedonia. The research is based on a construction site survey.

The study demonstrated that there is a necessity to extend the knowledge about the concept of sustainability and indicators of sustainable structures/buildings among construction professionals, particularly among managers as leading employees in implementation of procedures of sustainable construction which is appealing nowadays.

Namely, construction managers' behavioral changes are needed to increase the use of sustainable practices that will lead to:

- application of environmentally practices that will tend to: foster recycling, reduce energy use, reduce waste generation, reduce water consumption, reduction of building material wastage, increasing the use of recycled waste as building materials, water conservation, decrease the amounts of pollution, dust, noise…
- usage of energy-efficient technologies
- making sustainable construction management plan
- incensement of the level of safety and health at construction site
- including the use of green products with accent on locally produced green products

The authors of the paper believe that the study findings will contribute in understanding the construction managers' perception of sustainability and improving the building process in general.

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Sensitivity Analysis of Cost-effective Recommendations for Improving Building Energy Efficiency

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Abstract

Buildings are the biggest energy consumers; this energy is partly wasted because buildings constructed several decades ago do not meet the energy efficiency requirements of current legislation. Many of these exiting buildings will continue to be used for many more years and therefore they will continue to needlessly consume massive amounts of energy for heating unless their energy performance is improved. Stated issue with existing buildings is partly solved by implementing energy certification of buildings procedure. According to *Ordinance on energy audits of construction works and energy certification of buildings energy performance* certificate must provide information on the energy efficiency of building and cost-effective recommendations on how to improve building energy efficiency. However those recommendations do not address problem of changing fuel rates when calculating simple payback period of proposed recommendations. This research clarifies how various fuel rates can affect the simple payback period of proposed construction measures for improving energy efficiency of building. This case study is done by using sensitivity analysis on data obtained from several buildings which have undergone a process of energy certification and for which recommendations for improving building energy efficiency and simple payback period already exits.

Keywords: energy certification of building, recommendations for improving building energy efficiency, sensitivity analysis, fuel rates, cost-effective

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1. Introduction

European building sector is responsible for about 40% of total energy consumption . Furthermore, the stock of residential buildings constructed before the 1970's which have low performance regarding energy saving makes up more than 3/4 of the total existing residential buildings in European Union (Ghazi Wakili, Binder et al. 2014). Same situation is in Croatia where approximately 87% of total existing buildings are constructed before 1987 (Krstić, Koški et al. 2014). To reduce this great energy consumption of existing buildings and to increase energy efficiency in the Union the European Commission has put forward an Energy Performance of Buildings Directive . This directive was brought in order to achieve Union objective of 20% energy consumption reduction by the year 2020. This Directive obligates Member States to set minimum energy performance requirements for residential and non-residential buildings.

Main problem of existing buildings' is that great amount of energy is partly wasted because these buildings that were constructed several decades ago do not meet the current energy efficiency requirements according to current legislation in Union (Krstić, Koški et al. 2014). Energy renovation of these buildings has a great potential in energy consumption reduction. Reduction of energy consumption and improvement of energy performance of existing buildings also has an important role in promoting security of energy supply, technological development, job creation and opportunities for regional development and also can contribute to significant financial savings . Beside energy savings and financial savings energy renovation also increases life quality and comfort of living (UNDP 2012).

Joining the European Union Croatia started with fulfilling the obligation of energy certification of buildings as measure that provides information about energy consumption, performance and condition of new and existing buildings in relation to their energy performance. Energy certification of buildings procedure also provides proposal of cost-effective recommendations (measures) for energy performance improvement in order to reduce energy consumption and emission of CO_2. For every proposed measure simple payback period must be calculated. Calculation of this period is based on invested capital for proposed measure and savings that are achieved with those measures. For the current level of complexity and current legislation of energy certification procedure simple payback period is a good indicator of the viability of proposed energy efficiency measures.

However simple payback period does not address problem of changing fuel rates during time and currently there is no recommendation in legislation that clarifies this problem. Possible changes in energy prices in time are difficult to predict but due to the significant impact on simple payback period it is important to take it into account and consider.

The aim of this study is to determine relationship between fuel rates changes and associated simple payback period of proposed energy efficiency measures by using sensitivity analysis.

Nomenclature	
A	Surface area of the heated building section
V	Volume of heated air
f_0	Building shape factor
$Q''_{H,nd,ref}$	Specific annual energy needs for heating for referential climatic data

2. Energy efficiency measures

Measures to improve energy efficiency are defined as group of actions that generally lead to verifiable and measurable or estimable energy efficiency improvement and reduction of energy and water consumption . Energy efficient measures applied to existing buildings

during minor/major retrofits in order to reduce their energy consumption can be grouped into three categories (Pyloudi, Papantoniou et al. 2014):

- Building envelopes – thermal insulation, thermal mass, windows/glazing (including daylighting) and reflective/green roofs,
- Internal conditions – indoor design conditions and internal heat loads (due to electric lighting and equipment/appliances) &
- Building services systems – HVAC (heating, ventilation and air conditioning), electrical services (including lighting) and vertical transportation (lifts and escalators).

The Ordinance on energy audits of construction works and energy certification of buildings provides following measures to improve energy efficiency of buildings (UNDP 2012):

- Improvements of thermal performance of the envelope by applying thermal insulation,
- Replacement or improvement of the heating system,
- Replacement or improvement of air conditioning systems,
- Replacement or improvement of systems for hot water production,
- Change in energy sources where it is economically and ecologically viable,
- Appliance of renewable energy sources (solar, geothermal, biomass, etc.),
- Improvement of the efficiency of electrical and household appliances,
- Rational use of water &
- Energy management in general.

Recommendations proposed in the energy certificate used for improving energy efficiency of buildings generally include following („Narodne novine“ broj 48/14., 150/14.):

- Measures to be taken in conjunction with the significant reconstruction of the building envelope or technical building systems including the order of their implementation,
- Measures for individual building elements independent of a significant restoration of the building envelope or technical building systems.

Proposed measures must be reviewed and analyzed in relation to the so-called real referential energy consumption according to the buildings location and climate-geographical area and actual conditions of building usage . Proposed measures need to be analyzed with regard to their feasibility and the building service life and also assess the energetic, economic and environmental savings. It is suggested to propose a combination of those measures which lead to substantial cost savings along economically viable return on the investment . Energy savings should be expressed separately from the investment costs. Economic analysis is represented by the simple payback period, yet more cost demanding reconstruction can require more detailed economic analysis of cost-effectiveness of proposed measures .

However those recommendations for improving energy efficiency do not address problem of changing fuel rates when calculating simple payback period of proposed recommendations. This research tends to clarify how various fuel rates can affect the simple payback period of proposed construction measures for improving energy efficiency of building.

3. Case study buildings

This case study is done by using sensitivity analysis on data obtained from several buildings which have already undergone a process of energy certification and for which recommendations for improving building energy efficiency and simple payback periods already exits. Four buildings were used for this case study and their floor plans are presented in Figure 1. All buildings are located in Osijek-Baranja County, near Osijek and they are residential buildings used as family houses.

Some of obtained buildings parameters and buildings mayor characteristics are listed in Table 1. All buildings have natural ventilation, several exposed facades and central heating, which utilizes gas as an energy source. Buildings are built between year 1975 and year 1978. Buildings A and B have been partially reconstructed recently, those buildings have replaced old openings with new PVC windows with insulated glass and exterior shading. That is one of

two reasons why proposed measures that are analyzed in this study refer only to thermal insulation of walls and ceilings and they are proposed with regard to *Technical Regulation on the Rational Use of Energy and Thermal Insulation in Buildings* („Narodne novine“ broj 97/14, 130/14) restrictions regarding U-value of reconstructed building elements. Second measure, that can be implemented is replacement of old doors and windows, only for buildings C & D, since buildings A & B already have new doors and windows. However, this measure has given simple payback periods longer than 20 years for buildings C and D and therefore it is a second reason why this measure was not further considered in this case study.

All four buildings as a proposed measure have setup of thermal insulation, for exterior walls proposed measure is to set up 10 cm of expanded polystyrene (XPS) and for ceilings 20 cm of mineral wool insulation.

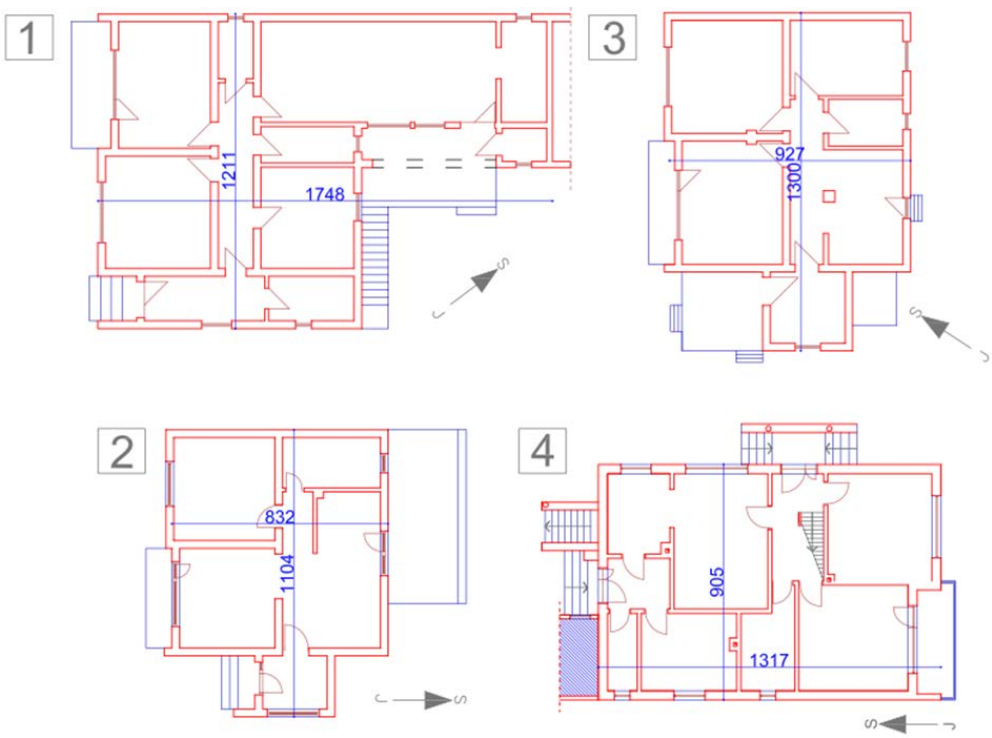

Fig. 1. Buildings floor plan

Table 1. Buildings mayor characteristics

Characteristics	Building A	Building B	Building C	Building D
A	121,59	51,54	87,24	115,55
V	379,96	161,08	272,63	361,08
f_0	1,06	1,5	1,15	1,43
Year of construction	1975	1978	1975	1978
Orientation	SW - NE	N - S	NW - SE	N - S
Year of reconstruction	2005	2000	-	-
Type of reconstruction	New PVC windows with insulated glass and exterior shading	New PVC windows with insulated glass and exterior shading	-	-
Exterior walls material	Full brick plastered with PCM	Full brick plastered with PCM	Full brick plastered with PCM	Block brick plastered with PCM
Openings characteristics	PVC, insulated glass	PVC, insulated glass	Wood, double frame	Wood, double frame

In order to calculate simple payback period it is necessary to determine current building energy performance i.e. annual energy consumption and annual heating costs. This is usually done together with CO_2 emissions calculations. Further, is necessary to evaluate above mentioned parameters after implementing proposed measure. Those parameters are calculated and shown in table 2 for proposed measure of setting up a thermal insulation. Parameters are calculated for current buildings states and possible future state after implementing proposed measure. Table 2 also shows how building energy efficiency rate changes after implementing proposed measures. In Croatia building energy efficiency rate goes from A+ to G and depends on $Q''_{H, nd, ref}$.

Table 2. Buildings energy consumption before and after proposed measure

BEFORE PROPOSED MEASURE				
Annual energy consumption [m3]	3241,05	2111,17	2304,86	2720,26
Heating costs	1.406,22 €	915,99 €	1.000,03 €	1.180,26 €
Annual emissions of CO_2 [kg]	6740	4390,32	4793,12	5656,97
$Q'_{H,nd,ref}$ [kWh/(m^{2}a)]	211	283	186	190
Building energy efficiency rate	F	G	E	E
AFTER PROPOSED MEASURE				
Annual energy consumption [m3]	1170,02	955,34	932,37	378,9
Heating costs	507,65 €	414,50 €	488,14 €	303,53 €
Annual emissions of CO_2 [kg]	2433,13	1986,7	1938,93	787,95
$Q'_{H,nd,ref}$ [kWh/(m^{2}a)]	77	128	75	26
Building energy efficiency rate	C	D	C	B

This case study revealed how new thermal insulation for observed buildings can decrease specific annual energy needs for heating from 51% to 73%. Figure 2 displays specific annual energy needs for heating, with respect to referential climatic data ($Q''_{H,nd,ref}$ [kWh/(m²a)]) and regarding the possible recommendations for improvement of buildings' energy efficiency:

- specific annual energy needs for heating for referential climatic data before proposed measures,
- specific annual energy needs for heating for referential climatic data after implementing measure restoration of old windows,
- specific annual energy needs for heating for referential climatic data after implementing measure of new thermal insulation &
- specific annual energy needs for heating for referential climatic data for both measures combined.

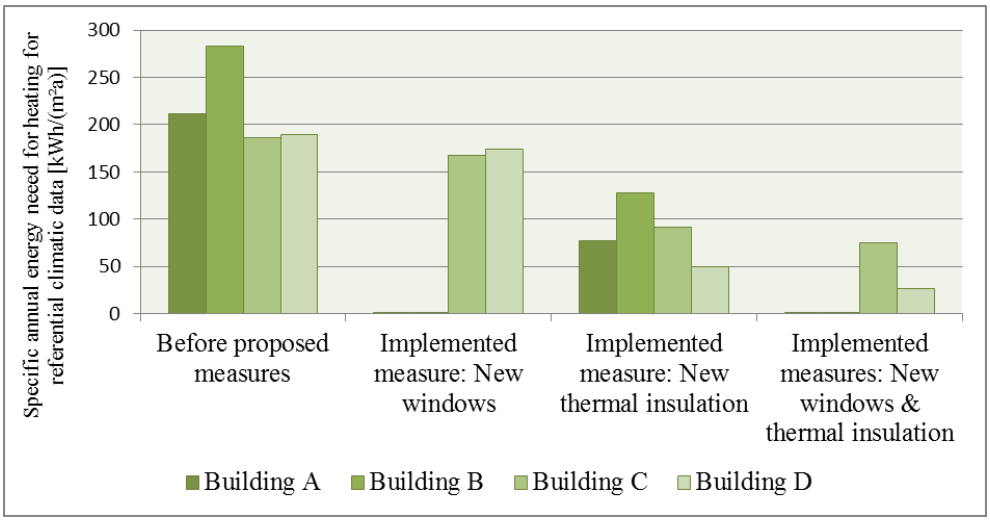

Fig. 2. Buildings' specific annual energy needs for heating for referential climatic data

4. Sensitivity analysis and case study results

Sensitivity analysis is a computational procedure that is used to predict the impact of changes in the input data to the output data model (Vigon, Tolle et al. 1994, Boussabaine 2007). In other words, it is procedure that analyses how changes in certain input data resulting from improper prediction or for some other reason, affects the evaluation of investment projects. By using this method it is possible to find the maximum and minimum data values within which the investment project is still economically justified and acceptable for performance (Jovanovic 1999). The sensitivity analysis is a modelling technique that is used to identify the impact of a change in the value of a single risky independent parameter on the dependent variable. The method involves three basic steps:

- The assignment of several reasonable values to the input parameter,
- The computation of corresponding values of the dependent variable &
- The analysis of these pairs of values (Kishk, Al-Hajj et al. 2003, Mithraratne, Vale et al. 2007).

The main advantage of the sensitivity analysis is swift implementation; the results can be easily presented, tabular or graphic. The main disadvantage of this method is omission of information on the probability of different outcomes and therefore final selection of variant solution still depends on personal judgment (Fuller and Petersen 1996). Sensitivity analysis has two limitations. First, it is a univariate approach, i.e. only one parameter can be varied at a time. Thus, it should be applied only when the uncertainty in one input-data element is predominant. Secondly, it does not aim to quantify risk but rather to identify factors that are risk sensitive. Thus, it does not provide a definitive method of making the decision (Kishk, Al-Hajj et al. 2003).

In this paper sensitivity analysis is used to determine how different values of an independent variable (fuel rates – gas price) will impact a dependent variable (simple payback period) under a given set of assumptions. In order to determine impact of fuel rates change on simple payback period changes in this case study gas price was varied in four steps. Gas price was increased and decreased in two steps by 10%. Initial gas price was 3,317 kn/m^3 i.e. 0,434 € calculated by using Croatian National Bank exchange rate list on day Mart 24 2015.

Investment costs of new thermal insulation were calculated based on the quantity of works and unit prices for each building separately.

Last step before calculating simple payback period was to calculate annual gas price for heating needs based on gas price and annual gas consumption for two observed states, before and after proposed measure of implementing new thermal insulation. All above mentioned data are presented in Table 3.

Table 3. Annual gas consumption and annual gas price before and after proposed measure

Buildings	Building A	Building B	Building C	Building D
BEFORE PROPOSED MEASURE				
Annual gas consumption [m^3]	3241,05	2111,17	2304,86	2720,26
Annual gas price [€]	1.406,22 €	915,99 €	1.000,03 €	1.180,26 €
AFTER PROPOSED MEASURE				
Annual gas consumption [m^3]	1170,02	955,34	1125,07	699,58
Annual gas price [€]	507,65 €	414,50 €	488,14 €	303,53 €
Investment for new thermal insulation [€]	7.613,05 €	5.487,30 €	7.159,04 €	8.798,00 €
Savings [€/a]	899,16 €	501,82 €	512,22 €	877,30 €
Simple payback period [Years]	8,5	10,9	14,0	10,0

For each gas price change, simple payback period was calculated as presented in Table 4. Quantity of works, unit prices and investment costs did not changed during these calculations. Current gas price was taken as initial step and simple payback periods were used from Table 3.

Table 4. Simple payback period for all buildings for implemented energy efficiency recommendation

Gas price [€/m^3]	Building A	Building B	Building C	Building D
0,35	10,58	13,67	17,47	12,54
0,39	9,41	12,15	15,53	11,14
0,43*	**8,47**	**10,93**	**13,98**	**10,03**
0,48	7,70	9,94	12,71	9,12
0,52	7,06	9,11	11,65	8,36

**Current gas price, march 2015.*

Gas prices were changed as already described in two steps, each step presents increase or decrease of 10% from initial gas price. Based on calculated simple payback periods regard to gas price changes simple payback periods changes were calculated and results are presented in Table 5.

Table 5. Changes of gas prices and simple payback periods changes

Gas price change [%]	Simple payback periods change [%]
-20,00%	25,00%
-10,00%	11,11%
0,00%	0,00%
10,00%	-9,09%
20,00%	-16,67%

Results of sensitivity analysis from Table 5 can be graphically presented in order to facilitate interpretation of obtained results.

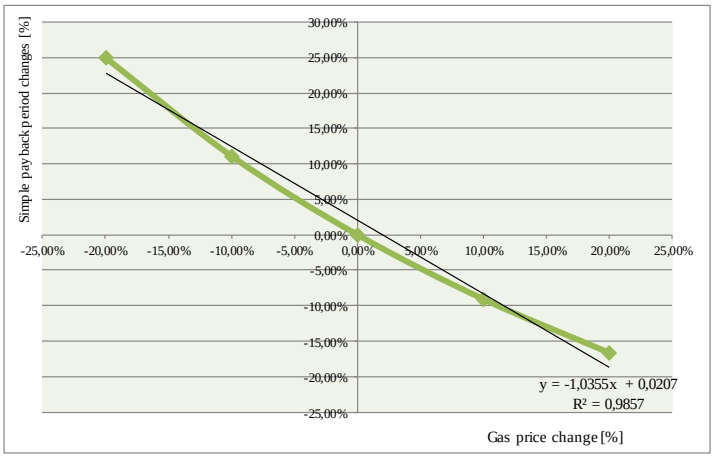

Fig. 3. Graphical presentation of sensitivity analysis results

5. Conclusion

This paper presents an investigation of fuel rate changes, in this case study gas prices, on simple payback periods changes. Calculation of simple payback period is mandatory according to *Ordinance on energy audits of construction works and energy certification of buildings* when carrying out energy certification of residential and non-residential buildings. For each given energy efficiency recommendation in energy certificate it is essential to calculate simple payback period. This helps the owners of real estate to conduct and to plan energy efficiency refurbishment. Since those periods are calculated based on investment costs and cost savings resulting from the reduction in gas consumption they are sensitive to price changes.

Gas prices in this case study were increase and decreased in order to determine their influence on payback periods although in the future we can expect fuel rates to decrease, this was done just for methodological reasons.

Simple payback periods for given recommendation of changing old joinery did not considered in this paper since they gave payback periods longer than 20 years. Nevertheless this recommendation should not be excluded when implementing energy efficiency measures since joinery affects thermal comfort and energy loses. In this case study this recommendation was taken into account only as a recommendation combined with thermal insulation restoration.

As expected results show extreme correlation between fuel rates changes and simple payback periods changes. Increase of fuel rates affects simple payback periods in a way of decreasing them. Although magnitude of simple payback period changes is not the same as magnitude of fuel rates changes. Magnitude of simple payback period drops somewhat slower than magnitude of fuel rates growth.

For future research correlation between fuel rate changes and changes of investment costs should be examined and their influence on simple payback period. Further, it would be recommended to examine influence of fuel rates changes on all commonly recommended energy efficiency measures from energy certificate.

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ESCO Models for Improving Energy Efficiency in the Construction Industry

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Abstract

ESCO (Energy Service Company) describes the companies that deliver the energy service or more specifically, develop, implement and provide or arrange financing for upfront energy efficiency (EE) investments for its clients. The fundamental concept of the ESCO business model is that the client does not have to come up with any upfront capital investment and is only responsible for repaying the investment made or arranged by the ESCO. Repayments are made from the energy savings. Issues related to energy efficiency are known for a long time and solving the problems of high energy demands, high and growing energy price is a global priority. This article aims to investigate and demonstrate how ESCO models can help in improving energy efficiency and achieving energy savings. Available literature regarding ESCO models, legal and strategic documents about energy efficiency and ESCO market reports were used as resources. It was shown that ESCO projects can achieve significant energy savings, are a great quality solution for improving energy efficiency and that the ESCO market in Europe, including Croatia, is constantly growing and has a big potential for further development.

Keywords: ESCO; energy efficiency; energy savings; energy service;

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1. Introduction

Energy efficiency is a term which has been around for quite a long time globally and in Croatia. Problems regarding to high energy demands, high and growing energy prices are something we encounter daily from the level of individual to local community, state and even on global level. This article wants to analyse and show how ESCO models can help in solving this problem, respectively, how can they improve energy efficiency and achieve energy savings. The focus of the content is to analyse current situation in Croatia and to show future possibilities for development of ESCO models on Croatian and European market. As resources, Croatian and other literature about ESCO models, legal and strategic documents like strategies, programmes and plans regarding energy efficiency, foreign ESCO market reports will be used. First part of the article is overview of building energy efficiency in Croatia. Also, legal and strategic framework is analysed to see what the current status is and the possibilities for implementation of energy projects in Croatia. Second part covers a review of ESCO models which include characteristics, services and activities provided by ESCO. Furthermore, a review of the energy performance contracting (EPS) models and the ESCO market analysis in Croatia and Europe was made.

2. Overview of building energy efficiency in Croatia

2.1. Legal and strategic framework

Croatia has been investing considerably more in improving energy efficiency and awareness about energy since 2005 through the project “Energy Efficiency Croatia” (EE project) initiated by Ministry of Economy and United Nation Development Programme (UNDP) with financial help from Global Environmental Facility (GEF) and Croatian Fund for Environmental Protection and Energy Efficiency (FZOEU).

There are many regulations and strategic documents in the field of energy efficiency which create legal and strategic framework. The goal is to improve energy efficiency and use of more efficient technologies. Some of the most important documents are:

- Energy Efficiency Act (Official Gazette 127/14)
- Long-Term Strategy for Mobilising Investment in the Renovation of the National Building Stock of the Republic of Croatia (Official Gazette 74/14) (Long-Term Strategy)
- National Energy Efficiency Programme for 2008 – 2016 (NEEP)
- 2nd National Energy Efficiency Action Plan for 2011–2013 (second NEEAP)
- 3rd National Energy Efficiency Action Plan for 2014-2017 (third NEEAP)

All of the mentioned documents are in coordination with EU legislative and the most important energy efficiency EU legislation documents are:

- Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC (Directive 2006/32/EU)
- Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast) (Directive 2010/31/EU)
- Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC Text with EEA relevance (Directive 2012/27/EU)

2.2. Overview of the Croatian National building stock

This overview is based on the document: Long-Term Strategy for Mobilising Investment in the Renovation of the National Building Stock of the Republic of (Long-Term Strategy).

Croatian national building stock is grouped by purpose into the following categories:

- Apartment buildings
- Family houses
- Public buildings
- Commercial buildings

This classification was used in Long-Term Strategy but also in National Energy Efficiency Programme for 2008 – 2016 and Directive 2012/27/EU. National building stock is organized into seven construction periods depending on the construction methods, materials used and applicable technical regulations:

- prior 1940;
- 1941 – 1970;
- 1971 – 1980;
- 1981 – 1987;
- 1988 – 2005;
- 2006 – 2009;
- 2010 – 2011.

Table 1 provides an overview of the national residential building stock and Table 2 an overview of the national non-residential building stock by the period of construction.

Table 1 Croatia's residential building stock by year of construction (Long-Term Strategy, 2014)

Year of construction	Apartment buildings		Family houses	
	Number	Area (m²)	Number	Area (m²)
prior to 1940	37.201	5.830.983	64.391	10.092.805
1941 - 1970	85.959	13.473.337	151.507	23.747.572
1971 - 1980	59.882	10.398.113	93.109	16.167.887
1981 - 1987	44.434	9.401.527	68.348	14.461.473
1988 - 2005	38.358	8.177.401	75.615	16.120.249
2006 - 2009	18.256	6.199.252	13.762	4.673.079
2010 - 2011.	6.600	1.957.449	4.976	1.475.551
TOTAL	290.689	55.438.063	471.708	86.738.615

Table 2 Croatian non-residential building stock by year of construction (Long-Term Strategy, 2014.)

Year of construction	Commercial buildings		Public buildings	
	Number	Area (m²)	Number	Area (m²)
prior to 1940	2.338	1.498.159	12.365	1.525.813
1941 - 1970	12.587	8.064.602	22.525	2.815.845
1971 - 1980	6.733	5.251.934	19.021	1.882.000
1981 - 1987	4.323	5.108.279	10.158	2.152.000
1988 - 2005	10.596	8.107.287	11.059	2.722.497

2006 - 2009	6.199	6.352.000	3.673	2.073.747
2010 - 2011.	1.952	2.158.198	1.395	610.000
TOTAL	44.728	36.540.459	80.196	13.801.902

According to Table 1 and Table 2 total residential building stock contains 762.397 buildings with the area of 142.176.678 m² of which 290.689 are apartment buildings with the total area of 55.438.063 m² and 471.708 are family houses with the total area of 86.738.615 m².

Non-residential building stock contains 124.924 buildings with the area of 50.342.361 m² of which 44.728 are commercial buildings with the total area of 36.540.459 m² and 80.196 are public buildings with the total area of 13.801.902 m².

In total, Croatian national building stock contains 887.321 buildings with the total area of 192.519.039 m² for the period until 2011.

2.3. Buildings energy performance and characteristics

Buildings energy performance and characteristics mainly depend on the time of construction. For example, in the period of the greatest construction boom between 1950 and 1980 because of the construction methods and the lack of quality technical regulations, buildings from that period are big energy consumers with the annual thermal final energy requirement for heating above 200 kWh/m²a. For comparison, today's standard houses spend under 100 kWh/m²a for heating while low-energy houses spend under 40 kWh/m²a and passive and zero-energy houses 15 kWh/m²a and less. (Vrcek, 2012.)

Buildings built between 1941 and 1980 have the biggest annual thermal energy requirement for heating averaging 200 kWh/m²a for entire Croatia, but also the biggest annual final energy consumption averaging 357 kWh/m²a. (Long-Term Strategy, 2014) This data corresponds with previous statement that buildings from this period are the biggest energy consumers. If we add data from Table 1 and Table 2, we can conclude buildings from that period are not only the biggest energy consumers but they are also the most numerous. In addition, continental Croatia is bigger energy consumer from coastal Croatia because of the climatic differences and higher energy demands.

Every construction period has its' own characteristics depending on the construction methods, materials used and applicable technical regulations. Especially important is the regulation framework. Updated regulations are always more strict and amended. Also, they increase demands for thermal insulation, i.e. maximum permitted heat transmittance coefficient U [W/ (m²K)] (earlier coefficient k). Coefficient is continually tightening for different structural elements. This statement will be shown on the example of external wall and floor on ground level with comparison of maximum permitted heat transmittance coefficient U [W/ (m²K)] from 1970 to 2005 which is shown in Table 3.

Table 3 Comparison of maximum permitted heat transmittance coefficient U [W/ (m²K)] from 1970 to 2005 for external wall and floor on ground level (Long-Term Strategy, 2014)

Structural element	Construction climate zone		
	I.	II.	III.
External wall			
1971.-1980.	1.69	1.45	1.28
1981.-1987.	1.225	0.93	0.83
1988.-2005.	1.20	0.90	0.80
Floor on ground level			
1971.-1980.	0.93	0.93	0.93
1981.-1987.	0.93	0.76	0.68
1988.-2005.	0.90	0.75	0.65

In conclusion, this overview provides access to number and area of building national stock in Croatia and building energy performance and characteristics. As earlier mentioned, every updated regulation is stricter regarding to thermal insulation and demands better total energy performance for buildings. Energy efficiency legal framework in Croatia is continually developing and is in good coordination with EU legislation. All of this is a good foundation for implementing measures for improving energy efficiency in which ESCO models find their application.

3. ESCO models

3.1. Characteristics

Directive 2006/32/EC has had a crucial role in establishing ESCO related terminology. Therefore, in this article, the following terms are used according to the Directive:

- "energy service company" (ESCO): a natural or legal person that delivers energy services and/or other energy efficiency improvement measures in a user's facility or premises, and accepts some degree of financial risk in doing so. The payment for the services delivered is based (throughout or partially) on the achievement of energy efficiency improvements and on the meeting of the other agreed performance criteria;
- "energy performance contracting" (EPC): a contractual arrangement between the beneficiary and the provider (normally an ESCO) of an energy efficiency improvement measure, where investments in that measure are paid for in relation to a contractually agreed level of energy efficiency improvement;
- "third-party financing" (TPF): a contractual arrangement involving a third party — in addition to the energy service provider and the beneficiary of the energy efficiency improvement measure — that provides the capital for that measure and charges the beneficiary a fee equivalent to a part of the energy savings achieved as a result of the energy efficiency improvement measure. That third party may or may not be an ESCO.

ESCOs develop, implement and provide or arrange financing for upfront EE investments for its clients. Repayments from savings allow clients to compensate ESCO's ongoing savings monitoring, Measurement & Verification (M&V) costs and assumption of risk through EPC or Third-Party Financing (TPF). The fundamental concept of the ESCO business model is that the client does not have to come up with any upfront capital investment and is only responsible for repaying the investment made or arranged by the ESCO. (IFC, 2011)

ESCO services include wide range of activities and some of the primary services are:

- energy analysis and audits
- Investment Grade Audit (IGA)
- comprehensive engineering and project design and specifications
- purchase, installation and delivery of equipment
- operation and maintenance of equipment
- measurement and verifications of savings
- savings guaranties and equipment performance

3.2. Contract business models

One of the most important aspects of EPC is the risk guarantees that are incorporated into the projects. In an EPC project the ESCO takes on the performance risk. This means that the ESCO is responsible that the EPC project reaches the agreed energy savings level. The remuneration to the ESCO is based on the performance of the project. Then there is also the financial risk. The party who takes on the financing of the project also takes on the financial risk. The investment needs to give return and if loans are taken they need to be paid back to the financial institution. (Wargert, 2011)

The two dominant EPC models in the world are shared savings and guaranteed savings. In Europe, a third approach is used called “chauffage.” (IFC, 2011)

3.2.1. Shared savings model

In a shared-savings EPC, the ESCO finances the total upfront capital cost of the project and is totally responsible for repaying the lender. The client pays the ESCO a percentage (or it can be a fixed amount) of its achieved savings from the project, large enough for the ESCO to repay the project investment to its lenders, cover M&V costs and any other associated costs. The energy-end user assumes no direct contractual obligation to repay the lender, only the ESCO has this obligation. (IFC, 2011) Illustration 1 shows shared savings model.

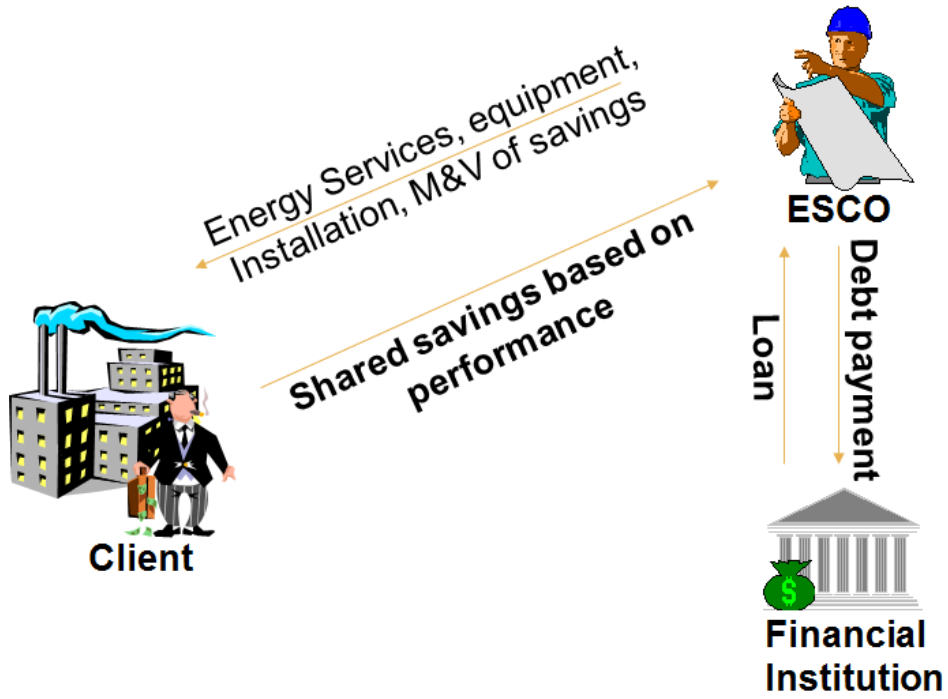

Illustration 1 Shared savings financial model (IFC, 2011)

This contract model brings ESCO considerably bigger risk then guaranteed savings model because ESCO takes on both the performance risk and the financial risk. Also, the shared-savings approach typically requires an equity investment, which in combination with the higher risk assumed by the ESCO carries a higher capital cost than the guaranteed savings structure.

Funding for ESCO project can be provided from several resources such as ESCOs own capital, financial loans, but also from other sources like EU funds or preferential loans and subventions. Anyhow, as earlier mentioned, ESCO takes on both types of risks and must have upfront capital for the investment. Illustration 2 shows financial structure in ESCO project carried upon shared savings contract. Financial shares between client and ESCO are agreed and are part of the contract. It is important to notice that every contract has duration and after contract has expired all of the savings from then on belong to client.

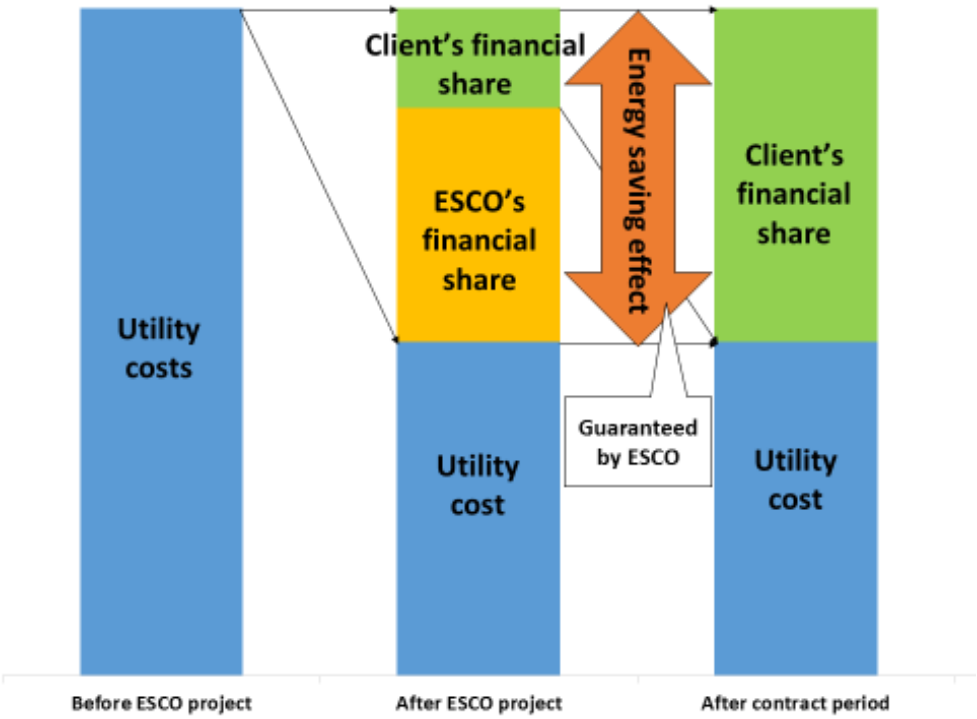

Illustration 2 Financial structure in ESCO project (shared savings contract)

The shared-savings concept is a good introductory model in developing markets because energy end users assume no financial risk, which overcomes the difficulty energy end-users in transitional economies have in satisfying banks' criteria for creditworthiness. However, this concept relies heavily on ESCOs' borrowing capacities and this presents a serious difficulty for small and even big ESCOs which lack access to financial resources. After incurring debt on even a limited number of projects, an ESCO is apt to find it is too highly leveraged to obtain financing for the implementation of more projects. The shared-savings concept therefore limits the long-term market growth and competitiveness of small ESCOs and leaves lots of "lost opportunities" in energy end-user facilities because of its high financing costs only allowing short payback measures to be implemented. (IFC, 2011)

Another author (Wargert, 2011) also indicates problems like taking on both types of risks by ESCO, sensitiveness to energy price drop and requirement of financially very strong ESCOs. Taking on both the performance and financial risk makes ESCO to play it a bit more "safe" when implementing the project. Often, the ESCO will concentrate a bit more on the safe solutions which have shorter payback times. This can have the effect that the project might not be as comprehensive compared to using guaranteed savings which was already earlier mentioned. The shared savings model is more sensitive to energy price drops. Since the revenues for the ESCOs are based on the payback from the energy savings, a drop in energy prices will make the payback times longer and it can become hard for ESCOs to cover their debts. It is however possible to stipulate a single energy price to limit this risk. This means that the ESCO and customer will agree on value of the service and neither party will gain from energy price changes. ESCO needs to be financially very strong. If an ESCO commits to several EPC projects they will become highly leveraged before the projects have paid back, which can typically take 5-12 years. This can mean that the ESCOs in some cases are too highly leveraged to get new bank loans which means they can't take on further projects. One of the important benefit for the customer with shared savings is that they will benefit from the savings from day one. They do not put in the initial investment but still save money from the energy savings as soon as the EE measures are done.

3.2.2. Guaranteed savings model

In a guaranteed savings EPC, the client essentially applies for a loan, finances the project and makes periodic debt service payments to a financial institution. The ESCO bears no direct contractual obligation to repay the lender, only the energy end-user assumes this obligation. The ESCO's guarantee is not a guarantee of payment to the lender but rather a guarantee of savings performance to the energy end-user that is usually equal to its repayments to the lender. (IFC, 2011)

Illustration 3 shows guaranteed savings financial model. Savings must be able to cover all the related project costs, including debt service to the lender, M&V fees to the ESCO and any other incremental costs (maintenance, etc.) incurred by the project, over a certain period of time.

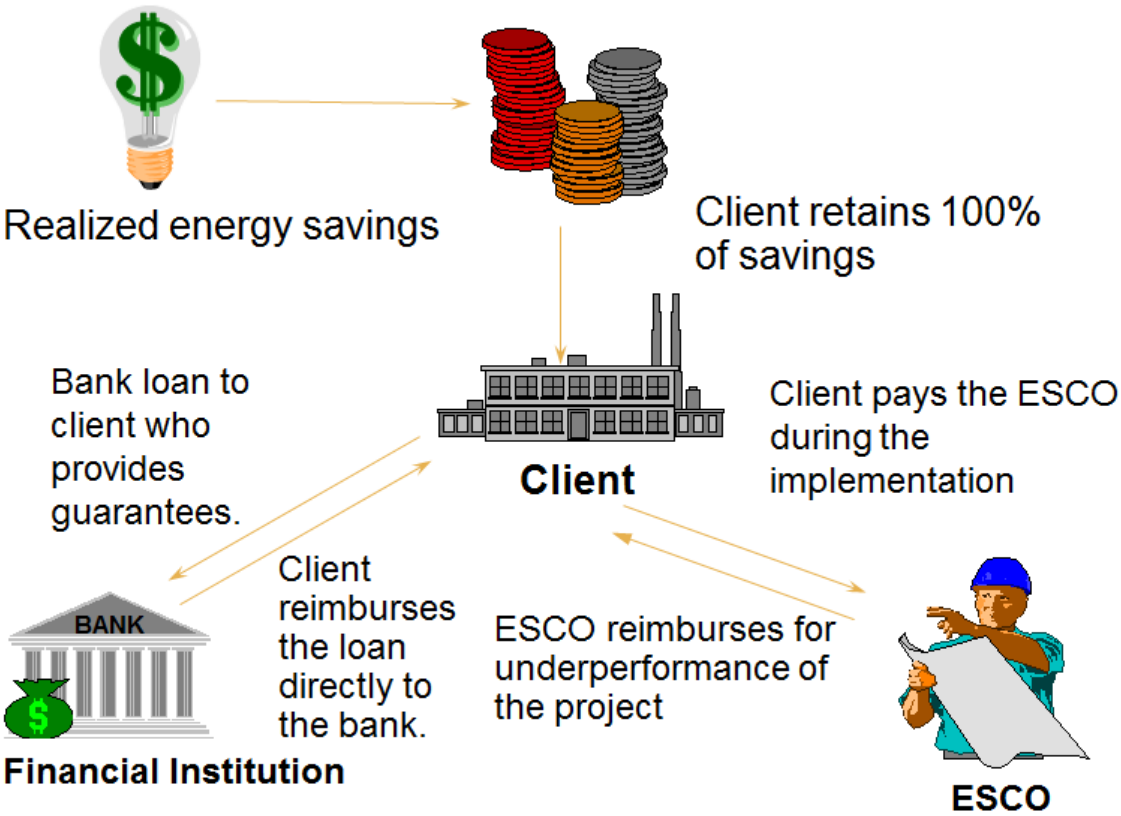

Illustration 3 Guaranteed savings financial model (IFC, 2011)

Illustration 4 shows financial structure in ESCO project agreed upon by guaranteed savings contract model. Client retains 100% of savings. There are three possible scenarios. First scenario (1) is when the guaranteed savings are equal to actual savings. In that case, client pays the services during the period of the contract. Second scenario (2) is when the actual savings are lower than guaranteed savings. In that case, ESCO compensates energy users with cash equivalent to the difference between the guaranteed and actual savings. Third scenario (3) is when the actual savings are bigger than guaranteed savings. In that case, the difference between the guaranteed and the actual savings is shared as per the agreement between ESCO and energy user. After the contract period, in any case, all of the savings belong to client.

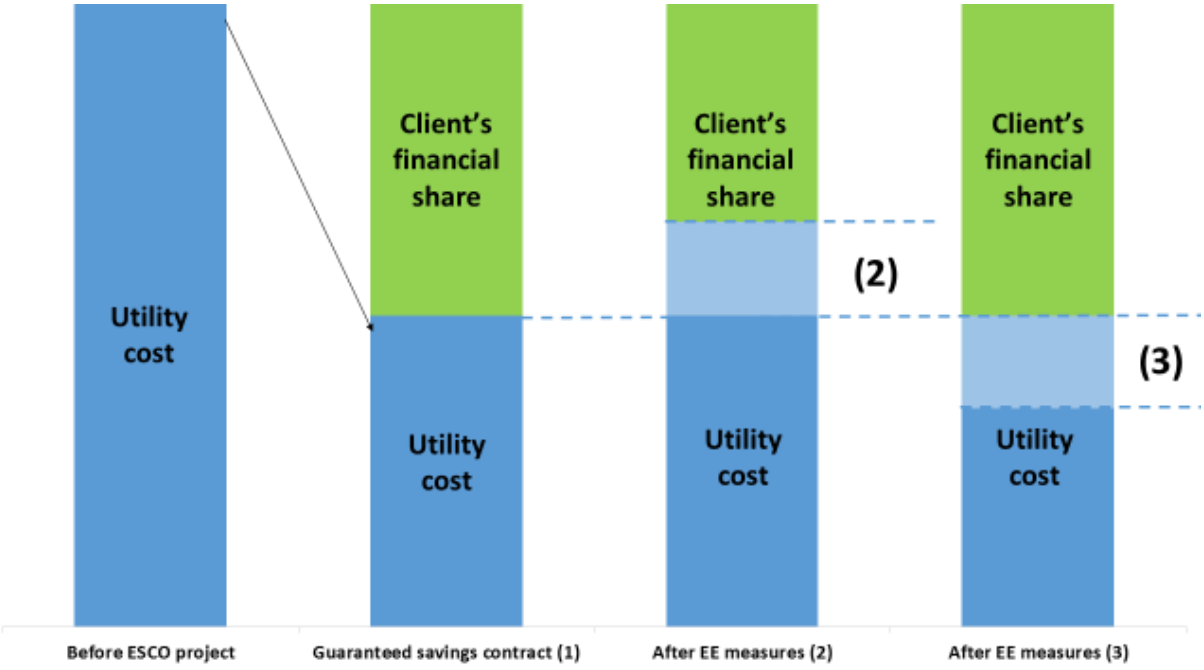

Illustration 4 Financial structure in ESCO project (guaranteed savings contract)

The guaranteed savings scheme is likely to function properly only in countries with an established banking structure, a high degree of familiarity with project financing and sufficient technical expertise within a banking sector that understands EE projects. It fosters long-term growth of ESCOs and finance industries because it enables newly established ESCOs with no credit history and limited capital resources to enter the market if they are willing to guarantee the savings to energy end-users who will secure the financing on their own. The primary benefit of this structure is that it significantly reduces financing costs for the municipalities, universities, schools and hospitals market by utilizing their tax-exempt status. This reduced financing cost enables a lot more project investments to be made for the same debt service level. The public sector normally prefers this structure in order to maximize the amount of infrastructure investments made in its facilities from a performance-based contract. (IFC, 2011)

Since the projects are financed by the customer from the start the ESCO can in many cases provide more comprehensive long-term measures since they don't have to apply the same risk management (such as concentrating on "safe" measures with short payback times). (Wargert, 2011.) The same author warns the guaranteed savings model needs a market with high awareness. Without this, customers will be less likely to trust the guarantees and financial institutions will be less likely to provide loans to the customer. So, guaranteed savings is generally more suited towards the mature market. The guaranteed savings model can however help build up a more aware and mature market in the long-term so in that sense it can be good for developing markets, assuming ESCOs can manage to use it successfully.

3.2.3. "Chauffage" contract

"Chauffage" or integrated solutions generally refer to a greater value-added approach. The concept offers conditioned space at a specified price per energy unit to be consumed or per some measurable criteria (square footage, production unit, etc.) through a supply and demand contract offered by the ESCO. The ESCO manages all supply and demand efficiencies. (IFC, 2011)

This type of contract has other names such as function contract or comfort contract. It is a contract form that revolves around the principle that the customer pays for a function rather than say MWh of delivered energy. This function can be for example: keeping a room at 21 degrees or keeping an office space lit at 500 lumen. Other functions can also be used, such as air quality etc. The most common function however, is keeping a space conditioned at a certain temperature. (Wargert, 2011)

A "chauffage" contract is usually setup in the way that the ESCO looks at what the customer pays to keep one square meter of space conditioned, say at a certain temperature. The cost will include energy costs, service & maintenance costs etc. The ESCO will then offer the customer a fixed fee that is lower than what the customer is currently paying, e.g. 90% of what they are currently paying. This is shown in illustration 5; if the customer pays €11.4 per square meter a year before the contract, the customer might pay €10.0 per square meter a year, fixed fee, after the contract to keep the space conditioned. Since the price is fixed the customer does not have to worry about price abnormalities, eg. due to extra-ordinary cold winters etc. The ESCO will take responsibility for everything needed to keep the customers facilities at the predetermined temperature (or lighting level etc.), this includes everything from fuel purchasing, energy transformation, delivery, operations, service and maintenance of the customer side technical facilities. (Wargert, 2011)

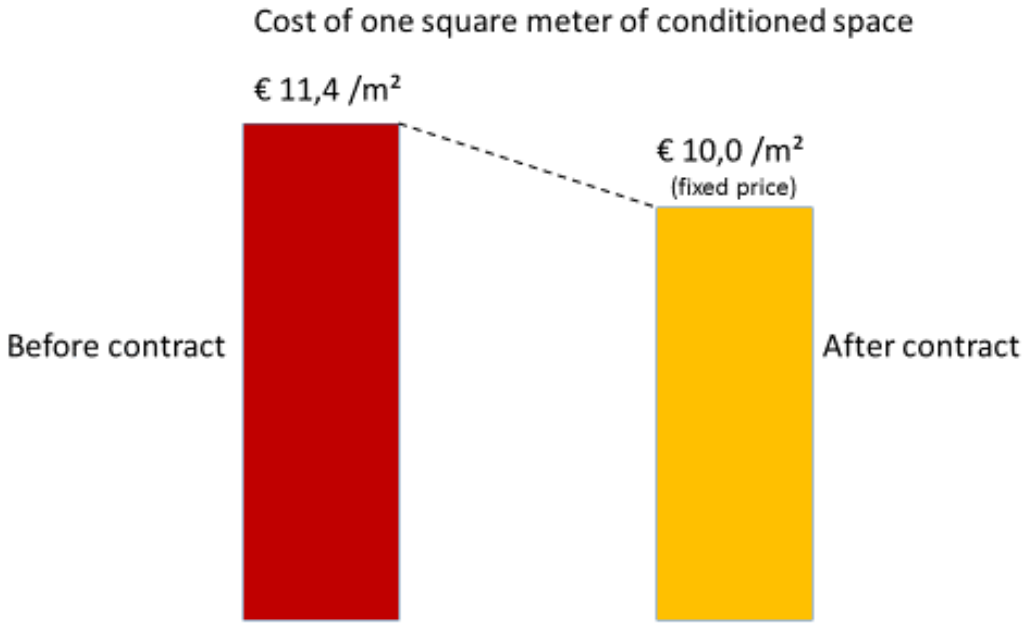

Illustration 5 The cost of one square meter of conditioned space, before and after project implementation (Wargert, 2011)

A "chauffage" contract is usually very extensive, often involving a thorough energy management plan, including retrofits and maintenance. It is generally considered appropriate only for large-scale energy end-users whose facilities feature substantial potential savings (e.g., hospitals, universities and large office buildings). This kind of agreement is often used in Europe to contract municipal services. The length of a chauffage contract is usually long, ranging from 10 to 25 years. (IFC, 2011)

„Chauffage" contract has a lot of strength. A big strength is the absence of customer investment and that any ESCO side investment will have a direct effect on the revenue. This helps making the chauffage contract an "easier" investment for the customer than if they have to make a large investment up front. Another strength is the strong incentive for the ESCO to

do EE measures to boost their profits. The “chauffage” contract doesn’t require the same amount of cooperation between the customer and the ESCO as with some other contract forms such as EPC. This makes it more seamless for the customer since most of the measures are carried out in the “background” and does not affect their core business. This model besides hospitals, universities and large office buildings, also fits property owners in the commercial buildings sector (such as owners of shopping malls). These customers have very high requirements for “functions” such as temperature levels (or lighting) because of the nature of their tenants: eg. shop owners who are dependent on their customers feeling “comfort” in their shops. (Wargert, 2011)

3.2.4. Contract business models comparison

While shared savings remains the dominant model in Europe, in North America over 90% of the EPC agreements are currently structured for guaranteed savings with the owner typically accepting the debt through TPF. The “chauffage” approach works well in countries where a lot of heating (or alternatively cooling) loads are present. It is often associated with transfer of obligations related to the operations and maintenance of a facility where energy savings are just one component of the full deal. The approach is often seen in Central and Eastern Europe in the context of municipal district heating plants. (IFC, 2011)

Table 4 represents comparison of the contract business models regarding to risks, location and contract period. In all type of models ESCO takes on performance risk. The risk is higher in shared savings and “chauffage” contract then in guaranteed savings contract because of the financial risk for ESCO. For client, guaranteed savings model brings higher risk because of the financial burden. Average contract period column is just the provisional data to show ratio between different models. Duration depends on many factors and every project is unique. However, guaranteed savings contract is shorter then shared savings contract because of the lower financing costs for the same project and the “chauffage” contract is the longest of the three models.

Table 4. Contract business models comparison

	Financial risk	Performance risk	Risk comparison	Location (dominant)	Average contract period	
Shared savings contract	ESCO	ESCO	Higher for ESCO	Europe	5 -12 years	(Wargert, 2011)
Guaranteed savings contract	Client	ESCO	Higher for client	North America	less than shared savings contract	(IFC, 2011)
"Chauffage" contract	ESCO	ESCO	Higher for ESCO	Europe	10 - 20 years	(IFC, 2011)

As opposed to EPC, in “chauffage” model there is not the same need for an energy baseline to compare with since there is no savings guarantee. An energy cost baseline will however need to be setup prior to project implementation to determine what the customer is paying prior to project implementation. The ESCO will look at what the customer is paying before the contract and then subtract a portion of this (eg. 10%, depends on risks, contract length etc.). After the project has been implemented you can simply remove any existing energy meters if you will, since the energy costs are fixed for the customer. Some measurements will

be made to secure the function (such as temperature, light level etc.) but the need for costly measurement & verification does not exist with the "chauffage" model in the same way as with EPC. (Wargert, 2011)

4. ESCO market analysis

4.1. Europe (2010 – 2013)

ESCO market analysis between 2010 and 2013 is mostly based on the document from European Commission called "ESCO Market Report", authors Bertoldi, Boza-Kiss, Panev and Labanca. (Bertoldi and al. 2014)

There are more ESCOs with more projects in 2013 than there were in 2010, and ESCOs have foraged in areas where they were rare before. Nevertheless, the markets are far from reaching their potential. There are only few mature markets, such as Germany, the Czech Republic, France, and Austria. Even these can expect to go through significant growth in the future. In spite of the financial crisis, the ESCO sector could kick-off in several typical non-ESCO countries, such as Denmark and Spain. Decrease or deterioration of the ESCO sector was rare during the observed period with only Hungary experienced a clear decline.

EPC and other alternative and locally tailored contracts have increased their popularity. The markets are driven as much by market forces (increasing energy prices, growing interest from potential clients, development of partnership between players on the demand and supply side, as well as between ESCOs and subcontractors), as by dedicated policy measures, regulations and financial solutions. Interestingly the list of drivers is similar in many countries, but the leveraging success factor (and leading barrier) is diverse.

The key conclusions of the previous ESCO status reports were that the ESCO markets of the European countries vary widely in terms of development and size, as well as in features and frameworks. While this statement is still accurate on the whole in 2013, the markets have more in common than before.

First of all, almost all of the European markets have grown since 2010, and only few of them remained stable or declined. The growth has unfolded in size, referring to a larger number of companies/projects, as well as in strength reflected in market volume, more developed market structure, availability of institutions, or wider market coverage. The growth has been largely fuelled by the growth of demand, i.e. an expansion of interest from the side of potential clients (e.g. the public sectors in the Czech Republic, Denmark, the UK), who look forward to alternative financial and managerial solutions of energy renovations. Nevertheless, there are countries where crucial regulatory drivers, information dissemination and financial solutions were introduced during the observed period. Interestingly, growth could be realised even in countries where the regulatory framework poses a problem for ESCOs (e.g. in Italy, Greece, the industrial sector of Slovakia, etc.). Table 5 shows number of ESCOs, market size and market potential in 25 countries with data from 2010 and 2013. It is important to notice that these values are rarely comparable because of the content - in case of the number of ESCOs differences are due to the definition of these companies in the given context, while in the case of the market sizes, sources include different parts of the value chain and/or calculate or estimate these in a variety of ways.

Table 5 Number of ESCOs, market size and market potential in 25 countries (Bertoldi and al., 2014)

	Number of ESCOs		**Market Size**		**Market potential estimated in 2012**
	in 2010	**in 2013**	**in 2010**	**in 2013**	
Austria	over 50	over 50	n/a	€15-20 mil	n/a
Belgium	10 do 15	10 do 15	n/a	€5 mil	€500 mil – several billion
Bulgaria	few	7-12	€6 mil	€33 mil	€500-900 mil
Croatia	2	10	€10 mil	€100 mil	n/a
Czech Republic	8-10	20	€2-4 mil	€10-20 mil	€100-500 mil
Denmark	10	15-20	€8-25 mil	€140-150 mil	€1 billion
Finland	8	5-8	€4 mil	€10 mil	€200 mil
France	100	350	€4-5 mlrd	€75-100 mil for EPC, €3.2 b/year for all	€250-500 mil for EPC, €5 billion for all ESCO projects
Germany	250-500	500-550	€1.7-2.4 billion	€3-4 billion, €150 mil for EPC	€20-30 billion
Greece	2	5	n/a	0	€5 mil
Hungary	30	10	n/a	n/a	n/a
Ireland	15	cca. 30	n/a	n/a	n/a
Italy	100-150	50-100	€275 mil in 2008 €387 mil in 2009.	€500 mil	€1-10 billion
Netherlands	50	50	n/a	n/a	€30 mil
Norway	5	10	€25 mil	n/a	n/a
Poland	3-10	30-50	€5-10 mil	€10-25 mil (2011)	€25-75 mil
Romania	14	15-20	€50 mil	n/a	n/a
Serbia	10	3-5	n/a	n/a	n/a
Slovakia	5	6-8	n/a	n/a	n/a
Slovenia	2-3	5-6	n/a	€3 mil	€15 mil
Spain	15	20-60	€100 mil	€300-400 mil	€1.5-2.6 billion
Sweden	8		€60-80 mil	€60-80 mil	€300 mil
Turkey		30	n/a	n/a	n/a
United Kingdom	20	30-50	€400 mil	n/a	n/a
Ukraine		cca. 30	n/a	€100 mil	n/a

Facilitators have a very important role in the development of ESCO markets. There are a number of organisations that act as facilitators in Europe, for example national (or local) energy (efficiency) agencies, (private) energy audit companies, some legal advisors and private facilitators, or the EPC procurement advisors. In a few countries the government or external donors like World Bank can set up agencies to stimulate the energy services markets.

ESCO projects are mostly implemented in the public sector (buildings and street lighting) and in industry. The preference depends on the national circumstances, on the openness and willingness of the public administration, on legal barriers in the public sector, and on factors such as size of the sector, size of the individual installations, financial capacities, long-term thinking in industry.

It could be noted during that sectors that were absolutely not attractive for ESCOs before, such as residential buildings and infrastructure (transport), were touched upon during the period 2010-2013. The problems related to these sectors include that they are decentralised and the projects would be very small while experiencing higher transaction (information and face-to-face interaction) costs. Moreover, the lack of trust from the potential clients is higher than in other sectors, potential clients have low liquidity and aversion to involve bank loans, and the split incentive problem is evident in most countries due to a high rate of renting, etc. These projects usually (but not always) combine some form of national or EU financial incentive with the ESCO technical realisation; therefore, a pure market based solution is not always available. Nevertheless, the contracts are often guarantee based, i.e. the main role of the ESCO is to support the project with a guarantee.

The European ESCO markets have been undoubtedly developing both in terms of volume and in complexity when compared to the findings of the 2010 or the previous ESCO status reports. Based on the analysis of the success factors of the markets across Europe, it is possible to collect a list of conditions and features that can possibly define a mature market. Such a list also indicates the likely directions of market transformation and the generally expected areas of improvement if a more functional ESCO sector is targeted. The conditions for a mature ESCO market can generally be described as follows:

- the ESCO concept is **known and understood**. Clients will still need additional information about the specific offer and contract types offered by suppliers, but a decision between own investment, ESCO project, outsourcing, etc. is done internally. The additional information is available from consultants, independent facilitators or public agencies;
- the market is **demand driven**, meaning that (potential) ESCO clients actively search for suppliers, and define their needs and requirements for an energy services project or package, announcing them and waiting for alternative solutions, which can be compared to each other;
- there are **alternative contract forms**, several of them available in a standard format or supported by guidebooks that have been prepared by an independent organisation with the involvement of market stakeholders;
- there are **alternative financial solutions**, including client-financing and bank involvement;
- **transaction costs are low**, historical data on energy consumption are available;
- **monitoring and verification** of savings is carried out with a standard and transparent method;
- there are **facilitators**, who can help clients decide about the available offers, while supporting the supplier side by undertaking lobbying activities, general promotion, training, certification, etc.;
- the energy and procurement general **policy framework does not hinder** ESCO projects and there is rarely a need for dedicated legislation for ESCOs. Nevertheless, ESCO definitions, standards, and sometimes specific laws can be necessary. On the other hand the ESCO solution will be the route to a sustainable economy (energy consumption) and not the goal of a legislation;
- **grants or preferential loans** – if available – **do not favour, nor disqualify ESCOs**. They should be gradual and provide non-refundable subsidies only for measures that have a very long payback time (i.e. would not be financed by market players), but are socially beneficial, and that are combined with more attractive measures in order to achieve e.g. deep retrofit or complex project or favour special social groups, etc.

Finally, while governments and public administrations often aim at developing the ESCO industry, this should be done in order to achieve energy savings or sustainable energy use, not for the sake of the industry itself. Policies and measure should indeed be aimed at socially beneficial ESCO market impacts and/or at the deepening of these impacts. Otherwise, the risk is that they can obstacle or not allow to fully exploit the positive outcomes linked to the ESCO business.

4.2. Croatian ESCO market

This overview is based on ESCO market reports from European Commission (Marino and al., 2010 and Bertoldi and al., 2014).

Table 6 shows basic information about ESCO market in Croatia for period between 2007 and 2010 including the number of ESCOs, size of the market, types of ESCOs etc.

Table 6 Summery of basic data of the Croatian ESCO market 2007-2010 (Marino and al., 2010)

Number of ESCOs	2
Size of the market	10 million euros
ESCO association	No
Type of ESCOs	Energy service and supply and facility management and operation companies
Market development	No significant change
Sector ESCO Projects & main EE measures	Complex public building projects and street lighting

As of 2013, in Croatia are active around 10 ESCOs that can provide energy services, mostly on the basis of energy service contracts with fixed fee. The majority of these firms are small private companies with limited own equity and financial capacities. There is one public company, HEP ESCO, which is also the most dominant on the market.

HEP ESCO d.o.o. is a daughter company of the national utility company HEP d.o.o. established in 2003 as an energy service-providing company which develops, executes and finances energy efficiency projects in the following areas: buildings (schools, offices, hotels, universities, hospitals, etc.), public lightning, industry and energy supply systems. It is the main and dominant player on the Croatian ESCO market and is recognized as a positive example of ESCO with the tendency of growing and big potential in the following years. This is also confirmed in the European market reports naming HEP ESCO as one of the more successful and positive examples of ESCO business implementation (IFC, 2011, Marino and al., 2010, Bertoldi and al., 2014)

Table 7 shows basic information about ESCO market in Croatia for period between 2010 and 2013 including number of ESCOs, size of the market, typical ESCO projects, main types of contract etc.

Table 7 Summery of basic data of the Croatian ESCO market 2010-2013 (Bertoldi and al., 2014)

Number of ESCOs	10 (one public ESCO)
ESCO market size	100 million euro
ESCO development	increasing since 2012
ESCO association	No
Typical ESCO projects	refurbishment of building envelope, heating systems and indoor lighting in public buildings; improvement of heating system in public buildings public lighting
Main type of contract	energy service contracts based on fixed fee very few EPC contracts

The Croatian ESCO market is relatively small and it is estimated to be around €100 million. At the same time, all the sectors have large saving potentials due to the obsolete status of the building sector. In the public sector most of the buildings were constructed in the period 1945- 1990 under the old building codes used before 1987. This was discussed in the first part of the article. The commercial sector and especially the facilities (hotels, shopping malls, camps, etc.) that are situated on the Adriatic coast have high energy efficiency potential because they are not connected to the gas pipe lines. Here demand side energy efficiency measures can be complemented with the installation of renewable energy technologies, due to the favourable climate conditions.

Croatia adopted its second NEEAP in February 2013. Energy services and ESCO are stipulated as one of the models for financing energy efficiency projects in the public sector, as well as in residential and commercial buildings. For implementation of the measures related to energy renovation of residential buildings, the second NEEAP set an expected energy saving target of 3,554 GWh for 2020, assuming that every year 1% of the building surface will be renovated or approximately 1.5 million m² of residential buildings per year until 2020, which should be realized with an investment volume of €300 million /year. ESCOs are expected to contribute to these savings significantly.

Pursuant to the second NEEAP, the Croatian government will prepare and implement a plan for the energy renovation of public buildings for period 2012 – 2016(2020). Focus has been set on public buildings constructed before 1987 and their renovation in terms of low-energy standards. The assumed renovation volume is around 479.000 m² per year (5% of the total floor area), which is expected to be realized with €96 million/year, to be sourced from IFIs, HBOR, commercial banks, European programmes, as well as through ESCOs.

Potential sources for financing ESCO projects are Croatian Fund for Environmental Protection and Energy Efficiency (FZOEU), The Croatian Bank for Reconstruction and Development (HBOR) and commercial banks.

The Croatian Environmental Protection and Energy Efficiency Fund offers co-financing for projects, programmes and measures for environmental protection, energy efficiency and renewable energies. It is the first and only extra budgetary foundation that provides incentives for energy efficiency and renewable energies projects. ESCO projects in the public and the private sectors are also eligible.

HBOR also offers preferential loans for up to 14 years to the winners of the tenders under the “Retrofitting programme for public buildings" (see more above). The loans are distributed through the HBOR and financed by European Investment Bank. However, this programme

has not been popular with ESCOs because they would have to take loans of 14 years, which is contradictory to their borrowing limitations.

Commercial banks in Croatia are aware of the ESCO model and they are interested in ESCO projects, but they need to learn more about financing ESCO projects and how to develop financial products for the ESCO market. They require as collateral 30% and more equity from ESCOs, while they also request alternative government guarantees which is just not suitable for ESCOs.

Legal and strategic framework regarding to energy efficiency is well developed in Croatia. Implementation of NEEAP should have big effect on ESCO market because it predicts energy efficiency measures in public sector will be implemented through ESCO projects. Nevertheless, ESCO in Croatia still needs financial incentive from state or other sources because commercial banks are still not willing to participate in a way suitable for ESCOs.

Market potential for energy efficiency projects in Croatia is estimated at more than 2.4 billion Croatian kuna and is on the steady increase. This is due to growing prices of oil, gas, electricity and other sources of energy, the process of harmonization with the EU where energy efficiency has become a high priority topic, the strengthening of “green” awareness, etc. (HEP ESCO, web, 2015)

5. Conclusion

Overview of building energy efficiency in Croatia showed that most of the national building stock is consuming enormous amounts of energy. Today’s legal and strategic framework regarding the energy efficiency is well developed and harmonized with EU legislation which is a positive thing considering the fact that increasing energy efficiency is a priority for EU and thereby for Croatia. All this is a good base for implementation of energy efficiency projects.

ESCO (Energy Service Company) describes the companies that deliver the energy service or more specifically, develop, implement and provide or arrange financing for upfront energy efficiency (EE) investments for its clients. The fundamental concept of the ESCO business model is that the client does not have to come up with any upfront capital investment and is only responsible for repaying the investment made or arranged by the ESCO. Repayments are made from the energy savings. Another characteristic of the model are performance guarantees for the client. Depending on financing and risk distribution, there are three basic contract models: shared savings, guaranteed savings and “chauffage”. With the growing market variations and new business models are developing. European ESCO market is constantly growing and has a big potential for further developing and Croatia is not an exception. HEP ESCO is the main and dominant player on the Croatian market and the only public ESCO. It implements projects in buildings, public lightning, industry and energy supply systems.

This article showed that ESCO projects can achieve significant energy savings and are quality solution for improving energy efficiency. This industry sector is constantly growing but there are still a lot of barriers to overcome to exploit the full business potential. This article can serve as a good information starting point about ESCO models and can contribute in spreading awareness and information about ESCO concept. A lack of awareness, knowledge and information about this business model from potential clients, financial institutions and politics is recognised as one of the main barriers in further development of the sector so this article can contribute in overcoming this problem.

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Economic Analysis of Bike Sharing System

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Abstract

Bike riding is associated with the promotion of environmental protection and physical activity among the population. The objective of this paper is to analyse bicycle sharing system (BSS) and the potential of bicycle transport in Europe, especially in the Czech Republic. Such a system can assist to achieve the goals of development of cycling as an alternative to the public transport system. This paper highlights economic effects of bike sharing systems. Main methodology used for the economic analysis of the BSS is based on the CBA approach. The economic impact demonstrates that bike sharing generates individual fuel and parking savings while stimulating local retail and commerce in a community. Bike sharing overall provides far-reaching benefits for a community and shows itself to be well worth the initial costs. This paper assesses the costs and financing of public bicycle sharing service. The success rate of BSS is analysed from the different points of view of the relevant stakeholders. The sustainability of the system is summarized in five important aspects. A number of indicators were identified for each one of these aspects; however, not all of the aspects fit to the natural indicator. Some of the indicators relate to several aspects. They can therefore only be used as a guideline for cities that want to implement BSS, or for evaluation criteria in regard to cities that already have BSS. The conclusive chapter highlights the key factors for efficient bicycle sharing systems in Europe and give suggestions for improvement of the existing systems.

Keywords**:** Bike sharing system (BSS), congestion, the bike strategy, endogenous factors, exogenous factors

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1. National cycling development strategy of the Czech Republic

Cycling can be divided into bicycle transport a bicycle touring. Cycling is connected with the support of the environmental protection and support of physical activity of the population. From these reasons three priorities of the cycling strategy in the Czech Republic were defined.

- development of cycling as equal mean of transport,
- development of cycling as a strengthening of the environmental and health protection,
- Assurance of co-ordination with next resorts and subjects.

Partial priorities are followed by objectives and operations. Partial priority axes are mutually connected and it is possible to work with then efficiently only in the case, if they are taken as a complex. The state offers the financial support, methodological and expert co-operation in cycling infrastructure development. The cycling strategy offers the co-ordination of activities of ministries, regions, municipalities and next subjects to develop the quality and safe cycling infrastructure network and the public knowledge of cycling as alternative form of transport (Martínek, 2005).

2. Potential of cycling in Czech Republic

The Czech households owns approx. four millions bicycles (similar to number of registered personal cars – approx. 4,6 millions). Cycling industry delivers various variants of bicycles intended for the city traffic or for sport. Besides there exists quite big amount of bike rentals (e. g. the project of The Czech Railways combining the train and bike transport held nearly in all region of the Czech Republic). The projects of public bike rental are currently on the pilot level only (e. g. the Homeport system in Prague), but public financial support can lead to the extension of these systems throughout the country. Currently the rate of cycling on the total transport performance is 7 % and the objective of the state support is to reach 10 % in 2020.

The usage of bicycles is arising not only in big cities (increase in Prague in 2011 is 46 %), but also in the countryside. Mainly in big cities (Prague, Brno, Ostrava) the potential for the step increase of the rate of the cycling transport on the total transport performance exists. E. g. in Prague 29 % of respondents admits that they would use the bicycle regularly, if the conditions for the safe transport there exist. Amount of cars in centres of smaller towns is the main reason of decreasing of the bikes usage there. This trend it is necessary to stop and to reverse, also regarding worse possibility to use public means of transport and increasing prize of fuelling (www.cyklostrategie.cz).

3. Analysis of bicycle sharing system

To reach the objective of the cycling development as a equal mean of transport using the bike sharing system (BSS) is possible. BSS is the network of tens or hundreds rentals or automatic stations with special bicycles, which is possible to rent at one station and at the second to return. BSS is used mostly in big cities for short distances, resp. for short time. But the regional systems for tourism also exist. Operators if city BSS usually are organizations directly controlled by cities, which include BSS into public transport system.

Bicycle sharing should contribute to the attractiveness of city-forming properties: movement akin to walking, reduce the occupation of space compared to motorized transport and positive environmental factors such as zero noise pollution and waste products, improve physical fitness of users and increase of the traffic safety and reduce car accidents.
If there worked in 2001 only a few BSS, then in 2011 there were already around 400 worldwide. The main impetus for the creation was the launch of two major systems: Bicing in Barcelona in 2007 and Vélib 'in Paris. Central, North and South Europe are well covered by BSS networks, but the countries of Eastern Europe are not so widespread. BSS enjoys the

greatest popularity in the southern European countries that have no tradition of using bicycles. In Central and Northern Europe also operate numerous systems BSS, but the extent of their use is lower there. Countries participating in the BSS can be classified according to the degree of advancement in the use of bicycles to the following groups:

- "Experienced cyclists"
- "Budding cyclists"
- "New Partners Union (EU)“

Experienced cyclists

The use of BSS was moderate in countries with good cycling infrastructure and the relatively large share of cycling in the modal structure, such as Austria, Germany and Sweden.

Budding cyclists

BSS have become very popular in countries such as France, Italy or Spain, even though there has not been previously developed culture of everyday use of a bicycle on the way to work. Great Britain, which has a relatively small share of cycling in the modal structure, recently launched in London an extensive system BSS - Barclays System Hire, but not with him still a great experience, which could be assessed.

New Partners Union (EU)

In the countries of Eastern Europe currently operates a few BSS. Czech Republic and Poland are learning the lessons learned by others. Feedback from more developed cities and countries in the use of BSS are very important for local governments creating a new BSS in the Czech Republic or Poland (www.cyklodoprava.cz).

4. Lifetime of bikesharing systems

The most important aspects of endurance BSS can be summarized into five chapters:

- bicycle infrastructure in the city,
- accessibility to users,
- safety,
- construction of bicycle and stations,
- funding model (ownership and operation)

For each of these aspects is given a number of indicators.

4.1 Bicycle infrastructure in the city

This category includes the existence and implementation of a plan of bicycle infrastructure for the city or region, the important element is the construction and maintenance of bicycle lanes and trails, directional sign on longer stretches of bike paths, providing security solutions in place to meet with cars (eg. intersections) and hiking (both crossings for pedestrians and cyclists, or place detours bus stops) safe docking sites wheels, especially at stations and stops of urban public transport.

Indicators for bicycle infrastructure are the following categories.

In absolute terms:

- net length of bicycle lanes for bicycles on the roadway and dedicated cycle paths;
- funds invested by municipalities for construction and maintaining of the infrastructure of bicycles: road and cycle lanes on the roadway, bicycle parking, separate crossings across the road wheels, lights, mobility centres etc.

In the categories of relative indicators:

- the ratio of net favourable for the operation of bicycles in proportion to the total length of the road network;
- the share of investment resources for the development of bicycle traffic on the of total investment costs connected with roads in the city.

Usually these information are not generally available, the first step would be to gather data on individual municipalities or agglomerations.

4.2 Accessibility for users

This aspect includes all activities that facilitate the access to the system, both in time and space. It covers issues such as easiness of registration - it is a simple operation of the system on first use; the density of stations, easy access to the wheels in stations and access to stations in the vicinity of the destinations of driving; rapid repair of damaged stations and bikes, and daily and yearly opening times.

With this aspect are associated with many indicators:

- systems with stations: the number of stations / 1,000 inhabitants;
- systems without stations: number of bikes / 1,000 inhabitants;
- station density (or bike density) in application / km^2
- average number of bikes on the station;
- daily opening hours / 24 hours;
- opening hours in the year / 365 days;
- the number of repairs per total loans (per unit of time, eg. a year);
- average and maximum repair time;
- number of missing bikes at a station or unsuccessful attempts to park the bike in the destination station (with respect to the crowded station) as a percentage of total borrowings.

4.3 Safety

BSS must be safe to use. In some cities, the BSS will contribute to an increase in the number of trips made by bicycle, and the more likely it is also an increase in accidents on bicycles. In this context, it is necessary that in assessing the situation were taken into account the relative values (e.g. the number of accidents per 1,000 trips), rather than absolute values. Safety criterion applies to the entire infrastructure of bicycles, but some aspects are specific to a given system, for example localization of stations, visibility and functioning of bikes (lights, brakes, parking etc.). The station should be located in places making no difficulties to other users of roads and sidewalks. The station would also not be an obstacle for other users of

public spaces such as city cleaning vehicles, snow removal, increasing the comfort of the disabled. Safety indicators are usually following:

- the number of bicycle accidents per year / 100,000 trips made by bicycle,
- the number of fatal accidents per year / 100,000 trips made by bicycle.

4.4 Construction of a bicycle and station

An important criterion that is applied to bicycles and their components attaching to station is appropriate to their durability and resistance to vandalism and theft. However this should not mean that they are too heavy or difficult during use. Bicycles should be uniform and distinctive appearance to ensure visibility in traffic. As in the case of other means of transport is a measure to enhance the recognizability of the system and increased safety. Solid construction of public bicycle leads to the fact that they are heavier, which makes more complicated driving comparing to driving private bicycles.

Indicators for the construction of bicycles and stations:

- weight of the bicycle,
- the number of thefts per year,
- number of severe damages to bikes or stations.

4.5Model of financing

Model of funding is obviously crucial for durability BSS. Two aspects of the BSS decide on the financing model: the ambitions of the local government and the size of the system relative to the size of the city. Indicators of success in funding are:

- annual costs (capital and operating) for system with stations without stations,
- daily number of trips / on the number of sites (or wheels),
- daily number of trips as a share of all journeys on the bicycles,
- bicycle modal share in the total daily number of rides, of which at least one end in the area of the exposure of the public bicycle to ride to work, ride the leisure travel business,
- modal share of bicycles in total kilometre.

Some of these indicators are difficult to measure. Especially those that require a questionnaire survey on the rides that are not conducted annually, with regard to costs (Martínek, 2007).

5. Economic and financial analysis of BSS – case study

Economic and financial analysis of a bicycle sharing system is based on an analysis of cash flows. Total cash flows can be determined by comparing operating income (supplemented by any additional benefits expressed in monetary units), and capital and operating expenditures (again, possibly supplemented by money expressed external costs). Depending on the project's lifetime is then in analysing of cash flows taken into account the time value of money using the appropriate discount rate.

5.1 Investment expenditures

Investment cost of bike sharing system can be divided into two parts. The first part consists of investments in the stands, and other investments in the bicycles themselves. Depending on the technology used and the performance of location stands the expenses associated with one driven machine are in the range of 500 - 1000 EUR, costs per unit bicycle is then in the range of 1000 - 1300 EUR. The amount of the stands should correspond to about 1.7 times the number of bicycles. It is also necessary to count with expenditures for terminals in the unit amount of 15 000 to 20 000 EUR. The quantities of required bikes depend on the extent and nature of the territory covered bike sharing system. From long experience, however, to ensure a functional BSS implies a very dense coverage of subject areas with a sufficient number of "nests".

5.2 Operational expenditures

Operating expenses are related mainly to the need to ensure the relocation of wheels in the event of long-term accumulation of wheels under more exposed nests, with expenditures on bicycle maintenance, maintenance of stations, expenditure on ensuring of system facilities, administrative expenditure and expenditure on renewals of stations and bikes. Annual operating costs are in the range of 1000 - 2000 per bicycle.

5.3 Operation incomes

Operating revenues associated with the BSS are mainly based on payments made by users of the system. Payments for the use of BSS must be set in a way that will motivate potential users to change the transport mode to bike sharing or at least to extend the use of transport just about bike sharing. It is not just the amount of payments; also structure of options of payment offered for use of the system is important. Payments options are for single or prepaid credit loans, time limits for free use of the BSS in the case of prepaid credit are also important.

Determination of operating income should be based on detailed marketing analysis, which demonstrates the interest of potential clients for the services BSS, at the same time should provide basic information on tariffs, which clients will be willing to accept.

5.4 Economic evaluation

Economic evaluation can be based on classical analysis of cash flows, using the principle of calculating the net present value (NPV). This principle is based on the sum of the discounted cash flows associated with the implementation and operation of the BSS. The key here is choice of discount rate. In the case of a public investor can rely on recommendations of the European Commission, within the framework of a CBA Guide (Sartori, 2014), which this rate for each project type defines. In the case that the implementation of the system enters commercial entity, must be respected the cost of capital required by a private entity. In this case it is necessary to allow for substantially higher discount rate than in the case of public investment.

Part of the economic evaluation is usually also a risk analysis. It can be limited to a simple sensitivity analysis, but you can perform a more detailed qualitative and quantitative analysis of project risks. It can also recommend and handle multiple variants (neutral, optimistic, pessimistic) for the definition of "catastrophic scenarios".

5.5 Non-financial impacts

The economic assessment may include, where appropriate, primarily non-financial costs and benefits that influence the effectiveness of the project in terms of the whole society. Benefits may be perceived as such: possible increase in the share of cycling at the expense of individual car transport or by public transport and reduce traffic problems in the area, increasing traffic diversity, increase transportation options, acceleration of individual transport within the locality, promotion of healthy mode of transport and increase the prestige of the city.

Cost makes up possible injuries caused by collision of cyclists and pedestrians or cyclists and motor vehicles, parking restrictions or other activities in the areas of installation of stands, possible deterioration of sight around the stands, possible traffic problems caused by borrowing and returning bikes around the stands and lost time users in the case of an empty stand and the inability to use the bike sharing system.

Experiences from already implemented projects show that you cannot count on benefit in terms of reducing the number of cars in city centres. Bike sharing mostly used by passengers prefer the means of public transport.

5.6 Results

Economic analysis was applied to the BSS planned for implementation in Brno. They were considered two financial models and for each of these models there were defined three variants - neutral, optimistic and pessimistic, varying according to the amount of investment and operating costs. For the optimistic variant, the level of costs at the lower limit above intervals were defined, to a pessimistic variant at the upper limit of intervals and for a neutral option were considered the mean costs. The first financial model was considered as public funding, second financial model allowed for the involvement of the private partner. As an efficient variant the optimistic variant for the first and also the second financial model appeared. Other variants are economically inefficient.

6. Conclusion

The enormous growth in bike-share systems all over the world in the past ten years has done a great deal to legitimize the bicycle as the mode of choice for urban commuting. The transformation of bike-share from the informal, “free bikes for the community” system to its official integration into the city’s public transport systems is an important step in creating more equitable and sustainable cities.

Bike-share, more than any other form of urban transport, has the ability to improve and transform our cities. Bikes allow individual freedom of movement, but without the CO2 emissions, congestion, and overuse of scarce street space that cars demand. In the more than 400 cities that have implemented bike-share, more people are now experiencing the health benefits, cost savings, flexibility, and enjoyment of the city that comes with cycling. As more cities consider bike-share, cities and streets are once again becoming dynamic places for people and not just cars. It would be very interesting to seeing how bike-share continues to innovate and cities evolve with more and better practices in bike-share.

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Infusing the PRiSM™ Sustainability Framework into the IPMA Project Excellence Model

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Abstract

The purpose of this paper is to suggest to project teams selected sustainability tools from the PRiSM (Projects integrating Sustainability Methods) sustainability framework, which was introduced in 2013 by the Green Project Management Association (GPM), that seem to be the most effective in improving the project management and project performance and thus result in achieving higher scores when a project is assessed by the IPMA Project Excellence Award criteria. The analysis of the two Models resulted initially in identifying 16 topics as interface between project management excellence and sustainability. These elements of sustainability were subsequently matched to the various criteria and sub-criteria of the IPMA Project Excellence Model and their correlation was considered by the authors as important. The methodology used included as a next step the completion of questionnaires, along with personal interviews with project managers who have applied at least one of the two Models. The final results of the research indicate a significant correlation between certain sustainability elements and project and project management excellence, while highlighting key sustainability processes and the way they can be adopted by project managers and project teams in their journey to project excellence.

Keywords: PRiSM™, Green Project Management®, IPMA®, Project Excellence Model, Project Excellence Award™, sustainability

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1. Introduction

Sustainability and sustainable development are ever recurring subjects in the discussion of meeting the needs of present and future generations. In recent years, theory and praxis have both recognized a direct link between sustainability and project management practices; at the 22nd World Congress of the International Project Management Association (IPMA) in 2008, IPMA Vice-President Mary McKinlay stated in the opening keynote speech that "the further development of the project management profession requires project managers to take responsibility for sustainability" (McKinlay, 2008).

The International Project Management Association (IPMA) has established in 2002 the Project Excellence Awards in order "to increase the recognition of projects from different countries, different industries and different organizations and to motivate project teams to develop and improve project management" (www.IPMA.ch). In its nine criteria and 22 sub-criteria, sustainability is present (e.g. People results) and IPMA PE Award Assessors actually look for sustainability elements when assessing projects. However, the Model does not suggest to organizations specific tools to manage project or introduce sustainability; it is the responsibility of the Project Manager and the project team to choose the right tools and methodologies (from existing ones or develop their own), in order to achieve high performance that could then materialize in the assessment process.

The need for the development of models that provide guidelines in applying as well as measuring sustainability not only in the organization's policies but in specific projects is created. The Green Project Management Association managed to respond to that need and create the PRiSM (Projects Integrating Sustainable Methods) Model and the Global P5 Standard for Sustainability in Project Management, which is its sustainability framework. This methodology incorporates elements that are standardized by the International Standards Organization (ISO), the UN Global Compact's Ten Principles (UNGC) and Global Reporting Initiative (GRI G4) Reporting Framework and integrates them in project management processes, which can then be applied, measured and optimized in order to benefit an organization by reducing its impact on environment, economy and society.

The purpose and main objective of the research presented in this paper is to suggest to project teams selected sustainability tools from the PRiSM Model that seem to be the most effective in improving the project management and project performance. This performance can be reflected on achieving higher scores when a project is assessed by the IPMA Award criteria. Therefore, the purpose of the research is not to suggest changes in the IPMA Project Excellence Model or Assessment process, but to suggest a set of sustainable tools to improve an organization's performance in it. The findings of this research can be used as a toolbox for organizations to systematically and methodically improve their performance and forge their way to excellence.

2. Background

One conceptual starting point to define sustainable development is that it is "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Bruntland, 1987). In the last few decades significant efforts for the environmental awareness of the people have been made and new disciplines, such as ecological economics and industrial ecology, have emerged. Organizations could not be unaffected by this change. "Proactively or reactively, companies are looking for ways to integrate ideas of sustainability in their marketing, corporate communications, annual reports and in their actions" (Holliday 2001). The past chairman of Association for Project Management (APM) Tom Taylor recognizes that 'the planet earth is in a perilous position with a range of fundamental sustainability Threats and Project and Program Managers are significantly placed to make contributions to Sustainable Management practices' (Association for Project Management 2006).

It is considered important to define sustainability's possible dimensions in project management, in order to better comprehend its impacts in different aspects of it. One of the most popular definitions is that sustainability is about balancing the three pillars, the social, the environment and the economic, known as three P's (people, planet , profit) (Elkington,

1997). However, according to literature review, performed by G. Silvius and R. Schipper (2014), sustainability has more dimensions in the project management field that are listed below. Sustainability is about:

- Both short-term and long-term orientation
- Local and global orientation
- Values and ethics
- Transparency and accountability
- Stakeholder participation
- Risk reduction
- Eliminating waste
- Consuming income not capital.

The result of this review was the suggestion of a complete definition of sustainable project management. "Sustainable Project Management is the planning, monitoring and controlling of project delivery and support processes, with consideration of the environmental, economical and social aspects of the life-cycle of the project's resources, processes, deliverables and effects, aimed at realizing benefits for stakeholders, and performed in a transparent, fair and ethical way that includes proactive stakeholder participation" (G.Silvius, R.Schipper, 2014).

In the framework of the research done in the field, it was considered important by the author to determine the areas of impact that sustainability can have in project management. For this purpose a literature review was completed, following the steps of one done by G. Silvius and R. Schipper (2014). Regarding the different process groups, according to a study of Eid (2009) in_a forum of project management practitioners who were asked about their assessment of the impact of sustainable development on project management processes, it was concluded that the respondents see opportunities for the integration of sustainability in all process groups of project management. The results are shown in the chart below.

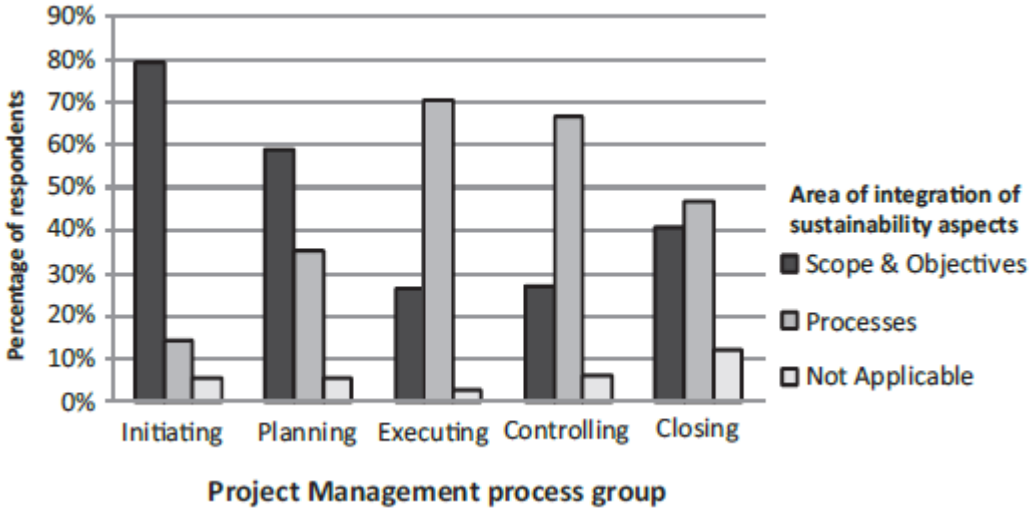

Fig. 1. Integration of sustainability aspects in project management groups (Eid, 2009)

Research so far has indicated that sustainability could have an impact on the following project management processes:

- Recognition of the context of the project
  The context of the project is one of the initial stages in Project Management. "Integrating the dimensions of sustainability in project management inevitably implies a broader consideration of the context of the project" (Silvius et al., 2012; Tharp, 2013). The long-term orientation of sustainable development contradicts the short and mid-term orientation of projects and programs. This contradiction can be resolved by understanding that a project contributes to realize long-term investment objectives" (Gareis et al., 2013).
- Project specifications/requirements/deliverable/quality criteria
  "Integrating the principles of sustainability will influence the specifications and requirements of the project's deliverable output, and the criteria for the quality of the

project" (Taylor, 2010). According to Mochal & Krasnoff (2013), Green Project Management is not suggesting new ways to gather requirements but incorporation of environmental considerations into your existing processes.

- Business Case/Costs/Benefits
  "The identification of costs, benefits and the business case of the project may need to be expanded to also include non-financial factors that refer to, for example, social or environmental aspects. Methods like the environmental impact analysis focus on ecologic aspects" (Gareis et al., 2013).
- Identification of stakeholders
  "Supporting the principles of sustainability – balancing social, environmental and economical interests, both short term and long term and both local and global – will increase the number of stakeholders of the project and in some cases, thinking green about project management will allow you to include some stakeholders that you may not have identified before." (Tharp, 2013). "Typical 'sustainability stakeholders' may be environmental protection pressure groups, human rights groups and nongovernmental organizations" (NGOs). (Silvius et al., 2012)
- Dimensions of project success
  Under the scope of the holistic approach, "it should be expected that the principles of sustainability are also reflected in the definition or perception of success of the project" (Silvius et al., 2013). According to Tharp (2013) "Integrating the principles of sustainability in the project charter will help define the result, objective, conditions and success factors of the project".
- Selection and organization of project team
  Another area of impact of sustainability is the project organization and management of the project team. However, a longer-term, sustainable focus requires the project manager to address elements such as equity quality, enhancement of work environment, education skill development and social inclusion for the project team (Tharp, 2013).
- Project sequencing and schedule
  Taylor (2010) recognizes that the consideration of sustainability in project planning, scheduling and sequencing can lead to benefits of less waste, job creation or better use of resources (for example by the offsite fabrication than onsite).
- Materials used
  An obvious impact area for sustainability in project management is the selection of materials used in the project (Silvius et al., 2012). One other impact area of sustainability in project management is the choice and rational use of materials during the project. The materials use includes the notion of life cycle assessment and therefore secures the possibility of reuse or recycle of materials. According to Crawford (2013) the consideration of sustainability in resources and procurement not only improves the carbon footprint, but also sends an important message about company's commitment to Corporate Social Responsibility, enhancing its reputation.
- Procurement
  The effect of sustainability is not related only to materials used as resources but also to processes related with procurement and supplies, by appreciating, for example the sustainability performance of potential suppliers. The values of sustainability, according to Tharp (2013) have to be reflected in procurement contracts, in areas such as bribery or child labor.
- Risk Identification and Management
  Risk management, affected by sustainability integration, needs to evolve and take into consideration environmental and social risks, following the project's life cycle and by assessing project's resources, deliverables and effects (Silvius et al., 2012).
- Stakeholder (interested parties) involvement
  The involvement and active engagement of stakeholders within the project can lead to good process results. Possible forms of this involvement could be, according to Gareis et al. (2013) periodic stakeholder information, invitations of stakeholders in analysis, planning meetings or workshops and invitation of stakeholders in initiation team.
- Project Communication
  The introduction of sustainability in project management processes would encourage proactive and open communication about the project, which could also encounter the

effects on environment and society (Taylor, 2010). The effective communication within the project will ensure, according to Tharp (2013) that stakeholders are informed about sustainability aspects of the project, their expectations are properly managed and their concerns are addressed. The project manager must also consider communication and proper engagement with extended stakeholders, for example with NGO's, activist groups or community members.

- Project Reporting
  In traditional Project Management, reports do not often consider sustainability. "Status reports should include a new section describing anything that the project encounters that is related to the environment. For example, describe any issues or risks that have an environmental impact" (Mochal & Krasnoff, 2013). "Through sustainability reporting the organization can keep track of the impacts of processes from initiation phase and organize corrective actions (Crawford, 2013).

Impact Areas	Publications											
	Pade et al. (2008)	Deland (2009)	Eid (2011)	Maltzman & Shirley (2010)	Taylor (2010)	Barnard et al. (2011)	Gareis et al. (2013)	Tharp (2013)	Silvius et al. (2012)	Crawford (2013)	Eskerod & Huemann (2013)	Mochal & Krasnoff (2013)
Recognition of the context of the project							✓	✓	✓			
Project specifications /requirements/deliverable /quality criteria	✓		✓	✓	✓	✓	✓		✓	✓		✓
Business Case/Costs/Benefits		✓	✓	✓	✓	✓	✓		✓	✓		✓
Identification of stakeholders	✓					✓		✓	✓	✓	✓	✓
Dimensions of project success	✓					✓	✓	✓	✓			✓
Selection and organisation of project team		✓	✓		✓			✓	✓	✓		✓
Project sequencing and schedule			✓	✓	✓		✓					✓
Materials used					✓	✓			✓	✓		✓
Procurement		✓	✓	✓		✓		✓	✓	✓		✓
Risk Identification and Management		✓	✓			✓	✓	✓	✓	✓		✓
Stakeholder (interested parties) involvement	✓						✓	✓			✓	✓
Project Communication	✓			✓		✓		✓	✓		✓	✓
Project Reporting		✓	✓	✓	✓	✓		✓	✓	✓		✓
Project Handover		✓			✓							
Organizational Learning					✓				✓	✓		✓

Fig. 2. Overview of the areas of impact of sustainability in project management according to various publications in the field

- Project Handover
  According to Taylor (2010), some handover aspects which could incorporate sustainability, include final testing, handover documentation, training of operators, warranties and guarantees and inspections and sign offs. According to Silvius et al. (2012) the closing processes are of significant importance in order to achieve sustainable results.
- Organizational Learning
  Organizational learning should be reviewed in order to include reports about how projects should learn ways to minimize for example waste or energy losses (Silvius et al. 2012).

In Figure 2, the areas of impact, which are identified by each one of the different publications for sustainability in project management, are synthesized and an overview of the areas of impact that are supported by the most publications, is presented.

3. Methodology

The research presented in this paper discusses selected sustainability tools from the PRiSM Model that project teams could use in order to improve project management and project performance and thus achieve higher scores when assessed by the IPMA Award criteria. The research was conducted in three phases. In the first phase, sustainability elements were selected from the PRiSM Model and their possible connection to specific criteria and sub-criteria of the IPMA Project Excellence Model was examined, always bearing in mind whether organizations could achieve higher scores at the IPMA Award criteria by implementing these sustainability practices. In the second phase, a questionnaire was formulated and in-depth interviews were conducted with experienced and certified project managers from Greece, who were aware of both models and have been strongly connected to either IPMA or GPM. The findings from the second phase helped refine the initial proposed connections of the two models. In the third phase, an updated version of the questionnaire was filled by Project Managers from Europe, North America, Australia and Africa, who have applied at least one of the two models. The questionnaire included information on both models. Overall 25 questionnaires have been collected, where the respondents were asked to evaluate on a scale from 1 to 5, with 1 being insignificant and 5 being very significant, their perception of the effect on the score in the IPMA Award criteria by the implementation of the proposed sustainability practices from PRiSM in their projects, and then comment on their responses.

The information provided in the questionnaires included the IPMA Project Excellence Model criteria and sub-criteria, and the selected sustainability elements from the PRiSM Model, as described below.

3.1. IPMA Project Excellence Model

- Criterion 1: “Project Objectives”
  1.1. "How the expectations and demands of parties involved are identified"
  1.2. "How the project objectives are developed, as well as how competitive interests are integrated on the basis of extensive and relevant information"
  1.3. "How the project objectives are imparted, realized, checked and adapted"
- Criterion 2: "Leadership"
  2.1. "How all managers set a credible example for "Project Excellence", effectively promote and actively support improvements within the project"
  2.2. "How all managers care for clients, suppliers and other organizations"
- Criterion 3: "People"
  3.1. "How the employees' potential is seen, used to achieve project results, maintained and developed"
  3.2."How all employees are involved, participate and are authorized to take independent action"
- Criterion 4: "Resources"
  4.1 "How the project plans and steers financial resources"
  4.2 "How the project plans and steers information"
  4.3 "How the project plans and steers suppliers and their services"

4.4 "How the project plans and steers other resources"

- Criterion 5: "Processes"
  5.1 "How the processes needed for the project success are identified systematically, managed, adapted and optimized"
  5.2 "How project management methods and systems are effectively adopted, how they are used and improved"
  5.3 "How the project prepares and documents past and current experiences so that other projects can benefit"
- Criterion 6: "Customer Results"
  6.1 "How customers judge the project in its achievements and results directly"
  6.2 "How customers judge the project in its achievements and results indirectly taking into account further measurements"
- Criterion 7: "People Results"
  7.1 "How employees and managers judge the project, the teamwork within the project, the achievements and project results directly"
  7.2 "How employees and managers judge the project, the teamwork within the project, the achievements and project results indirectly taking into account further measurements"
- Criterion 8: "Results of other parties involved"
  8.1 "How the other interested parties affected by the project perceive the project directly"
  8.2 "How the other interested parties affected by the project perceive the project indirectly taking into account further measurement"
- Criterion 9: "Key Performance and Project Results”
  9.1. “To what extent the project achieves its objectives.”
  9.2 "The performance of the project taking into account measurements beyond 9.1”

3.2. PRiSM Model

- Stakeholder Management
  Active engagement throughout the project, evaluation of various interest and power levels in order to develop different action plans, integration of NGOs and environmental protection groups.
- Sustainability Objectives Definition
  Definition of objectives and methods used related to the environment, the society and the economy and how they tie to organizational goals and standards (e.g. how the waste will be managed)
- Integration of Sustainability Elements in Business Case/ Charter
  Annex including references to Corporate Sustainability Governance and always reviewed from a CSR perspective by leveling the deliverables against Environmental Management Systems.
- P5 Impact Analysis- People
  Define, analyze and address project impacts regarding people and society, e.g. labor practices, human rights, strong connection with corporate social responsibility
- P5 Impact Analysis- Planet
  Define, analyze and address project impacts regarding the environmental bottom line, e.g. transportation, air emissions, energy consumption, waste etc.
- P5 Impact Analysis- Profit
  Define, analyze and address project impacts regarding the financial bottom line, include external costs when calculating returns, sustainability-based decision making process that maximize return
- P5 Impact Analysis- Product
  Define, analyze and address impacts in product throughout its lifecycle, e.g. amount of energy, recycling, raw materials used
- P5 Impact Analysis- Process
  Define, analyze and address impacts of processes in all the project phases, level of maturity and efficiency of processes to determine their level of sustainability
- Sustainability Management Plan
  Recording of sustainability objectives from the P5 analysis, scoring diagrams and indicators in order to apply changes and achieve sustainability throughout the project

- P5 and Quality Management
  Convergence with sustainability aspects in every process of quality management, avoidance of rework and energy waste by achieving success from the first time, inputs from different ISO's define the level of quality
- Sustainability Risk Management
  Sustainability Risks Identification and evaluation and integration of the results in the P5 analysis, identification of positive elements of risks within the project, benefits management
- Sustainable Approach in Human Resources Management
  Disclosure and understanding of benefits from sustainable approach through the project team, active involvement in the designation of sustainable practices, greater appreciation of the measures taken
- Green Procurement Management
  Supplier selection according to sustainability factors (recyclable materials, local markets etc.), procurement plan indicating how materials will be managed throughout the project life-cycle
- Sustainability Reporting
  Organizational Report that gives information about performance in all the key factors of the P5 analysis, communicates performance information in the organization. Bolsters organization's sustainability initiatives.
- P5 and Project Status Reporting
  Integration of reports with scoring matrix from P5 Impact analysis and reporting of changes and improvements due to this analysis throughout the project's life-cycle in order to meet sustainability goals
- P5 & Project Closeout Report
  Recording of sustainability issues that arose during the project, new areas to focus on future, measures to mitigate sustainability based risks based on the P5 analysis during the project, final project score from P5.

This information gave participants, who were familiar with only one model, the opportunity to get to know the other as well. This spread of information is also an additional objective of the research.

4. Data analysis and findings

4.1. Respondents classification and typical example of responses' analysis

In the first part of the questionnaire the responders were asked about their experience in the project management field and, based on their responses, were divided into three groups (see Table 1).

Table 1. Grouped Data – Years of Experience in project management

Groups	Description	Percentage (%)
0-4 years	Moderate	25%
4-12 years	Sufficient	20%
>12	Extensive	55%

According to the data concerning the connection with one of the two models and the certifications obtained the project managers were additionally divided into two groups: those who have been involved with the IPMA Project Excellence Model (IPMA Certified in Project Management, IPMA Project Excellence Award Assessors or IPMA Project Excellence Award Finalists) and for the purposes of this research will be called group A, and those who have been oriented towards the Green Project Management (GPM Certified) and will be called group B. Although some responders belonged to with both categories, instead of creating an additional group, the stronger connection was chosen and they were counted only in one of the two groups.

Table 2. Affiliation with the Models

Groups	Percentage (%)	Designation
IPMA oriented	52%	Group A
GPM oriented	48%	Group B

In the second part of the questionnaire the respondents were asked to evaluate on a scale from 1 to 5 their perception of the effect on the score in the IPMA Award criteria by the implementation of the proposed sustainability practices from PRiSM in their projects. In the analysis the responses were grouped into three categories, each one being represented by a different color. The first one includes the selections 1 and 2 (insignificant, very small effect on the performance) and is represented as the red color bar in the diagrams, the second one includes the selection 3 (medium effect), which is represented by the yellow color bar and, finally, the two selections of 4 and 5 (large – very large effect) are represented as green bars in the diagrams. The three different colors will be used to characterize each category. The following table shows the different groupings of the responses.

Table 3. Grouped Data – Rankings on the effect on the score in the IPMA Award criteria by the implementation of the proposed sustainability practices from PRiSM

Groups	Description	Designation
1-2	Insignificant – very small	Red
3	Medium	Yellow
4-5	Large – Very Large	Green

A typical diagram showing the grouping of the responses is presented below.

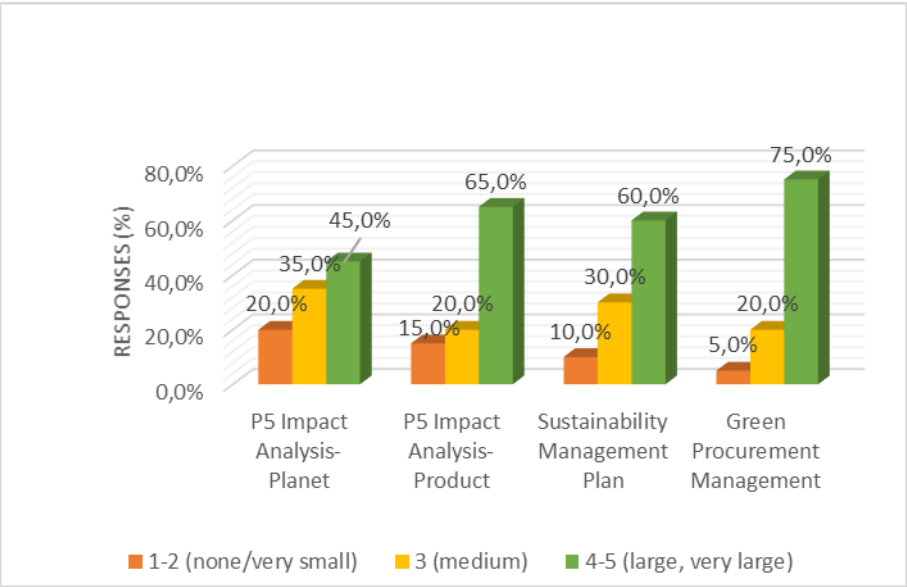

Fig. 3. Performance improvement in sub-criterion 4.4 by the integration of sustainability aspects

As indicated above, P5 Impact Analysis in Planet and Product categories, Sustainability Management Plan and Green Procurement Management were 4 sustainable practices which were considered by the authors relevant to the improvement in an Organization's performance in sub-criterion 4.4, which involves the ways a project plans and steers resources. According to the evaluation by the responders, Green Procurement Management is the element that has the highest percentages in the green category. Based on the comments from the personal interviews, it is believed by many experienced project managers that the organization and

selection of suppliers based on sustainable criteria, such as suppliers' selection from local markets or selection based on how recyclable and friendly to the environment are the raw materials they use or whether they have an active environmental management policy etc. will have a large effect on the performance in the mentioned sub-criterion. This is evident from the fact that only 5% of the responders are in the red category. The Planet category from P5 Impact Analysis has, on the other hand, the highest rates on the first two selections, the red and the yellow. Many responders have commented that there is a medium effect only in the case that the P5 Impact Analysis- Planet is performed for the suppliers; selection and organization, otherwise they do not see any direct connection to 4.4 sub-criterion. Although 55% of the responders have identified a very small or medium effect on the project performance, as obtained from the diagram, those from group A (IPMA oriented) reach 70% in these categories. The segregation of project managers based on their experience however has indicated, on this specific element, that project managers with extensive experience have selected by only 40% the yellow and red categories. The other two elements are believed by the majority of the responders to have a medium or large effect on the performance in excellence. It was commented during the interviews that the Sustainability Management Plan can affect in a large scale the way supplies are organized, ordered and stored, by an extensive organizing plan from the initiation phase of the project and by minimizing waste and losses.

4.2. Proposal of implementation of PRiSM elements in Criterion 1 "Project Objectives" of the IPMA PE Model

Based on the responses regarding the first criterion ("Project Objectives") of IPMA Project Excellence Model, the key elements that have the most noticeable effect in it and its sub-criteria are analyzed here.

One of these sustainability elements from the PRiSM Model that affects an organization's performance towards excellence, especially in sub-criterion 1.2 ("How the project objectives are developed, as well as how competitive interests are integrated on the basis of extensive and relevant information") is the definition of the Sustainability Objectives and their connection to organizational goals, as 95% of the responses are in the yellow and green categories.

Sustainability Risk Management as well as the integration of Sustainability Elements in the Business Case are believed by a 75% of the responders to affect in a large or very large degree (green column) the performance, especially in 1.2 sub-criterion.

Additionally, the introduction of sustainability in Stakeholder Management with the active participation of stakeholders as well as the involvement of new environmental groups is, as pointed out by the personal interviews, of vital importance in order to achieve excellence, and this is recognized by a 95% of the responders in green and yellow categories. A few have also pointed out the use of Level of Interest/ Power to Influence Matrix in balancing the different interests of stakeholders, which is also proposed by the PRiSM Sustainability Model.

Regarding the elements of the P5 Impact Analysis, they appear in lower percentages in sub-criterion 1.2 than in 1.3 ("How the project objectives are imparted, realized, checked and adapted"). It is noticeable that the majority of the responses in the red section (rates 1 and 2) are given by group A (IPMA related responders). This can be partly justified, because, according to the comments received, the P5 Impact Analysis has a stronger connection to the ways project objectives can be realized and improved than in the formulation of them.

In sub-criteria 1.2 and 1.3 it is generally noticed, in all the sustainability elements proposed, that the rating given by project managers with extensive experience (>12 years) is higher than the average and a rise from 10% to 25% of the responses in green category is reported. This is indicated in the diagram below.

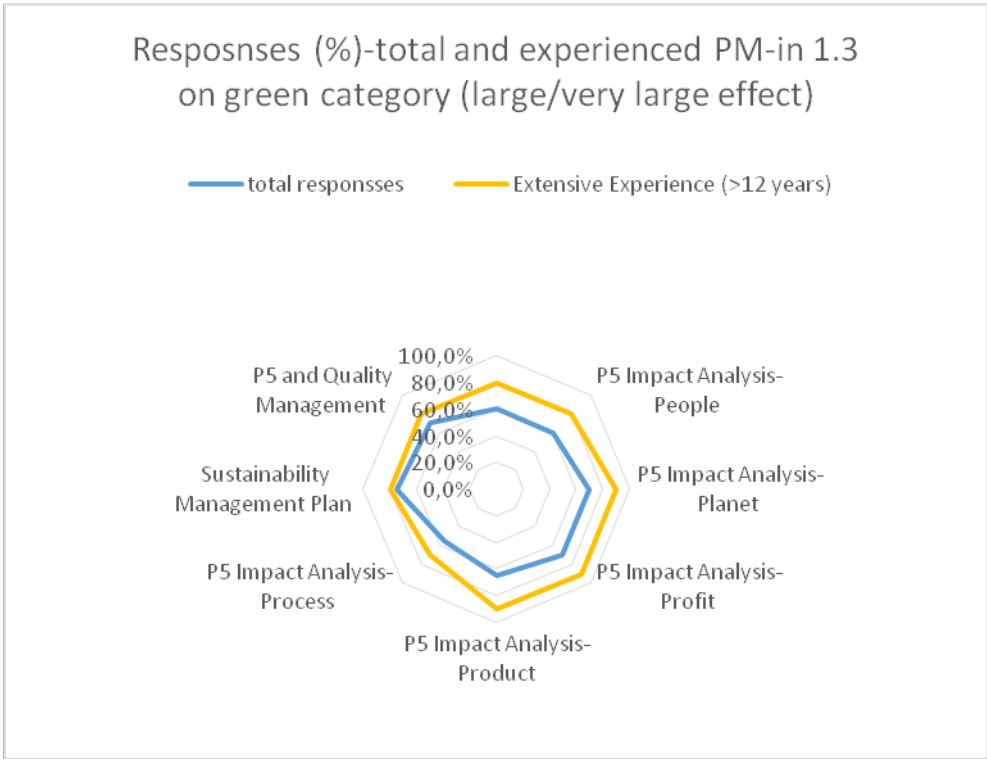

Fig. 4. Responses of project managers with extensive experience (>12 years) compared to total ones regarding the evaluation on the level of improvement in sub-criterion 1.3 by the integration of sustainability elements

In the table below, the sustainability elements that have been reported from the analysis of the responses as having a large effect (depicted in gold colour) or medium effect (depicted in silver colour) in one or more of the sub-criteria of criterion 1 are listed. The same colour depiction was used for all criteria.

It must be noted that in the analysis, the differences in the responses from experienced project managers were deemed to have more weight for the final proposal of implementation of PRiSM elements in each Criterion of the IPMA PE Model.

Table 4. Sustainability elements that have a medium (silver) or large (gold) effect according to the analysis of the responses in Criterion 1.

CRITERION 1 "PROJECT OBJECTIVES"			
Sustainability Elements	**1.1**	**1.2**	**1.3**
Sustainability in Stakeholder Management	*LARGE EFFECT*		
Sustainability Objectives Definition		*LARGE EFFECT*	*MEDIUM EFFECT*
Integration of Sustainability Elements in Business Case/ Charter		*LARGE EFFECT*	
P5 Impact Analysis – People		*LARGE EFFECT*	*MEDIUM EFFECT*
P5 Impact Analysis – Planet		*LARGE EFFECT*	*LARGE EFFECT*
P5 Impact Analysis – Profit		*MEDIUM EFFECT*	*LARGE EFFECT*
P5 Impact Analysis – Product		*MEDIUM EFFECT*	*LARGE EFFECT*
P5 Impact Analysis – Process		*MEDIUM EFFECT*	*MEDIUM EFFECT*
Sustainability Management Plan		*LARGE EFFECT*	*LARGE EFFECT*
P5 and Quality Management		*MEDIUM EFFECT*	*LARGE EFFECT*
Sustainability Risk Management		*LARGE EFFECT*	

4.3. Proposal of implementation of PRiSM elements in Criteria 2 – 9 of the IPMA PE Model

The following Tables show the proposed sustainability elements from the PRiSM Model into each of the remaining Criteria (2 to 9) of the IPMA PE Model, in order for a project to achieve higher scores when assessed by these criteria.

Table 5. Sustainability elements that have a medium (silver) or large (gold) effect according to the analysis of the responses in Criterion 2.

CRITERION 2 "LEADERSHIP"		
Sustainability Elements	**2.1**	**2.2**
Sustainable Approach in Human Resources Management	*LARGE EFFECT*	

Table 6. Sustainability elements that have a medium (silver) or large (gold) effect according to the analysis of the responses in Criterion 3.

CRITERION 3 "PEOPLE"		
Sustainability Elements	**3.1**	**3.2**
P5 Impact Analysis- People	*MEDIUM EFFECT*	
Sustainable Approach in Human Resources Management	*MEDIUM EFFECT*	*LARGE EFFECT*

Table 7. Sustainability elements that have a medium (silver) or large (gold) effect according to the analysis of the responses in Criterion 4.

CRITERION 4 "RESOURCES"			
Sustainability Elements	**4.1**	**4.3**	**4.4**
P5 Impact Analysis-Profit	*LARGE EFFECT*		
Green Procurement Management	*MEDIUM EFFECT*	*LARGE EFFECT*	*LARGE EFFECT*
P5 Impact Analysis – Planet			*MEDIUM EFFECT*
P5 Impact Analysis – Product			*MEDIUM EFFECT*
Sustainability Management Plan			*LARGE EFFECT*

Table 8. Sustainability elements that have a medium (silver) or large (gold) effect according to the analysis of the responses in Criterion 5.

CRITERION 5 "PROCESSES"			
Sustainability Elements	**5.1**	**5.2**	**5.3**
P5 and Quality Management	*LARGE EFFECT*		
P5 Impact Analysis – Process	*MEDIUM EFFECT*		
Sustainability Risk Management		*LARGE EFFECT*	
P5 and Project Status Reporting		*LARGE EFFECT*	*LARGE EFFECT*
P5 & Project Closeout Report			*LARGE EFFECT*

Table 9. Sustainability elements that have a medium (silver) or large (gold) effect according to the analysis of the responses in Criterion 6.

CRITERION 6 "CUSTOMER RESULTS"		
Sustainability Elements	**6.1**	**6.2**
P5 Impact Analysis – People	*LARGE EFFECT*	
P5 Impact Analysis – Product	*LARGE EFFECT*	*LARGE EFFECT*

Table 10. Sustainability elements that have a medium (silver) or large (gold) effect according to the analysis of the responses in Criterion 7.

CRITERION 7 "PEOPLE RESULTS"		
Sustainability Elements	**7.1**	**7.2**
P5 Impact Analysis – People	*MEDIUM EFFECT*	*LARGE EFFECT*
Sustainable Approach in Human Resources Management	*LARGE EFFECT*	

Table 11. Sustainability elements that have a medium (silver) or large (gold) effect according to the analysis of the responses in Criterion 8.

CRITERION 8 "RESULTS OF OTHER PARTIES INVOLVED"		
Sustainability Elements	**8.1**	**8.2**
Stakeholder Management	*LARGE EFFECT*	*LARGE EFFECT*

Table 12. Sustainability elements that have a medium (silver) or large (gold) effect according to the analysis of the responses in Criterion 9.

CRITERION 9 "KEY PERFORMANCE AND PROJECT RESULTS"	
Sustainability Elements	**9.2**
Sustainability Risk Management	*LARGE EFFECT*
P5 Impact Analysis – People	*MEDIUM EFFECT*
P5 Impact Analysis – Planet	*MEDIUM EFFECT*
P5 Impact Analysis – Profit	*LARGE EFFECT*
Sustainability Reporting	*LARGE EFFECT*

5. Conclusions

After the analysis of the responses it was generally noticed that project managers from group A (IPMA oriented) were more hesitant and reserved. This is evident in questions where the red category (insignificant-very small effect) rises up to 20%-30% and responders from group A make up about 30%-40% (a 10% rise on the average) of the total responses. This can be related to the fact that some of the sustainability elements are already integrated in IPMA Project Excellence Model and therefore their effect was considered very small by group A. However the purpose of the research is not to investigate the level of integration of sustainability elements from the PRiSM Model into the IPMA PE Model or to suggest new sustainability inputs to the existing model, but to evaluate the level of improvement in the scores an organization could achieve when assessed by the IPMA PE Award criteria, by implementing the suggested sustainability practices.

The years of experience have affected the fluctuation of the responses the opposite way. In responses with high rates in the red and yellow category, the responses of project managers with extensive experience (12 or more years) have been by a 70% in the green category (about 10% to 15% higher than the average). Finally, regarding the gender of the responders, no variation was noticed in the responses between male and female.

As shown in Tables 4 to 12, each selected PRiSM sustainability element has a different effect on IPMA PE Model criteria. Some sustainability elements have a large effect on many criteria, while others have a large or medium effect on fewer. An example of large effect on many criteria is the following: regarding the effect of P5 Impact Analysis, it was generally observed that it has a larger effect on the initiation phase of the project, in the stage of project objectives (Criterion 1) and especially in the ways they are developed and then imparted, checked and adapted, than in the stage of executing (Criterion 5 "Processes"). It has a considerably large effect also in the criteria related to results and especially affects an organization's performance, regarding project and people results (Criteria 7 & 9). Another example is the effect of the sustainability elements connected to parties involved in the project is considered very large by the majority of the responders. The integration of sustainability in Stakeholder Management, with the active involvement of stakeholders and the integration of

sustainability related parties (NGO's, environmental protection groups etc.) can affect an organization's performance in the award in a very large degree, both in the objectives category in sub-criterion 1.1 (which involves the identification of expectations of interested parties) and in the results of other parties on how the perceive the project directly and indirectly. The Sustainable Approach in Human Resources Management with the active engagement of employees in decision making can improve in a large degree the performance in 2.1 (which involves the actions taken by the project manager within the project team), in 3.1 and 3.2 (which involve how the employees 'potential is seen and used and how they are involved and authorized to take independent action) as well as in 7.1 (which involves what the project achieves regarding the satisfaction and expectations of the employees involved), as reported by over 65% of the responders. It is actually acknowledged by many, during personal interviews that, the employees' empowerment to make decisions and take independent action is the key to this criteria, therefore developing culture through Human Resource Management is substantial.

Further research is needed on the field by using a larger number of respondents, by segmenting the responses by project type, and finally by implementing the proposed practices in projects and getting feedback.

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PAPERS IN CROATIAN

Obnova zgrada na poplavljenim područjima u Slavoniji

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Sažetak

Tijekom mjeseca svibnja 2014. godine, na području Vukovarsko-srijemske županije dogodile su se poplave koje su svojim opsegom, intenzitetom i neočekivanošću ugrozile zdravlje i živote većeg broja ljudi, imovinu te okoliš. Vodni val je zahvatio različitim intenzitetom šest mjesta: Račinovci, Rajevo selo, Gunja, Strošinci, Đurići i Posavski Podgajci. Ukupno, po početnim podatcima radi se o građevinskim štetama na 2.689 obiteljskih kuća, 4.713 pomoćnih i gospodarskih zgrada te 32 zgrade javne namjene, s procijenjenom vrijednosti štete od 1.17 mlrd. kn, uz štete u poljoprivredi i infrastrukturi.

Ministarstvo graditeljstva i prostornoga uređenja je prema posebno donesenom *Zakonu o saniranju posljedica katastrofe na području Vukovarsko-srijemske županije*, zaduženo za provedbu organizirane obnove zgrada. Na terenu je zatečena neorganizirana lokalna uprava, neriješeni vlasnički odnosi i neuredni registri građana. Problematiku s tehničke strane predstavljale su preizgrađene parcele i različiti tipovi građe kuća. Osim navedenog, karakteristika ove poplave bilo je dugotrajno natapanje podova i zidova zgrada sa zagađenom vodom, što je zahtijevalo poseban pristup sanaciji.

Obnovu je trebalo organizirati i voditi kao složeni projekt od velikog broja sudionika, uz postavljene ciljeve: brza reakcija – brza obnova – brzi povratak ljudi. Početna faza projekta obnove bila je ključna za uspješnu realizaciju. Izrada strukture raščlanjenih poslova, analiza kritičnog puta i ograničenja, te analiza optimalnih sudionika uz projektni pristup procesima organizirane obnove kao i ranije stečena iskustva s poslijeratnom obnovom, omogućila su planiranu realizaciju prema ispunjenju postavljenih ciljeva. Iskustva iz ovog projekta trebala bi poslužiti za efikasnije postupanje pri sličnim katastrofalnim situacijama.

Ključne riječi: katastrofa; poplava; građevinske štete; obnova zgrada; upravljanje projektom

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1. Uvod

Tijekom mjeseca svibnja 2014. godine, na području Vukovarsko-srijemske županije dogodile su se poplave koje su svojim opsegom, intenzitetom i neočekivanošću ugrozile zdravlje i živote većeg broja ljudi, imovinu te okoliš. Na ukupno branjenoj dionici od 210km, 17. svibnja 2014. došlo je do proloma nasipa na području mjesta Račinovci u 14,55 sati i Rajevog sela u 15,12 sati, DUSZ, 2014. Vodni val je zahvatio različitim intenzitetom šest mjesta: Račinovci, Rajevo selo, Gunja, Strošinci, Đurići i Posavski Podgajci. Ukupno, po početnim podatcima iz Državne geodetske uprave (u daljnjem tekstu: DGU) poplavom je bilo zahvaćeno 2.689 obiteljskih kuća s 4.713 pomoćnih i gospodarskih zgrada te 32 zgrade javne namjene, s preliminarno procijenjenom vrijednosti štete od 1.17 mlrd. kn, uz štete u poljoprivredi i infrastrukturi, Vlada RH, 2014.

Slijedom tih događaja Vlada Republike Hrvatske (u daljnjem tekstu: Vlada) je na sjednici održanoj 20. svibnja 2014. donijela Odluku o proglašenju katastrofe za područje Vukovarsko-srijemske županije, kako bi što žurnije započeo postupak saniranja posljedica koje nije bilo moguće spriječiti i otkloniti redovnim djelovanjem nadležnih tijela. A nakon te Odluke, još niz posebnih odluka kojima su se donosile mjere nužne za hitno djelovanje u području zaštite ljudskog zdravlja i imovine. U međuvremenu, s obzirom na opseg i intenzitet nastalih posljedica, pristupilo se izradi posebnog zakona, kojim se propisuju mjere, aktivnosti i prava radi učinkovitog i sveobuhvatnog saniranja posljedica katastrofe na području Vukovarsko-srijemske županije koje je pogođeno poplavom.

Zakon o saniranju posljedica katastrofe na području Vukovarsko-srijemske županije (NN 77/14) (u daljnjem tekstu: Zakon) izglasan je u Hrvatskom Saboru 18. lipnja 2014., a sadrži potrebni okvir za donošenje i provedbu mjera u području zaštite zdravlja ljudi, graditeljstva - obnova stambenih i gospodarskih zgrada te zgrada javne namjene, u području porezno - dužničkih odnosa, poduzetništva i obrta, prometne infrastrukture, poljoprivrede i veterinarstva, rada i mirovinskoga sustava, pravosuđa, obrazovanja, prava hrvatskih branitelja iz Domovinskog rata i zaštite kulturnih dobara, Sabor RH, 2014. Posebno se uređuje način privremenog smještaja stradalnika za vrijeme obnove stambenih zgrada, a uređuju se i pitanja deponiranja mulja, glomaznog otpada i ostalih naplavina te drugo.

Temeljem usvojenog Zakona, Vlada je po hitnom postupku donijela programe obnove i saniranja posljedica katastrofe, na prijedlog nadležnih središnjih tijela državne uprave. Tako je na prijedlog Ministarstva graditeljstva i prostornog uređenja (u daljnjem tekstu: MGIPU), na sjednici Vlade 03. srpnja 2014. usvojen Program obnove i saniranja posljedica katastrofe na području Vukovarsko srijemske županije – obnova zgrada (u daljnjem tekstu: Program), Vlada RH, 2014.

Opisanim zakonodavnim okvirom, donesenim u rekordnom vremenu, omogućeni su efikasniji postupci djelovanja državne uprave i javnih poduzeća te žurna sanacija posljedica katastrofe.

2. Priprema za obnovu zgrada

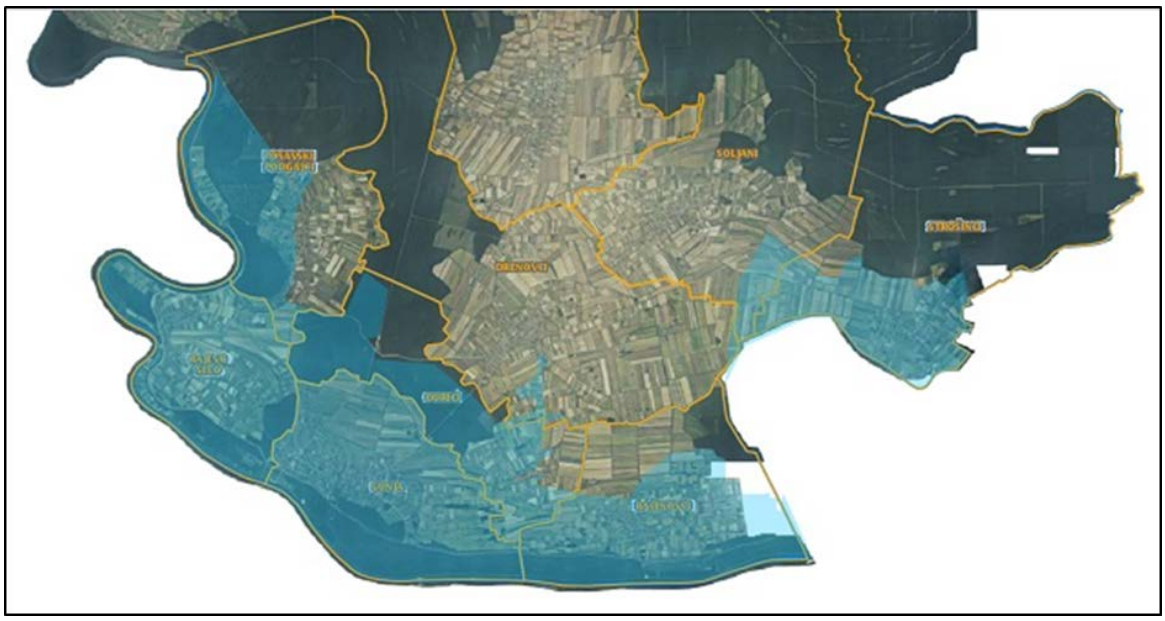
Obnova nakon djelovanja katastrofe, predstavlja specifični i zahtjevni projektni zadatak. Iz tog razloga je za uspješno provođenje iste, potrebno primijeniti principe upravljanja projektima. Ukoliko znamo da je projekt pothvat ograničen vremenom i troškom, koji mora doseći određeni rezultat prema zahtjevima i standardima kvalitete, HUUP 2008., slijedi priprema prema postavljenim ciljevima. Svaki projekt ima svoj životni ciklus i u njemu nekoliko faza: početna faza, faza provedbe i završna faza, Omazić i Baljkas, 2005. Kako bi projekt ispunio zadane ciljeve, nužna je kvalitetna priprema i sagledavanje mogućih prepreka u provedbi, Olsson, 2006.

Početna faza projekta obnove zgrada obuhvaćala je sljedeće aktivnosti:

1. Snimak obuhvata i obima šteta;
2. Definiranje ciljeva obnove;
3. Izrada strukture raščlanjenih poslova;
4. Analiza kritičnog puta i kritičnih ograničenja u obnovi;
5. Analiza optimalnih sudionika i opreme u realizaciji obnove i
6. Analiza potrebne zakonodavne potpore za provedbu obnove.

2.1. Snimak obuhvata i obima šteta

Početni podatci o obuhvatu i obimu šteta na zgradama prikupljani su indirektno i direktno. Indirektno uz pomoć DGU, digitalnim preklapanjem katastarskih podataka o česticama i zgradama, sa zračnom snimkom poplavljenih područja na dan velike vode (21.05.2014.) i orto-foto snimkom istog područja (Ilustracija 1.).



Ilustracija 1. – Obuhvat poplavljenog područja

Direktno su prikupljeni podatci za stjecanje osnovne slike o obuhvatu i obimu šteta, terenskim izlaskom službenika Uprave za inspekcijske poslove, Ministarstva graditeljstva i prostornoga uređenja (u daljnjem tekstu: MGIPU). Pri tome, početni boravak u poplavljenom području bio je otežan zbog nužnih mjera zaštite zdravlja (Ilustracija 2.).

Ilustracija 2. – Mjere zaštite na izlasku iz poplavljenog područja

Tako prikupljeni početni podatci dali su osnovnu sliku o obimu oštećenjima zgrada u šest mjesta: Račinovci, Rajevo selo, Gunja, Strošinci, Đurići i Posavski Podgajci, i ukupno zahvaćenih 2.689 obiteljskih kuća s 4.713 pomoćnih i gospodarskih zgrada te 32 zgrade javne namjene.

Nakon dobivenog broja zgrada koje su zahvaćene poplavom, te usporedbe s terenskom snimkom procijenjenog stupnja oštećenja po mjestima, izvršena je kategorizacija građevinskih oštećenja na zgradama. Analizom su identificirane četiri kategorije oštećenja prema visini vodnog lica poplave (VLP) i potrebnim građevinskim zahvatima za popravak:

I. kategorija – zgrade za koje je utvrđena maksimalna VLP na razini do uključivo 0,90 metara iznad kote ulaznog prostora u zgradu i koja ne zadovoljava kriterije propisane za IV kategoriju – potrebni manji radovi po obimu i složenosti;

II. kategorija – zgrade za koje je utvrđena maksimalna VLP na razini višoj od 0,90 metara, a da nije zahvaćen niti jedan dio krovne konstrukcije i koja ne zadovoljava kriterije propisane za IV kategoriju – potrebno više jednostavnih radova i ev. izmjena prozora;

III. kategorija – zgrade za koje je utvrđena maksimalna VLP na takvoj razini da je zahvaćen bilo koji dio konstrukcije krova nad tlocrtnim gabaritima zgrade i koja ne zadovoljava kriterije propisane za IV kategoriju – potrebno više radova različite složenosti i radova na konstruktivnim dijelovima zgrade;

IV. kategorija – zgrada koja zbog djelovanja poplave ili zbog posljedica djelovanja poplave ima nedostatke ili građevinska oštećenja zbog kojih nisu više ispunjeni temeljni zahtjevi za građevinu te stoga nije prikladna za uporabu – izgradnja nove zamjenske zgrade;

Naknadno se u toku provedbe obnove pojavila potreba za dodatnom **0. kategorijom** oštećenja zgrada, koje su imale poplavljene podrume ili/i pojavu kapilarnog uzdizanja vode preko nadtemeljnih zidova te oštećenja u prostorijama za boravak ljudi ili stvari i životinja.

Dva su parametra u obnovi uočena kao specifična, zbog kojih je trebalo posebno voditi računa u pripremi:

1. Trebalo je imati u vidu specifičnost ove poplave koja je nastala od proboja nasipa i kao takva se desila u području koje nije bilo plavljeno ranije, ali i voda koja se proširila područjem nije mogla otjecati. Posljedica zadržavanja vode nekoliko tjedana je natapanje zidova i obloga zagađenom vodom iz staja, septičkih jama i crkotina.

2. Trebalo je voditi računa o tri oblika građevnog materijala koji je upotrebljavan na tom području: ćerpiči, pečena opeka vezana blatom i klasična gradnja pečenom opekom koja je vezana cementnim mortom. Naime, u kući koja je građena iz ćerpiča (nepečena glina miješana sa slamom i prirodno sušena) kada se natapa vodom dolazi do razgradnje nosivih zidova. Takva kuća može na prvi pogled izgledati kao da je potrebna manja sanacija, međutim ona je izgubila svojstva mehaničke otpornosti i stabilnosti te je istu potrebno u potpunosti ukloniti i izgraditi zamjensku. Slična situacija je i s kućama koje su građene iz pečene opeke gdje je za vezno sredstvo korišteno blato. Dakle, i relativno nisko VLP može u potpunosti uništiti loše građenu kuću (ilustracija 3.).

Analizom karakteristične obiteljske kuće iz promatranog područja, i mogućeg oštećenja po kategorijama, te osnovnih vrsta radova na sanaciji ili izgradnji nove obiteljske kuće, procijenjeni su troškovi po kući. Nastavno, prema prikupljenim početnim podatcima izvršena je orijentaciona raspodjela jediničnih troškova i dobiven preliminarni ukupni trošak za obnovu zgrada u iznosu od 1.17 mlrd. kn, Vlada 2014.

Ilustracija 3. – Tradicionalna oštećena kuća iz čerpića

U pripremnoj fazi, MGIPU se javila Hrvatska komora inženjera građevinarstva (u daljnjem tekstu: HKIG) i ponudila usluge svojih članova na volonterskoj bazi. Postignut je dogovor, koji je kasnije formaliziran u vidu Sporazuma o suradnji (09.06.2014.), prema kojem su članovi HKIG volontirali jedan radni dan, a HKIG je donirala prijevoz inženjerskih grupa i izradu računalne aplikacije za troškovnike sanacije, dok je MGIPU organizirao kretanje na terenu i dnevnu okrjepu. Temeljem tog sporazuma HKIG i MGIPU su organizirali tehničko snimanje zgrada i obradu podataka što uključuje: izlazak na teren timova inženjera (po dvojica) i određivanje nužnih radova sanacije na zgradama (obiteljskim kućama s pomoćnim i gospodarskim zgradama), izmjera količina, evidentiranje u pripremljene obrasce, fotodokumentacija i kratki opis zatečenog stanja. Nakon što su timovi građevinskih inženjera obišli teren, drugi dan su se podaci iz zapisnika organizirano u Centru za obradu podataka pri HKIG, unosili u el. bazu koja automatikom povezuje količine s stavkama troškovnika za izvođenje radova. Takvom organizacijom inženjeri nisu gubili vrijeme na unos podataka i može se pratiti napredak i troškovi sanacije s jednog mjesta. Uključivanje HKIG prije donošenja Zakona je bilo od velikog značenja za ubrzanje obnove, ali i kao psihološka podrška svim mještanima koji su napustili svoje domove, jer su kroz pojavu inženjerskih ekipa na terenu vidjeli da organizirana obnova kreće. Kasnije, po donošenju Zakona, uvedene su posao izrade snimaka stanja ugovorne tvrtke sa ciljem ubrzanja postupanja na terenu.

Slična suradnja je ostvarena sporazumno i s Hrvatskom komorom arhitekata za volontersku provedbu natječaja za odabir tri tipska projektna rješenja za zamjenske nove kuće (27.06.2014.).

2.2. Definiranje ciljeva obnove

U poplavom zahvaćenim zgradama nastala su oštećenja zbog kojih je stanovništvo evakuirano, te je smješteno u privremeni smještaj. Primarno, nastala oštećenja bilo je potrebno sanirati i dovesti zgrade u funkcionalno stanje kako bi zgrada bila primjerena za stanovanje i korištenje, te kako bi se u iste što prije mogli vratiti njihovi korisnici, i kako bi se postigla normalizacija životnih uvjeta. Trebalo je postići brzu obnovu kako bi se što više mještana uspjelo vratiti svojim kućama prije dolaska zime.

Ujedno, nova stambena zgrada treba biti tako projektirana i izgrađena da bude najmanje energetskog razreda B, čime bi se doprinijelo ispunjenju europskog cilja za smanjenjem

utroška toplinske energije i smanjenjem štetnih emisija, Europska komisija, 2105. Republika Hrvatska kao država članica preuzela je obavezu aktivno doprinositi europskim ciljevima i to s konkretnim pokazateljima, te je prepoznata prilika da se kroz organiziranu obnovu izvrši dodatni napor i realizira doprinos.

Postavljen je još jedan ekološki cilj, za uklanjanje azbestno-cementnih (salonit) ploča pokrova na zgradama, odnosno smanjenje prisustva azbesta u prostoru. Slijedom tog cilja uklanjat će se sav salonitni pokrov sa zgrada zahvaćenih poplavom i postaviti zamjenski laki pokrov. Ova zamjena pokrova smatrat će se pilot-projektom prema točki 7. Zaključaka sa zajedničke tematske sjednice Odbora za zaštitu okoliša i prirode, klase: 351-01/13-02/19, ur. broja: 6521-29-14-19, i Odbora za zdravstvo i socijalnu politiku, klase: 022-03/14-01/50, ur. broja: 6521-10-14-03, Hrvatskog sabora, pri čemu se prikupljaju podaci o provedbi istog.

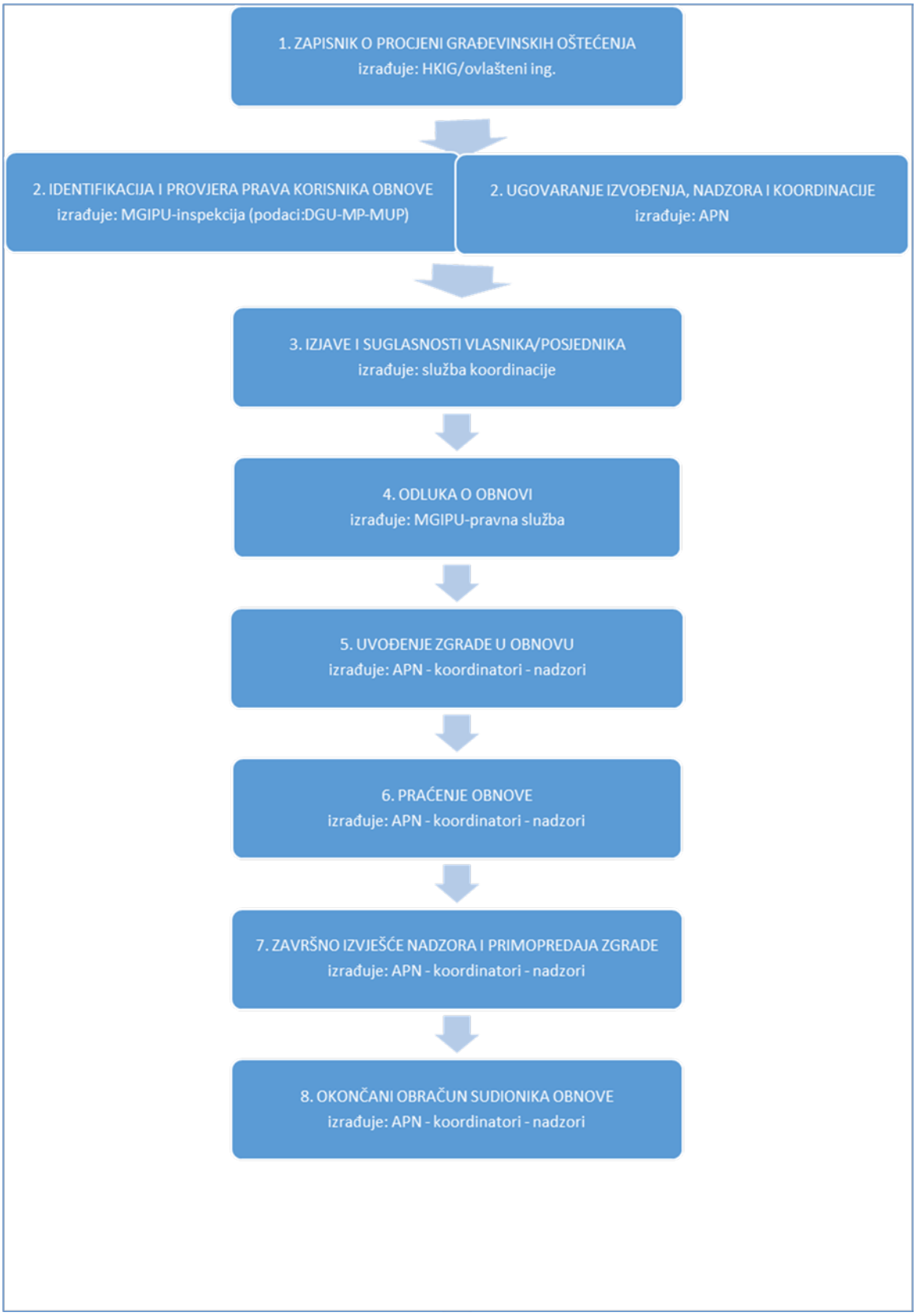
Kao jedan od ciljeva postavljeno je i aktiviranje lokalne građevinske operative na radovima u obnovi.

2.3. Izrada strukture raščlanjenih poslova

Na temelju dosadašnjih iskustava iz upravljanja građevinskim projektima i vođenja Programa poslijeratne obnove, te postavljenih ciljeva, odlučeno je za prve dvije kategorije oštećenja zgrada omogućiti korisnicima obnove odabir da li će preuzeti fiksna sredstva i u vlastitoj organizaciji izvršiti popravke na zgradama, ili će odabrati organiziranu obnovu putem ugovornih izvođača. Cijelo vrijeme planiranja vodilo se računa o psihološkim efektima i stanju korisnika obnove.

Posebno je u suradnji s Institutom - IGH, napravljena analiza radova i materijala na sanaciji poplavljenih zgrada, te je predložena tehnologija za sanaciju.

U nastavku je prikazan hodogram aktivnosti za sanaciju zgrada u organiziranoj obnovi od I. do III. kategorije oštećenja (Ilustracija 4.).



Ilustracija 4. – Hodogram aktivnosti za sanaciju zgrada I. – III. kat. oštećenja

2.4. Analiza kritičnog puta i kritičnih ograničenja u obnovi

Slijedom preliminarnog uvida u stanje šteta, definiranja ciljeva obnove i strukture raščlanjenih poslova, pristupilo se analizi kritičnog puta i kritičnih ograničenja u obnovi. Dosadašnja iskustva iz vođenja sličnih projekata upućivala su na sljedeća ograničenja:

- *Postupci javne nabave* – dugotrajna procedure za veliku javnu nabavu s neizvjesnim rokom završetka s obzirom na moguće žalbene postupke;
- *Upravni postupci za izdavanje odobrenja za obnovu korisnicima obnove* – opterećenje izmorenih i stradalih korisnika obnove u ishođenju potrebne dokumentacije kojom dokazuju svoje pravo na obnovu, te rješavanje predmeta prema načelima upravnog postupka s pripadnim zakonskim rokovima;
- *Vrijeme potrebno za projektiranje i ishođenje građevinskih dozvola* – prema važećim zakonskim odredbama;
- *Vremenski uvjeti i tehnološki zahtjevi za izvođenje radova* – s obzirom da se radi o vodom (zagađenom) natopljenim zidovima i podovima zgrada, potrebno je provesti otvaranje zidova kako bi se mogli isušiti, pranje i dezinfekcija, sušenje te popravak i vračanje uklonjenih slojeva (fasade, žbuke, glazure). Poseban hodogram aktivnosti je za sanacije, a poseban za izgradnju nove zamjenske kuće.

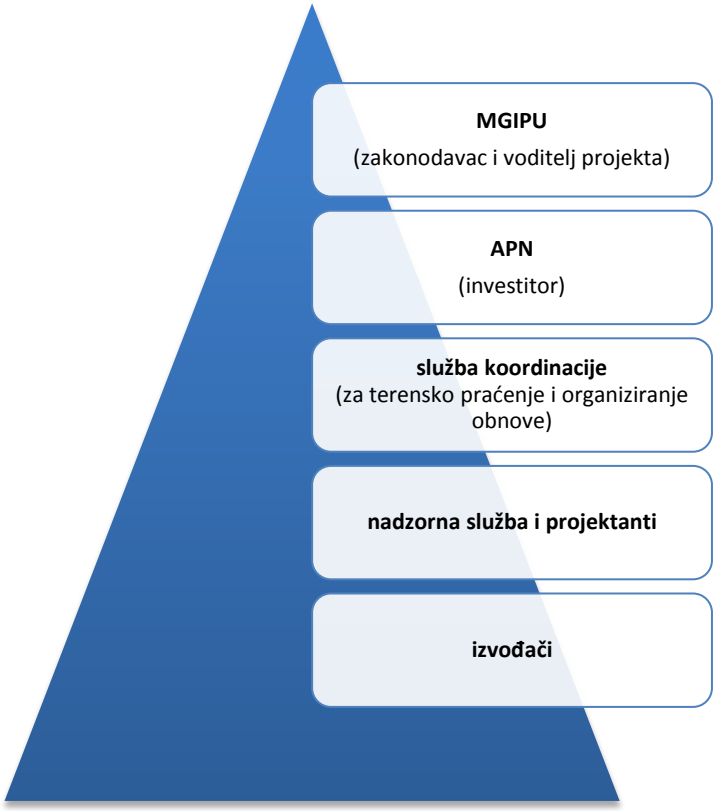
2.5. Analiza optimalnih sudionika i opreme u realizaciji obnove

U sljedećem koraku analizirani su optimalni sudionici i računalne aplikacije za provedbu i praćenje obnove. Organizaciona shema je postavljena (ilustracija 5.) s dvije službe za koordinaciju na terenu koje su preuzele svaka po približno polovicu zgrada za sanaciju, i to ITVZ (u Gunji) i Institut - IGH (u ostalih 5 mjesta). Služba koordinacije zadužena je za koordiniranje svih aktivnosti obnove na terenu i komunikaciju s korisnicima obnove. Za investitora koji će provoditi javne pozive za nabavu roba i usluga, iste ugovarati, isplaćivati i pratiti u realizaciji, odabrana je javna ustanova Agencija za pravni promet i posredovanje nekretninama (APN) s obzirom na stručnu ekipiranost i iskustvo u gradnji, te uključenost u sustav PDV-a. MGIPU usmjerava obnovu, daje tumačenja propisa, prati dinamiku realizacije, priprema liste korisnika obnove koje koordinatori pozivaju na davanje - Izjava o obnovi (uključenje u obnovu), odobrava pokretanje procesa obnove - Odlukom o obnovi, komunicira s drugim državnim tijelima u vezi obnove. Posebno se vodi briga o informiranju građana, tako da se na Web stranici MGIPU nalaze sve relevantne informacije u vezi obnove, otvoren je i info telefon, te su štampani letci s osnovnim informacijama o pravima i tijeku obnove.

Zasebna koordinacijska služba je postavljena za obnovu zgrada javne namjene.

Za praćenje tijeka obnove, ali i za potporu u donošenju Odluka o obnovi, izrađena je posebna geoinformatička aplikacija u suradnji s APIS-IT d.o.o. Aplikacija je nazvana eObnova i sadrži podatke MUP-a o prebivalištima osoba, podatke iz zemljišnih knjiga o vlasništvu nekretnina i podatke o posjedu iz DGU, te podatke iz orto-foto snimke, prostornih planova i dr.

Sve faze postupka obnove mogu se detaljno evidentirati i pratiti, a sve zgrade na poplavljenom području prikazane su i na interaktivnoj karti. Prikaz zgrade na karti mijenja se kako postupak obnove napreduje, pa se na nekom području jasno mogu razlikovati zgrade za koje je tek identificiran korisnik obnove, od onih na kojima je obnova u tijeku ili onih koje su u potpunosti završene. S obzirom na vrste radova i specifičnosti pojedinog postupka, koriste se čak 22 različita simbolička prikaza zgrada u pojedinim statusima i fazama (ilustracija 6.).



Ilustracija 5. – Organizaciona shema obnove

Ilustracija 6. – Izgled radnog ekrana u aplikaciji eObnova

IT rješenje eObnova napravljeno je sukladno principima europske INSPIRE direktive koja definira dijeljenje i mogućnost kombiniranja prostornih podataka iz različitih izvora korištenjem standardnih Web servisa, uz poštivanje pratećih normi iz serije ISO 191xx. Konkretno, prostorni podaci iz aplikativne baze prikazuju se na karti korištenjem standardnih servisa za prikaz karata (Web Map Service – WMS) te se mogu preklapati s podacima dostupnim preko istih takvih servisa od strane Državne geodetske uprave (Web Map Tile

Service – WMTS), dakle osnovni skup podataka aplikacije dopunjuje se podacima iz dodatnog vanjskog izvora.

2.6. Analiza potrebne zakonodavne potpore

Kako bi se omogućila realizacija zacrtanih ciljeva, potrebno je u što većoj mjeri ukloniti prepoznata kritična ograničenja. Ranije navedena kritična ograničenja (pod 2.4) u provedbi projekta obnove, moguće je otkloniti posebnim zakonom kojim se delogira Zakon o javnoj nabavi, oslobodi se od primjene Zakona o gradnji vezano uz ishođenje građevinske dozvole, te se usvoje procedure odlučivanja o pravu na obnovu koje su drugačije od propisanog upravnog postupka.

S obzirom da je sanacija područja zahvaćenog poplavom uključivala i niz drugih državnih tijela, a ne samo MGIPU, pristupilo se izradi Zakona, koji sadrži potrebni okvir za donošenje i provedbu mjera u području zaštite zdravlja ljudi, graditeljstva - obnova stambenih i gospodarskih zgrada te zgrada javne namjene, u području porezno - dužničkih odnosa, poduzetništva i obrta, prometne infrastrukture, poljoprivrede i veterinarstva, rada i mirovinskoga sustava, pravosuđa, obrazovanja, prava hrvatskih branitelja iz Domovinskog rata i zaštite kulturnih dobara. Posebno se uređuje način privremenog smještaja stradalnika za vrijeme obnove stambenih zgrada, a uređuju se i pitanja deponiranja mulja, glomaznog otpada i ostalih naplavina te drugo.

Zakonom je između ostalog omogućeno ugovaranje građevinskih radova na temelju javnog poziva i tako je riješeno glavno kritično ograničenje koje se odnosi na vrijeme potrebno za nabavku usluga. Nadalje, u obnovi se ne primjenjuju odredbe Zakona o gradnji, a kako bi se skratilo vrijeme potrebno za izradu projektne dokumentacije i ishođenje građevinskih dozvola.

Zakonom je određeno:

- Pod stambenom zgradom podrazumijeva se zgrada u kojoj je u vrijeme nastanka katastrofe opisane ovim Zakonom stanovao njezin vlasnik, odnosno srodnik vlasnika ili u kojoj je vlasnik, odnosno srodnik vlasnika imao prijavljeno prebivalište ili boravište. Pod pojmom stambene zgrade razumijevaju se i pomoćne i gospodarske zgrade koje su u funkciji stambene zgrade.
- Obnova zgrada provodi se uz suglasnost njihovih vlasnika, odnosno posjednika ako vlasnik nije dostupan ili se ne može utvrditi, osim uklanjanja zgrada i izgradnje novih, koje je dopušteno samo uz suglasnost vlasnika. Uklanjanje zgrada za koje nema suglasnosti vlasnika obavlja se u skladu s propisima koji uređuju nadzor gradnje i drugim propisima.
- Popravku zgrade, isplati novčanih sredstava umjesto popravka, odnosno uklanjanju zgrade i izgradnji nove zgrade, pristupa se na temelju odluke o obnovi koju donosi ministar nadležan za graditeljstvo i prostorno uređenje. Odluka o obnovi donosi se u skladu s Programom, s obzirom na činjenično stanje zgrade koje zapisnikom sačinjenim na licu mjesta utvrdi ovlašteni inženjer građevinarstva te činjenica koje utvrdi ministarstvo nadležno za poslove graditeljstva i prostornoga uređenja, a nakon dobivanja suglasnosti vlasnika odnosno posjednika zgrade.
- Odluka o obnovi nije upravni akt.

Temeljem usvojenog Zakona, Vlada je po hitnom postupku donijela programe na prijedlog nadležnih središnjih tijela državne uprave, kojima se detaljno razrađuju mjere i postupci potrebni za sanaciju nastalih šteta. Tako je na prijedlog MGIPU, na sjednici Vlade 03.07.2014. usvojen Program, Vlada RH, 2014. Programom je između ostalog određeno pravilo o veličini pripadne nove zamjenske kuće:

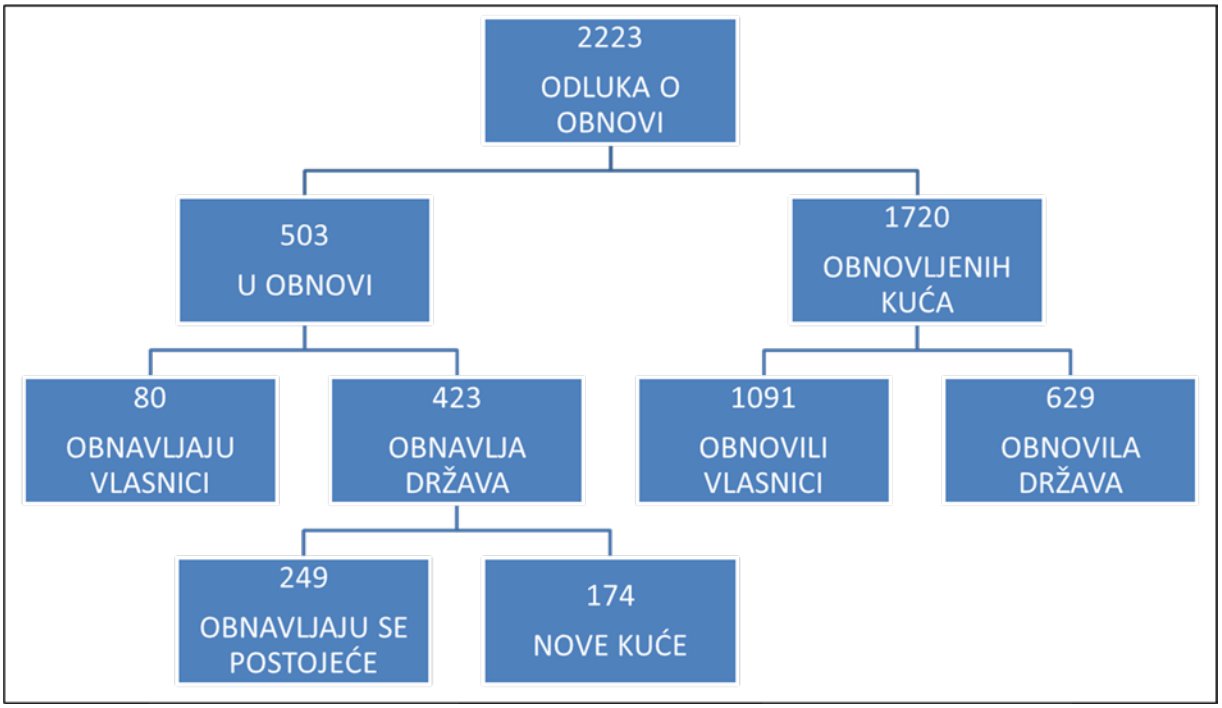
- Korisna tlocrtna površina zatvorenog dijela nove stambene zgrade iznosi od 55,00 m2 za jednu ili dvije osobe, 70,00 m2 za tri ili četiri osobe, te 85,00 m2 za pet i više osoba. Dopušteno je odstupanje za +/-2% ukupne korisne tlocrtne površine u odnosu na propisane veličine nove stambene zgrade.

S obzirom na posebne mjere koje određuje Zakon, isti se primjenjuje jednokratno, strogo namjenski i s rokom trajanja od godine dana od stupanja na snagu.

3. Provedba obnove zgrada

Provedba obnove započela je sklapanjem ugovora sa sudionicima obnove i uvođenjem u posao. U provedbi obnove zgrada, uključeni su sudionici opisani u poglavlju 2.5. U organiziranoj obnovi sudjeluje 20 izvođača, 21 nadzorna služba i projektna kuća, te 3 službe za koordinaciju.

Ukupno je do trenutka pisanja ovog teksta (svibanj 2015. god.) izdano 2.223 Odluke o obnovi, na osnovi provjere u MGIPU i prikupljenih Izjava korisnika obnove, koje se daju pod materijalnom i kriviičnom odgovornosti i uz ovjeru potpisa javnog bilježnika (ilustracija 7.).



Ilustracija 7. – Shematski prikaz rezultata obnove

Kroz mogućnost vlastite obnove isplaćuju se sredstva u dvije rate. Prva rata se isplaćuje avansno, a druga rata po dovršetku obnove i na temelju očevida i zapisnika službe za koordinaciju. Iznosi isplate ovise o kategoriji oštećenja kuće:

a) Za 0. kategoriju oštećenja isplaćuje se fiksno i ukupno 20.000 kn;
b) Za I. kategoriju oštećenja isplaćuje se fiksno i ukupno 40.000 kn i
c) Za II. kategoriju oštećenja isplaćuje se fiksno i ukupno 70.000 kn.

Do sada su evidentirane 1.091 završene obiteljske zgrade kroz vlastitu obnovu isplatom sredstava iz državnog proračuna, dok su još 80 obiteljske zgrade u radu. Ukupno je do sada isplaćeno 61 mil. kn za vlastitu obnovu, dok je za organiziranu obnovu do sada utrošeno 241 mil. kn.

Radovi organizirane obnove se trenutno izvode na još 11 zgrada javne namjene s manjim oštećenjima, i 423 obiteljskih zgrada. Dio zgrada su u nekom od problematičnih statusa, i vjerojatno neće biti obnovljene. Naime, u prikupljanju podataka o pravima na obnovu, uočen je veliki broj nesređene vlasničke dokumentacije, ali i nelogičnosti kod prijavljenih prebivališta. S obzirom da se radi o znatnim sredstvima iz državnog proračuna, potrebno je kao prethodno pitanje riješiti zakonsko pravo na obnovu. Slijedom uočenih nepravilnosti, za pojedine slučajeve je zatražena dodatna provjera u MUP-u, te je do dostave očitovanja zaustavljena obnova tih zgrada. Temeljni zadatak obnove je povratak ljudi, tj. prema Zakonu, ne može se obnavljati kuća onome tko u njoj nije boravio.

Prilikom obnove zgrada javne namjene, nastojalo se unaprijediti stanje i tom prilikom su prema potrebi promijenjeni sustavi grijanja s mazuta na plin. Kod obiteljskih zgrada, nove

zgrade su projektirane i izvedene prema svim važećim standardima i s B energetskim razredom (ilustracija 8.).

Najavljene su primopredaje za brojne zgrade i završetci prve faze obnove. Do sredine kolovoza 2015. godine očekuje se dovršetak prve faze radova za većinu zgrada koje su uvedene u posao i one koje se nalaze u vlastitoj obnovi. Naime izvođenje je podijeljeno u dvije faze zbog tehnoloških razloga. Prva faza podrazumijeva popravak do razine unutarnjeg uređenja kako bi se mještani mogli vratiti svoji kućama, a za drugu fazu će se radovi na ovojnici kuća izvoditi u toku proljeća ovisno o vremenskim uvjetima, sve kako bi se što bolje omogućilo sušenje zidova.

Ilustracija 8. – Zamjenska obiteljska zgrada

4. Zaključno

Tijekom mjeseca svibnja 2014. godine, na području Vukovarsko-srijemske županije dogodile su se poplave koje su svojim opsegom, intenzitetom i neočekivanošću ugrozile zdravlje i živote većeg broja ljudi, imovinu te okoliš. Vodni val je zahvatio različitim intenzitetom šest mjesta: Račinovci, Rajevo selo, Gunja, Strošinci, Đurići i Posavski Podgajci. Ukupno, po početnim podatcima radi se o građevinskim štetama na 2.689 obiteljskih kuća s 4.713 pomoćnih i gospodarskih zgrada te 32 zgrade javne namjene, s procijenjenom vrijednosti štete od 1.17 mlrd. kn, uz štete u poljoprivredi i infrastrukturi.

Takav obim razaranja u prirodnoj katastrofi, koji se nije mogao predvidjeti, mobilizirao je sve kapacitete države, a Vlada RH i druga državna tijela učinili su maksimalan napor kako bi se maksimalno smanjile štetne posljedice na živote i zdravlje ljudi, te gubitak i daljnje oštećenje imovine. Najveći udio u sanaciji poplavljenih područja nosi MGIPU, i ulaže dodatne napore kako bi se obnova što prije završila i mještani vratili svojim kućama. Planirani rokovi završetka su sredinom kolovoza 2015. god. za sve zgrade za koje su do svibnja izdane Odluke o obnovi, tj. njihovi vlasnici su stekli pravo na obnovu. Kroz postupke obnove dolazi do izražaja ne sređeno stanje evidencije osobne imovine što znatno otežava realizaciju obnove, te će neke zgrade biti dovršene kasnije ili će njihovi vlasnici ostati bez prava na obnovu.

Iz novih iskustva na pripremi i provedbi obnove nakon ove katastrofe, uočena je potreba za izradom općeg zakona kojim bi se postavio okvir za djelovanje u sličnim budućim situacijama, ali i potreba za sređivanjem vlasničkih evidencija građana.

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Primjena buildability / constructability koncepta na infrastrukturnim projektima javnih naručitelja

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Sažetak

Buildability odnosno constructability je koncept upravljanja projektima razvijen na temelju znanstvenih istraživanja provođenih u Sjedinjenim Američkim Državama, Velikoj Britaniji i Australiji. Svrha razvoja koncepta je postavljanje sustava upravljanja projektima radi uklanjanja projektnih prepreka i postizanja ukupnih ciljeva projekta. Prvenstveno se to odnosi na stvaranje koristi svim sudionicima u projektu u pogledu smanjenja ukupnih troškova i/ili poboljšanja konačne kvalitete dovršenog projekta.

Cilj ovog rada je analizirati mogućnosti primjene buildability / constructability koncepta na infrastrukturnim projektima javnih naručitelja u RH, unutar danih zakonskih i organizacijskih okvira, te određivanje mjera koje je potrebno poduzeti za njegovu prilagodbu, a koje su neophodne u slučaju njegove primjene.

Za definiranje zaključka i dokaza primjenjivosti predloženog koncepta, provest će se studija slučaja (case study) na konkretnom projektu izgradnje auto-cestovnog mosta (most Svilaj preko rijeke Save).

Ključne riječi: buildability; constructability; upravljanje projektima; javni naručitelji, infrastrukturni projekti;

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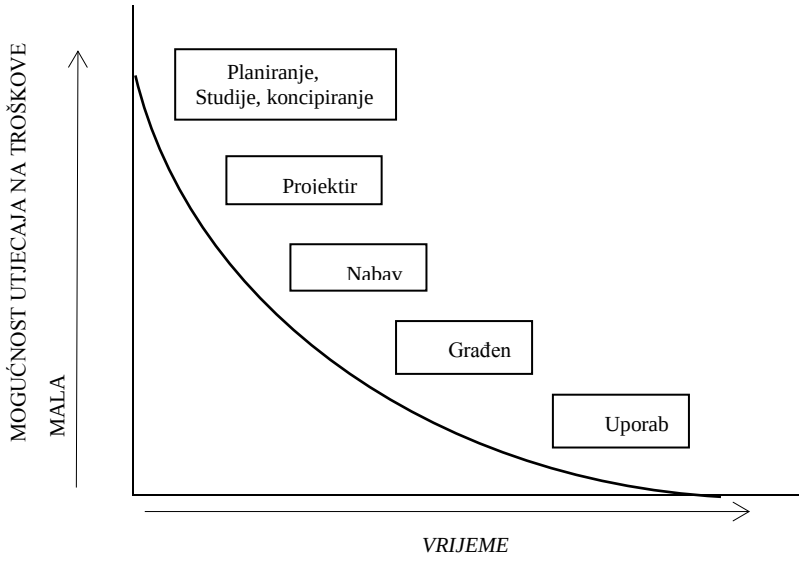
1. UVOD

Buildability odnosno *constructability* je koncept upravljanja projektima razvijen na temelju znanstvenih istraživanja provođenih u razvijenim zemljama, u prvom redu Sjedinjenim Američkim Državama, Velikoj Britaniji i Australiji. Svrha razvoja tog koncepta je postavljanje sustava upravljanja projektima radi uklanjanja projektnih prepreka i postizanja ukupnih ciljeva projekta. Prvenstveno se to odnosi na stvaranje koristi svim sudionicima u projektu u pogledu smanjenja ukupnih troškova i/ili poboljšanja konačne kvalitete dovršenog projekta.



Ilustracija 1. Krivulja mogućnosti utjecaja na ukupne troškove projekta (Construction Industry Institute - CII 1986.)

Cilj primjene koncepta je povezivanje faza projektiranja i izvođenja radova, koje su inače odvojene prema tradicionalnim, uobičajenim načinima upravljanja projektima, te postizanje boljeg povezivanja svih sudionika u projektu. To se posebno odnosi na rane faze projekta u kojima je mogućnost uvođenja promjena najjednostavnija, a potencijalno smanjenje ukupnih troškova najveće.

U Republici Hrvatskoj do sada nisu u znatnijem opsegu provedene znanstvene rasprave (istraživanja) o mogućnostima primjene *constructability* / *buildability* koncepta. Za ocjenjivanje mogućnosti primjene predloženog modela upravljanja građevinskim projektima kod javnih naručitelja, potrebno je provesti analizu važeće zakonske regulative, važećih smjernica i internih pravilnika relevantnih za vođenje i upravljanje projektima usvojenih od javnih naručitelja, te ostalih ograničavajućih faktora koji mogu utjecati na uspješnost samih infrastrukturnih projekata.

1.1. Razvoj buildability/constructability koncepta i pregled svjetskih iskustava

Za razumijevanje koncepta, potrebno je u prvom redu upoznati njegove definicije koje su predočene u nastavku, a koje su postavljene nakon analize rezultata i zaključaka iz provedenih istraživanja.

Construction Industry Research and Information Association - CIRIA (1983), Velika Britanija definira buildability na slijedeći način: "*Buildability predstavlja mjeru do koje projektiranje građevine olakšava njezinu izgradnju, u skladu s ukupnim zahtjevima za dovršenu građevinu*"

Construction Industry Institute - CII, SAD (1986) definirala je constructability *kao*: "*Sustav za postizanje optimalne integracije izvođačkog znanja iskustva u planiranju, projektiranju, nabavi i radovima na terenu u procesu građenja te balansiranje između različitih projektnih ograničenja i ograničenja okoline za postizanje ukupnih projektnih ciljeva".*

Construction Industry Institute Australia - CIIA (1997), pojam constructability označava kao: *Sustav za postizanje optimalne integracije izvođačkog znanja u proces građenja i uravnoteženja različitih ograničenja projekta i okoline, u cilju postizanja maksimalizacije projektnih ciljeva i učinkovitosti građenja"*

1.2. Razvoj koncepta

Razvoj koncepta započinje 60-tih godina prošlog stoljeća, a temelji se na rezultatima znanstvenih istraživanja i studija provedenih u Velikoj Britaniji (*Emmerson* 1962 g., *Banwell* 1964. G, *Higgin i Jessop* 1963 g). Zaključak svih tih istraživanja je bio da praksa upravljanja projektima ugovaranih prema tradicionalnom modelu nabave, s međusobno odvojenim fazama projektiranja i građenja, dovodi do nesuglasica između timova projektanata i izvođača radova.

Na osnovu provedenih istraživanja CIRIA prvobitno postavlja sedam kategorija smjernica za primjenu *bulidability* koncepta u praksi, dok ih Adams (1989) nastavno određuje čak šesnaest. Navedene smjernice su određene na slijedeći način:

- temeljito istraživanje,
- uzimanje u obzir pristup gradilištu u fazi projektiranja,
- uzimanje u obzir mogućnost skladištenja materijala potrebnih za izgradnju već u fazi projektiranja,
- projektiranje u cilju postizanja minimalnog trajanja izvođenja radova "pod zemljom",
- projektiranje u cilju što ranijeg zatvaranja konstrukcije objekta,
- korištenje pogodnih materijala,
- projektiranje u skladu sa sposobnostima izvođača za izvođenje pojedinih vrsta radova,
- projektiranje u cilju postizanja jednostavne montaže,
- planiranje u cilju postizanja maksimalnog ponavljanja operacija i njihove standardizacije,
- postizanje maksimalnog mogućeg korištenja strojnog rada,
- dopuštanje razumnih tolerancija,
- dozvoljavanje praktičnog slijeda operacija,
- izbjegavanje višestrukih dolazaka specijaliziranih radnika,
- planiranje u cilju izbjegavanja oštećenja već izvedenih radova,
- projektiranje u cilju sigurne gradnje,
- jasno komuniciranje.

Slično razvoju *buildability* konceptu u Velikoj Britaniji, u Sjedinjenim Američkim Državama razvijao se je *constructability* koncept. Ciljevi tamo provedenih znanstvenih istraživanja odnosili su se na promicanje kvalitete, efikasnosti, produktivnosti i troškovne učinkovitosti građevinske industrije.

Udruženje *Business Roundtable* dovršilo je 1983. godine četverogodišnju studiju o troškovnoj učinkovitosti građevinske industrije Sjedinjenih Američkih Država.

Zaključci iz navedene studije i drugih znanstvenih istraživanja koji su se bavili srodnom tematikom bili su poticaj osnivanja *Construction Industry Institute*-a (CII) 1983. godine koji je djelovao pod okriljem Teksaškog Sveučilišta u Austinu. Unutar Instituta osnovana je i radna grupa za *constructability* (*Constructability Task For*ce), koja je publicirala veći broj znanstvenih radova i drugih publikacija s ciljem promoviranja, primjene i daljnjeg razvoja koncepta. Rezultati svih tih istraživanja sumirani su u publikaciji *Constructability Concept files* iz 1987. godine. U publikaciji je predočeno 14 principa primjene koncepata podijeljenih prema fazama projekta za koje su se provodila istraživanja:

I. *Constructability* koncept u konceptualnoj fazi projekta:

I-1: *Constructability* programi postaju sastavni dio planova izvođenja projekta,
I-2: U planiranje projekta se aktivno uključuje izvođačko znanje i iskustvo,
I-3: Uključivanje u rane faze izvođenja radova se uzima u obzir u razvijanju strategije ugovaranja radova,
I-4: Sveobuhvatni projektni vremenski planovi uzimaju u obzir aspekte izvođenja radova,
I-5: Osnovni pristupi u projektiranju uzimaju u obzir glavne metode izvođenja radova,
I-6: Planovi organizacije gradilišta utječu na učinkovitost građenja.

II Constructability koncept u fazi projektiranja i nabave:

II-1: Vremenski planovi koji se odnose na faze projektiranja i nabave uzimaju obzir aspekte izvođenja radova,
II-2: Projektna dokumentacija je koncipirana na način da omogućava učinkovito izvođenje radova,
II-3: Projektnim rješenjima teži se standardiziranim elementima,
II-4: U razvoju specifikacija se uzima u obzir postizanje učinkovitosti izvođenja radova,
II-5: Projektna rješenja modula i/ili pred-montaže se izrađuju na način da olakšavaju proizvodnju, transport i njihovo postavljanje,
II-6 Projektnim rješenja uzimaju u obzir dostupnost izvođaču radnika i osoblja, materijala i opreme za fazu izvođenja radova,
II-7 Projektna rješenja omogućavaju izvođenje radova pri nepovoljnim vremenskim uvjetima.

III *Constructability* koncept u fazi izvođenja radova:

III-1 *Constructability* koncept je poboljšan kada se koriste inovativne metode izvođenja radova.

Osim u velikoj Britaniji i Sjedinjenim Američkim Državama, *constructability* koncept je devedesetih godina prošlog stoljeća također razvijan i istraživan i u Australiji, u suradnji s američkim znanstvenicima, a pod okriljem *Construction Industry Institute-a Australia* (CIIA). Na temelju tamo provedenih istraživanja, 1993. godine prezentirano je dvanaest *constructability* principa (Francis and Sidwell, 1996), a koji u usklađeni sa specifičnostima građevinske industrije u Australiji. Oni se odnose na:

1. **integraciju** - koncept mora biti sastavni dio planova izvođenja projekta,
2. **izvođačko znanje** - pri planiranju projekta mora se aktivno uključiti izvođačevo znanje i iskustvo,
3. **vještine projektnog tima** - iskustvo, vještine i sastav projektnog tima moraju biti prikladni za provođenje projekta,
4. **organizacijske ciljeve** - učinak koncepta je pojačan kada projektni timovi postignu usuglašenost korporacijskih ciljeva naručitelja i ciljeva projekta,
5. **raspoložive resurse** - odabir tehnologije i projektnih rješenja moraju biti u skladu sa vještinama i raspoloživim resursima,
6. **vanjske faktore** - mogu utjecati na dinamiku odvijanja radova i troškove projekta,
7. **program** - planirana dinamika mora biti realna, uzimati u obzir fazu izvođenja radova; postizanju ciljeva programa mora biti posvećen cjelokupni projektni tim,
8. **metodologiju izvođenja radova** - projektna rješenja moraju uzimati u obzir metodologiju izvođenja radova,
9. **pristup gradilištu** - učinak koncepta je pojačan ukoliko se mogućnost pristupa gradilištu razmotri u fazama projektiranja i izvođenja radova,
10. **specifikacije** - učinak koncepta je pojačan ukoliko se u obzir kod definiranja specifikacija uzima u obzir efikasnost izvođenja radova,
11. **inovacije kod izvođenja radova** - upotreba inovativnih tehnologija u izvođenju radova pojačava učinkovitost koncepta,
12. **povratne informacije** - koncept se može unaprijediti u primjenu na budućim sličnim projektima ukoliko se od strane projektnog tima provede analiza nakon završetka faze izvođenja radova.

1.3. Implementacija koncepta u praksi

Ovisno o specifičnostima građevinskih projekata kojima bi se upravljalo prema njegovim principima, koncept je u praksi moguće primijeniti na više načina, a od kojih dva možemo posebno istaknuti.

Jedan od načina je unutar organizacija ili korporacija usvajanjem odgovarajućih procedura, odnosno organiziranjem poslovnih procesa koji ga promiču.

Drugi pristup se oslanja na usvajanje i prihvaćanje odgovarajućih tehničkih propisa, smjernica i pravilnika kojima se jednoznačno definiraju kriteriji i načini njegove primjene. Takav pristup je na primjer usvojen u Singapuru, gdje je Državna Uprava za graditeljstvo (*Building and Construction Authority - BCA*) donijela je više pravilnika za projektiranje objekata visokogradnje kojima se potiče standardizacija, jednostavnost i integracija elemenata.

1.4. Prepreke implementaciji buildability/constructability koncepta

U znanstvenim istraživanja identificirane su i najčešće prepreke implementaciji *buildability/constructability* koncepta. One mogu biti prisutne i u organizacijskom i u projektnom okruženju. Jedan dio tih prepreka se odnosi na uobičajene vladajuće poslovne običaje u građevinskoj industriji, a drugi dio na međusobne ugovorne odnose između sudionika u projektima.

Osim opisanih, u važno je prepoznati i prepreke svojstvene samo javnom sektoru, koje su također prisutne u Republici Hrvatskoj, a odnose se na:

- relativno nefleksibilno zakonodavstvo u pogledu postupaka nabave,
- sustav javnog otvaranja ponuda i njihove evaluacije temeljen na dokumentaciji za nadmetanje koja uglavnom sadrži projektnu dokumentaciju razrađenu do relativno visoke faze i precizno određuje specifikacije projekta,
- odabir ponuda po kriteriju najniže ukupne cijene definirane na temelju nepromjenjivog troškovnika
- pretpostavljene forme ugovora koje uvjetuju nepromjenjivost jediničnih cijena,

Koncept se ipak može primijeniti kod javnih naručitelja, jer alternativni modeli ugovaranja i upravljanja projektima uglavnom nisu zabranjeni važećim zakonodavstvom.

2. Analiza trenutnog stanja i dosadašnjih modela nabave i upravljanja infrastrukturnim projektima kod javnih naručitelja u RH

Za analizu mogućnosti primjene *buildability/constructability* koncepta potrebno je proanalizirati trenutnu praksu ugovaranja radova infrastrukturnih projekata kod javnih naručitelja te predočiti sustave upravljanja upravljanje istima.

U ovom radu su analizirani slijedeći javni naručitelji: Hrvatske autoceste d.o.o., Autocesta Rijeka-Zagreb d.d., Hrvatske ceste d.o.o., HŽ infrastruktura d.o.o., Ministarstvo financija RH dr.

2.1. Planiranje investicije i izvori financiranja

Infrastrukturni projekti javnih naručitelja u RH se uglavnom planiraju u skladu sa prethodno usvojenim dugoročnim strateškim dokumentima. Na osnovu tih dokumenata, razrađuju se srednjoročni programi razvoja i izgradnje infrastrukture, a podredno navedenim programima razrađuju se godišnji planovi građenja, koji ujedno predstavljaju podlogu za izradu planova nabave koji su propisani Zakonom o javnoj nabavi.

Javni naručitelji infrastrukturne projekte uglavnom financiraju iz vlastitih prihoda, raznih trošarina, proračunskih i van-proračunskih nameta koji su određeni kroz važeće zakonodavstvo, te naposljetku kreditnim zaduženjima. Obzirom da je Republika Hrvatska punopravna članica EU dio investicija u infrastrukturu se sufinancira i iz raznih fondova EU koji su joj na raspolaganju.

2.2. Faze infrastrukturnih projekata kod javnih naručitelja u RH

Faze građevinskih projekata javnih naručitelja uglavnom se temelje na primjeni tradicionalnog modela nabave i nametnutog zakonskog okvira unutar kojeg posluju.

Podjela faza projekata prema Hugesu (1991.g), uz određene preinake i prilagodbe je prikladna za većinu javnih naručitelja koji provode infrastrukturne projekte. Pri tome se navedena podjela faza može djelomično pojednostaviti na slijedeći način:

- Planiranje
- Projektiranje
- Nabava i ugovaranje
- Izvođenje radova i građenje
- primopredaja / korištenje objekata

2.2.1. Planiranje

Kako je već napomenuto, za planiranje prioriteta, dinamiku razvoja i visinu potrebnih financijskih sredstava u Republici Hrvatskoj se za potrebe izgradnje nove i/ili održavanje postojeće infrastrukture donose strateški, programski i planski dokumenti. Spomenuti dokumenti predstavljaju okvir izrade planova poslovanja javnih naručitelja koji izgradnje i razvoja infrastrukture koja im je povjerena na upravljanje i gospodarenje.

2.2.2. Projektiranje

Projektiranje za potrebe provođenja infrastrukturnih projekata za javne naručitelje uglavnom provode vanjske projektantske kuće temeljem sklopljenih ugovora za projektiranje. Pod projektiranjem se podrazumijeva izrada idejnih, glavnih i izvedbenih projekata te ishođenje svih potrebnih dozvola i suglasnosti potrebnih za početak izgradnje.

Dokumentacija za nadmetanje za provođenje postupaka javne nabave radove se uglavnom izrađuje na osnovi projektne dokumentacije dovršene u visokom stupnju gotovosti, a faze projektiranja i izvođenja radova su u većini slučajeva funkcionalno potpuno odvojene, te je njihova integracija gotovo u potpunosti onemogućena.

Mogućnost integracije spomenutih faza je upravo osnovni preduvjet za primjenu bilo kakvog alternativnog modela nabave građevinskih radova i vezano uz njih primjene alternativnog koncepta (modela) upravljanja projektima.

U određenim slučajevima i u dosadašnjoj praksi u vrlo ograničenoj se je mjeri provodila integracija faza projektiranja i građenja u fazi građenja i to uglavnom na inicijativu izvođača radova kod već sklopljenih ugovora o građenju . Izvođači su, u takvim slučajevima, najčešće nakon započinjanja radova, predlagali izvjesna "poboljšanja" projektnih rješenja i njihovu prilagodbu tehnologiji građenja i raspoloživim kapacitetima. Takav pristup bez posebno detaljno razrađenog sustava vrednovanja alternativnog projektnog rješenja i osiguranja drugih ugovornih i organizacijskih preduvjeta, nije dobar. Ovisno o slučaju, može biti neselektivan te otvoriti više pitanja u pogledu upitne i teško mjerljive koristi, koju postiže naručitelj prihvaćanjem izmjena projektne dokumentacije.

2.2.3. Nabava i ugovaranje

Javni naručitelji su pri provođenju postupaka nabave roba, radova i usluga obvezni poštivati odredbe Zakona o javnoj nabavi (NN 90/11). U iznimnim slučajevima nabave javnih naručitelja se ne provode u skladu sa odredbama navedenog Zakona, a to je najčešće slučaj kada sredstva osiguravaju kreditori kao što su npr. EBRD, Svjetska Banka i dr.

Svi obveznici primjene Zakona o javnoj nabavi za nabavu roba, usluga ili radova dužni su koristiti jedan od slijedećih propisanih postupaka javne nabave:

- otvoreni
- ograničeni
- pregovarački – s prethodnom objavom ili bez prethodne objave
- natječaj – otvoreni ili ograničeni
- natjecateljski dijalog

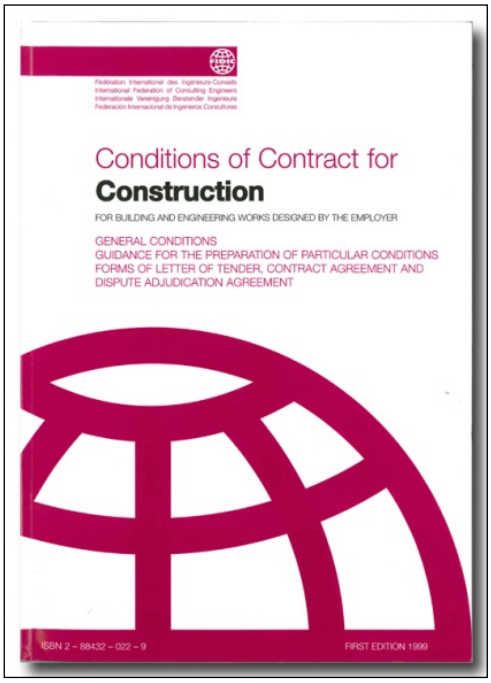
Za nabavu radova, usluga stručnog nadzora i projektiranja kod javnih naručitelja se uglavnom primjenjuje otvoreni postupak i pregovarački postupak bez prethodne objave.

Javni naručitelji za infrastrukturne projekte u praksi koriste razne forme ugovora koji su sastavljeni u skladu sa odredbama Zakona o obveznim odnosa (NN 35/05, 41/08, 125/11) i

Posebnih uzanci o građenju (SL SFRJ 18/77), osim ako njihova primjena nije izrijekom isključena.

Kod složenih infrastrukturnih projekata ugovori o građenju se vrlo često baziraju na FIDIC-im (*Federation International des Ingenieurs Conseils - Međunarodna federacija savjetodavnih inženjera)* formama ugovora. Navedene forme ugovora su međunarodno prepoznate i priznate, te njihovu primjernu preporučuju i međunarodne financijske institucije i kreditori.

Karakteristika je svih standardnih formi ugovora prema FIDIC-u da su u njima tumačenja i izrazi izvedeni iz anglo-saksonskog pravnog sustava (*Common Law*) i da su vrlo opsežni u definiranju prava i obaveza strana, te su iz tih razloga takvi ugovori samodostatni. Pravni sustav Republike Hrvatske, s druge strane, bazira se na europskom kontinentalnom pravu (*Code Civil)*, tako da se ugovorima definiraju samo osnovna prava i obaveze, dok su ostali odnosi regulirani opsežnim zakonodavstvom.



Ilustracija 2. FIDIC-ova "Crvena knjiga“ (www.fidic.org)

Najčešće se za ugovore o građenju kod javnih naručitelja koristi forma ugovora u skladu s FIDIC-ovom „Crvenom knjigom“, a koja je namijenjena ugovorima o građenju prema projektima naručitelja.

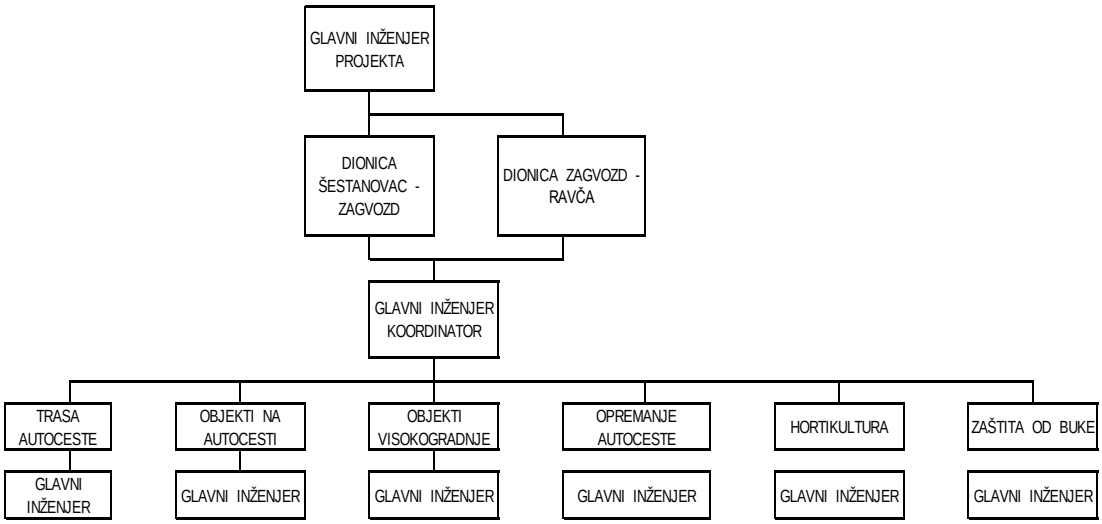
Ovdje je također važno istaknuti da ugovor sastavljen prema FIDIC-ovoj "*Crvenoj knjizi*", omogućuje izvođaču, da pod određenim uvjetima, integraciju faza projektiranja i izvođenja radova u smislu "*Value Engineering-a"*. To je djelomično na tragu primjene *buildability / constructability* koncepta. Međutim, u tome se slučaju dovodi u pitanje transparentnost i ispravnost postupaka javne nabave.

2.2.4. Izvođenje radova - građenje

Za upravljanje infrastrukturnim projektima, javni naručitelji u pravilu formiraju projektne timove koji su sastavljeni od vlastitog stručnog osoblja koje ima kompetencije za upravljanje

projektima. Od slučaja do slučaja projektni timovi naručitelja upravljaju projektima u suradnji s projektnim timom stručnog nadzora, pri čemu pojedini javni naručitelji ponekad i sami provode dio stručnog nadzora u skladu sa mjerodavnim zakonodavstvom i vlastitim ustrojem. Ovdje valja naglasiti da postoje i drugi slučajevi kad se upravljanje projektima u potpunosti prepušta vanjskim konzultantima.

Uslugu stručnog nadzora u svojstvu vanjskog konzultanta javni naručitelji u većini slučajeva ugovaraju s konzultantom u smislu zadovoljavanja uvjeta iz Zakona o gradnji (NN 153/13) i Zakona o arhitektonskim i inženjerskim poslovima i djelatnostima u prostornom uređenju i gradnji (NN 152/08, 49/11).



Ilustracija 3. Primjer sheme projektne jedinice za upravljanje jednim od projekata u poduzeću Hrvatske autoceste d.o.o.

2.2.5. Primopredaja / korištenje objekta

Pod primopredajom krajnjem korisniku se u najvećem broju slučaja podrazumijeva interna predaja izgrađenih objekata unutar sustava organizacije javnih naručitelja.

Pri razmatranju primjene *buildability / constructability* ili sličnih koncepata, nužno je u procese primopredaje izgrađenih objekata krajnjim korisnicima ugraditi mehanizme kojima se omogućava analiziranje stečenih znanja i davanje povratnih informacija o uspješnosti projekta i drugim sudionicima koji nisu sudjelovali u svim fazama njegove realizacije.

3. Primjena buildability/constructability koncepta kod infrastrukturnih projekata javnih naručitelja u RH

Na temelju znanstvenih istraživanja i iskustava zemalja u kojima se primjenjuje *buildability/ constructability* koncept, realno je pretpostaviti da se taj koncept može primijeniti i kod većine javnih naručitelja u RH i to prema principima CIIA-a

Smjernice za primjenu *buildability* koncepta razvijene od strane CIRIA-e, uglavnom se odnose na fazu projektiranja. Za fazu građenja smjernice su više usmjerene na organizaciju

gradilišta izvođača. To iz pozicije javnog naručitelja, ne predstavlja suviše bitan faktor ispunjavanja projektnih ciljeva.

Sa druge strane, smjernice razvijene od strane CII-a čine se prikladnijim, premda su one usmjerene na faktore bitne za projekte izgradnje objekata visokogradnje. To ograničava njihovu relevantnost za javne naručitelje kod projekata izgradnje infrastrukture.

Constructability principi razvijeni od strane CIIA-e dovoljno su općeniti i primjenjivi za građevinsku industriju u Republici Hrvatskoj. Stoga se može zaključiti da je njihova primjena moguća u sustavima javnih naručitelja. Međutim, zbog specifičnosti poslovanja javnih naručitelja, potrebna je njihova prilagodba zahtjevima i specifičnostima istih.

Nastavno će se predočiti prijedlog potrebnih mjera povezanih s mogućnostima primjene *constructability* koncepta kod javnih naručitelja i to sukladno *constructability* principima razvijenim od strane CIIA-e.

3.1. Integracija

Integracija faza, odnosno uključivanje koncepta u planove izvođenja projekta, polazi od više preduvjeta. Primarno je riječ o formama ugovora i postupcima nabave, uključujući kriterije odabira najpovoljnijih ponuda. Kako bi se integracija faza, faze projektiranja i građenja uopće mogla ostvariti, potrebno je nabavu građevinskih projekata provoditi po *Design and Build* modelu.

Zakon o javnoj nabavi, izričito ne zabranjuje ugovaranje radova po *Design and Bild* modelu nabave. Međutim, takav model se do sada uglavnom nije koristio kod javnih naručitelja.

3.1.1. Postupci nabave

Design and Build model nabave kada se primjenjuje Zakon o javnoj nabavi (NN 90/11) moguće je primijeniti ispune li se slijedeći preduvjeti:

- mogućnost davanja alternativne ponude od strane ponuditelja u fazi nuđenja,
- primjena kriterija odabira ekonomski najpovoljnije ponude.

3.1.2. Metodologija odabira najpovoljnije ponude

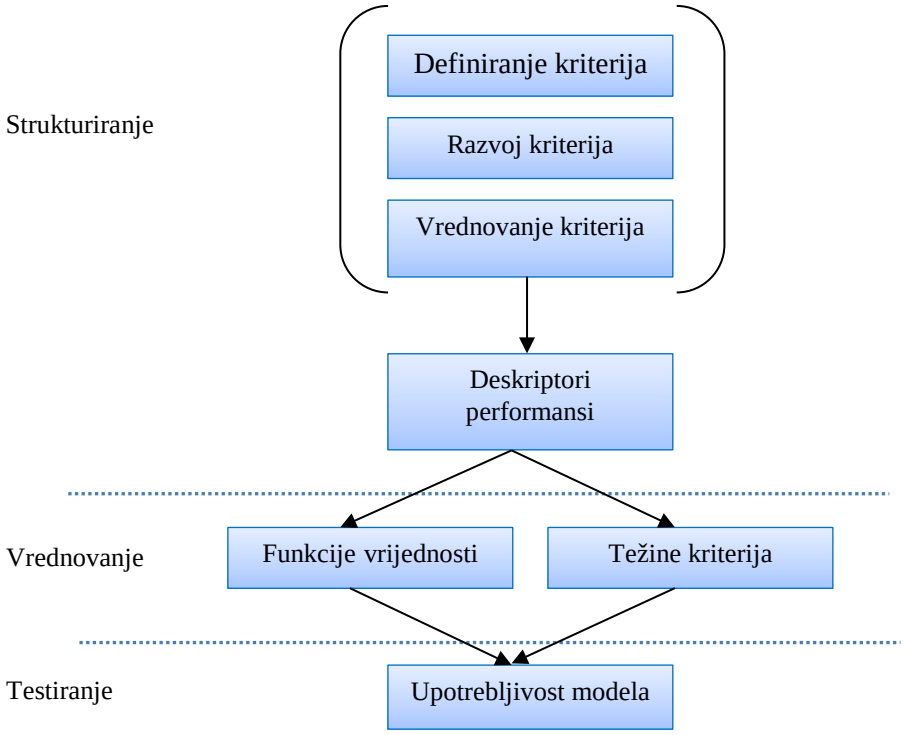
Za nabavu radova kod javnih naručitelja, gotovo isključivo se koristi kriterij najniže ukupne cijene, za one ponuditelje koji su zadovoljili ostale formalne uvjete natječaja.

Ako bi za odabir ponuda naručitelj usvojio kriterij ekonomski najpovoljnije ponude, mogao bi u konačnici postići bolju "vrijednosti za novac". U skladu s takvim pristupom naručitelju može biti i povoljnije da plati više za proizvod s nižim troškovima održavanja u odnosu na jeftiniji proizvod s višim troškovima održavanja, budući da će tada, u planiranom periodu amortizacije početno skuplji proizvod biti u konačnici jeftiniji (Ministarstvo gospodarstva RH, Uprava za sustav javne nabave, 2013). U tom slučaju bilo bi potrebno zadovoljiti slijedeće preduvjete:

- različiti kriteriji moraju biti povezani s predmetom nabave,
- u pozivu na nadmetanje ili u dokumentaciji za nadmetanje mora se navesti relativni značaj svakog pojedinog kriterija,
- kriteriji za odabir ne smiju biti diskriminirajući i moraju biti povezani s predmetom nabave.

Analiziranjem stanja u javnom sektoru na području Republike Hrvatske, može se uočiti očiti nerazmjer postotka nabave provedene prema kriteriju ekonomski najpovoljnije ponude u odnosu prema kriteriju najniže ukupne cijene. Prema podacima dostupnim za posljednjih godina, nabave provođene po kriteriju ekonomski najpovoljnije ponude kreću u rasponu od 0,67%-1,42% od ukupnih vrijednosti svih realiziranih javnih nabava. Taj se postotak za zemlje EU27 znatno razlikuje od zemlje do zemlje. U prosjeku za sve članice Unije, on u javnom sektoru iznosi 71% u korist nabava provedenih po kriteriju ekonomski najpovoljnije ponude (Hunjak, 2013) .

S druge strane, na području Republike Hrvatske navedeni se je kriterij uglavnom primjenjivao za nabave određenih konzultantskih usluga. Za nabavu radova, prema javno dostupnim podacima, kriterij ekonomski najpovoljnije ponude uglavnom se nije primjenjivao.



Ilustracija 4. Izgradnja modela za ekonomski najpovoljniju ponudu (Hunjak 2013.)

Prvi korak pri određivanju ekonomski najpovoljnije ponude odnosi se na utvrđivanje kriterija relevantnih za njezin odabir. Oni se mogu razlikovati od projekta do projekta, ovisno o specifičnostima, vrstama i ukupnom obimu radova predmeta nabave, te prema važnosti odnosno težini (ponderu) kriterija. Među važnijim težinskim faktorima odabira ekonomski najpovoljnije ponude je ukupna cijena ponude. Sukladno direktivama EU (Directive 2004/18/EC, Art 53) i s njima usklađenom naputku Ministarstva gospodarstva Republike Hrvatske, za slučajeve nabave radova, težinski faktor ukupne cijene ponude mora iznositi najmanje 50 % u odnosu na težinske faktore drugih kriterija.

3.1.2.1. Kriteriji odabira najpovoljnije ponude i modeli evaluacije

Kriteriji relevantni za primjenu kod nabave radova na projektima izgradnje infrastrukture mogu biti slijedeći:

- **cijena** - jedan od najvažnijih kriterija vrednovanje ponuda, kojem se dodjeljuje relativno velika težina (ponder) u odnosu na druge kriterije,
- **operativni troškovi** - predstavljaju pogonske troškove, troškove redovnog održavanja i troškove upravljanja,
- **funkcionalne osobine** - kriterij je primjenjiv u slučajevima nabave i ugradnje opreme i postrojenja od kojih se očekuje postizanje određenog nivoa performansi,
- **kvaliteta** –uglavnom definirana mjerodavnim zakonodavstvom, pravilnicima, standardima i normama, pri čemu u pravilu nisu dopuštena značajnija odstupanja,
- **rok dovršetka** - može se dovesti u vezu sa smanjivanjem i/ili povećavanjem troškova naručitelju te ostvarivanju prihoda.

Pri postavljanju modela odabira ekonomski najpovoljnije ponude mogli bi se razmotriti i drugi kriteriji. Međutim, za projekte izgradnje infrastrukture oni nisu posebno relevantni, a njihovo uvođenje bi moglo dovesti u pitanje objektivnost odabira.

Pri evaluaciji ekonomski najpovoljnije ponude u praksi su prepoznata dva modela (Ministarstvo gospodarstva RH, Uprava za sustav javne nabave, 2013):

- **apsolutni model** - za svaki od kriterija, uključujući i ne-cjenovne, utvrđuje se određeni novčani iznos koji se dodaje ili oduzima od ponuđene cijene i na taj se način utvrđuje "kvalitativno usklađena" cijena,
- **relativni model** - određuje relativni značaj pojedinog kriterija za odabir u postotku, nakon čega se relativni značaj pretvara u maksimalni broj bodova.

3.1.2.2. Određivanje težine kriterija

Određivanja težine pojedinih kriterija, odnosno njihovog maksimalnog raspona potrebno je povezati s nekim od mjerila ekonomske isplativosti. Najjednostavnijim i najobjektivnijim mjerilom javnih naručitelja može se smatrati veličina troškova. Za većinu javnih naručitelja postoji mnoštvo podataka prikladnih za analizu troškova, donosno određivanja težine pojedinih kriterija.

Kod postavljanja modela odabira ekonomski najpovoljnije ponude, potrebno je voditi računa da model bude što jednostavniji, te da uzima u obzir samo troškove izvedene na temelju mjerljivih parametara.

3.1.3. Forme ugovora o građenju

Ugovaranje radova prema *Design and Build* modelu nabave, zahtjeva promjenu formi ugovora o građenju kod većine javnih naručitelja. Ukoliko bi se pridržavali u praksi prihvaćenih formi ugovora, mogla bi se primijeniti forma bazirana na FIDIC-ovoj "*Žutoj knjizi*".

Ugovori bazirani na "Žutoj knjizi" uobičajeno se koriste pri ugovaranju izgradnje elektrotehničkih i strojarskih postrojenja i građevinskih radova koji se ugovaraju po *Design and Build* modelu, odnosno za radove koje projektira izvođač.

Za razliku od "*Crvene knjige*", u ugovorima sastavljenim prema "*Žutoj knjizi*" izvođač je odgovoran za izradu projektne dokumentaciju. Također ovdje valja istaknuti i različite načine definiranja fiksne i paušalne (*Lump sum*) ugovorne cijene. Tako se u ugovorima baziranim na FIDICO-ovoj "*Žutoj knjizi*" plaćanje izvedenih radova provodi u skladu je s ugovorno definiranom dinamikom plaćanja, a ne kao prema "*Crvenoj knjizi*" - temeljem jediničnih cijena i izmjerenih količina.

Ilustracija 5. FIDIC-ova "Žuta knjiga" (www.fidic.org)

Kod ugovora temeljenim na FIDIC-ovoj "*Žutoj knjizi*", veći dio rizika je prebačen na izvođača radova. S druge strane, izvođaču je omogućeno da pri projektiranju radova na temelju specifikacija i zahtjeva naručitelja, prilagodi projektno rješenje vlastitoj tehnologiji, znanju i raspoloživim resursima - što i jest jedan od ciljeva primjene *buildability*, odnosno *constructability* koncepta.

3.1.4. Specifikacije

Specifikacije pogodne za primjenu koncepta mogle bi u većini slučajeva biti razrađene kroz formu idejnoga projekta. Uz ovakav pristup moguće je relativno precizno određivanje premeta nabave. To je posebno važno radi zadovoljenja zakonskih uvjeta vezanih uz javnu nabavu, transparentnosti samih postupaka, te osiguranja i zadovoljenja i drugih preduvjeta definiranih relevantnim zakonskim okvirom.

Obaveza izvođača radova bi u tom slučaju, između ostalog, bila izrada glavnih i izvedbenih projekata i druge potrebne tehničke dokumentacije te naposljetku i ishođenje potvrde glavnog projekta ili građevinske dozvole u ime naručitelja. Ovakvim pristupom drastično bi se smanjio rizik naručitelja u pogledu dodatnih troškova i dodatnog vremena za projektiranje i provođenje upravnih postupaka, odnosno taj rizik bi se gotovo u potpunosti prebacio na izvođača radova.

3.1.5. Metodologija izvođenja radova

U slučaju primjene koncepta te *Design and Build* modela nabave, potencijalni izvođač radova bi već u fazi nuđenja morao detaljno razraditi tehnologiju izvođenja radova i predočiti naručitelju dokaze o raspoloživosti potrebnih resursa, stručnih znanja i vještina kako bi se ocijenila prihvatljivost njegove ponude u pogledu zadovoljavanja traženih uvjeta i specifikacija projekta.

Analiziranje metodologije izvođenja radova u fazi evaluacija ponuda zahtijevalo bi da osoblje naručitelja koje je sudionik u takvoj vrsti postupka nabave ima dovoljno inženjerskog znanja i iskustva za ocjenu njezine prihvatljivosti.

3.2. Izvođačko znanje i raspoloživi resursi

U fazi nabave zasnovanoj na specifikacijama projekta razrađenim u formi idejnom projektu, potencijalnim ponuditeljima, je omogućeno da projektna rješenja prilagode vlastitim resursima. Time bi se otvorio dodatni prostor za ulaganje organizacije izvođača u vlastiti razvoj, samim time i provedbu daljnje optimalizacije projekta te u konačnici povećanja vlastite konkurentnosti i stvaranja pozitivnog financijskog efekta naručitelju.

Za postizanje potpune učinkovitosti koncepta, tražene specifikacije projekta, moraju biti dovoljno općenite da daju dovoljnu slobodu ponuditeljima pri izbora metoda i tehnologija izgradnje, te da ne nameću rješenja kojima bi se pojedini ponuditelji bili odvedeni u neravnopravan položaj u odnosu na druge kojima je specifična tehnologija dostupnija.

3.3. Organizacijski ciljevi

Uspješna implementaciju koncepta zahtijeva osiguranje određenih preduvjeta. U prvom je redu riječ o usmjerenosti organizacije na njegovu primjenu i povećanje stupnja prilagodljivosti uvođenju promjena. Za postizanje potpune učinkovitosti koncepta navedeno je potrebno promatrati sa stajališta organizacije izvođača radova, organizacije timova koji provode stručni nadzor izgradnje te organizacija javnih naručitelja.

Implementacija koncepta je znatno jednostavnija unutar organizacija izvođača radova, budući da su ti sustavi u većini slučajeva fleksibilniji za prihvaćanje promjena od organizacija naručitelja. Većina poduzeća izvođača već i sada unutar svoje organizacije ima stručne službe koje se isključivo bave razradom tehnologija izvođenja radova i prilagodbe projektnih detalja ovisno o specifičnostima projekta i dostupnosti potrebnih resursa, a u nekim slučajevima i izradom dijelova projektne dokumentacije.

Primjena *buildability / constructability* koncepta kod javnih naručitelja zahtjeva mnogo složenije promjene, odnosno prilagodbe unutar njihove organizacije i promjena uobičajenih principa upravljanja projektima.

3.4. Vještine projektnog tima

U slučaju primjene *buildability / constructability* koncepta kod javnih naručitelja, bilo bi potrebno formirati zajednički multidisciplinarni projektni tim sa stručnjacima organizacija projektanta i izvođača radova, te organizacijama naručitelja i stručnog nadzora. Zajedničkim radom svih članova tima, objedinile bi se faze projektiranja i građenja.

Infrastrukturni projekti u pravilu su složeni. Uz njih je vezana opsežna i raznovrsna projektna dokumentacija sa specifičnom dinamikom izrade ovisnom o fazama projekta. Stoga bi u slučaju primjene *buildability / constructability* koncepta, članovi projektnog tima naručitelja i stručnog nadzora trebali imati kompetencije za reviziju i evaluaciju projekta u pogledu zadovoljenja specifičnih ciljeva projekta.

3.5. Program

Izvođaču je prepušteno da odabirom tehnologije i adekvatnom razradom projektnih rješenja sam programira dinamiku izvođenja radova ovisno o dostupnosti vlastitih resursa i vlastitom znanju. Zajednički projektni tim sastavljen od predstavnika svih sudionika u projektu, unutar domene vlastitih nadležnosti, mora biti posvećen uklanjanju barijera koje mogu nepovoljno utjecati na dinamiku.

Ovdje se također postavlja pitanje kompetencije članova projektnog tima, posebno zajedničkog tima naručitelja i stručnog nadzora. Oni na vrijeme moraju identificirati sve

faktore mogućeg nepovoljnog utjecaja na predviđenu dinamiku odvijanja radova, te ocijeniti prikladnost poduzimanja mjera prema zajedničkom prijedlogu izvođača radova i projektanta.

3.6. Pristup gradilištu

Izvođač ima obavezu izgradnje svih gradilišnih putova neophodnih za potrebe organizacije vlastitih radova. Učinak koncepta u pogledu uspostavljanja gradilišne komunikacije i odabira mogućeg pristupa gradilištu ili pojedinim značajnijim objektima, može se ostvariti predviđenom metodologijom izvođenja radova.

3.7. Vanjski faktori

Vanjski faktori utjecaja na uspješnost pojedinog projekta u najvećoj su mjeri utjecaji raznih interesnih skupina. Njihovom identifikacijom, može se definirati njihovo područje interesa, razina utjecaja i njihova važnost. U većini projekata izgradnje infrastrukture, možemo prepoznati uobičajene interesne skupine.

Sa svim interesnim skupinama potrebno je postići adekvatnu razinu komunikacije te zadovoljenje njihovih zahtjeva. Primjenom koncepta prema kojem je izvođač odgovoran za projektiranje, mogući rizici odnosa i komunikacije s vanjskim interesnim skupinama u najvećoj mjeri su prebačeni upravo na njega.

3.8. Inovacije pri izvođenju radova

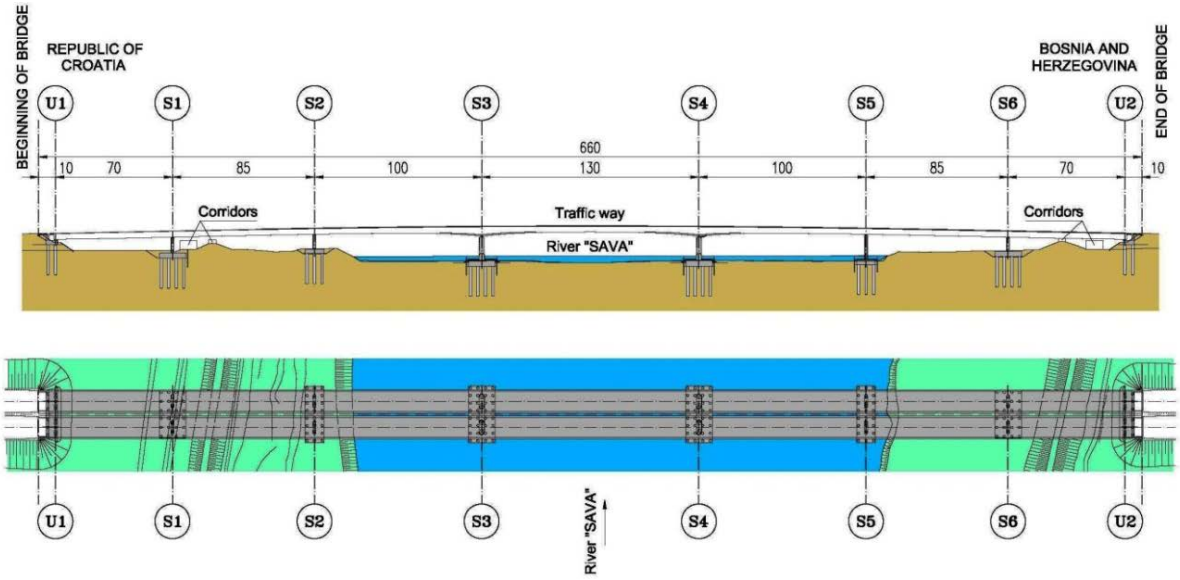
Primjena *buildability / constructability* koncepta potiče izvođače radova na ulaganja u istraživanje, razvoj te uvođenje novih tehnologija u poslovne procese s ciljem pojačavanja njihove učinkovitosti. Integracijom faza projektiranja i građenja ostvarili bi se preduvjeti u pogledu prilagodbe projektnih rješenja vlastitim resursima i njihovog efikasnijeg planiranja na razini portfelja svih projekata u kojima sudjeluju.

3.9. Povratne informacije

Među važnijim uvjetima koje u sklopu primjene koncepta potrebno zadovoljiti jest postavljanje sustava prikupljanja i analize podataka relevantnih za ocjenu uspješnosti projekta. Podaci i analitički rezultati mogu poslužiti za utvrđivanje mjera kojima bi se poboljšala uspješnost drugih budućih projekata. Valja naglasiti da većina javnih naručitelja već sada ima uspostavljenu baza podataka adekvatnih za provođenje takvih analiza.

4. Studija Slučaja - izgradnja mosta preko rijeke "Save" kod Svilaja

Most "Svilaj" preko rijeke Save sastavni je dio međunarodnog pan-europskog cestovnog koridora Vc - Budimpešta-Beli Manastir-Osijek-Sarajevo-Ploče. Koridor Vc je dio europske mreže autocesta s oznakom E-73 koja sjever Europe povezuje s Jadranom i predstavlja okosnicu cestovne prometne infrastrukture u istočnom dijelu Hrvatske. Most "Svilaj" je ujedno i kontaktna točka auto-cestovne mreže Republike Hrvatske i Bosne i Hercegovine.



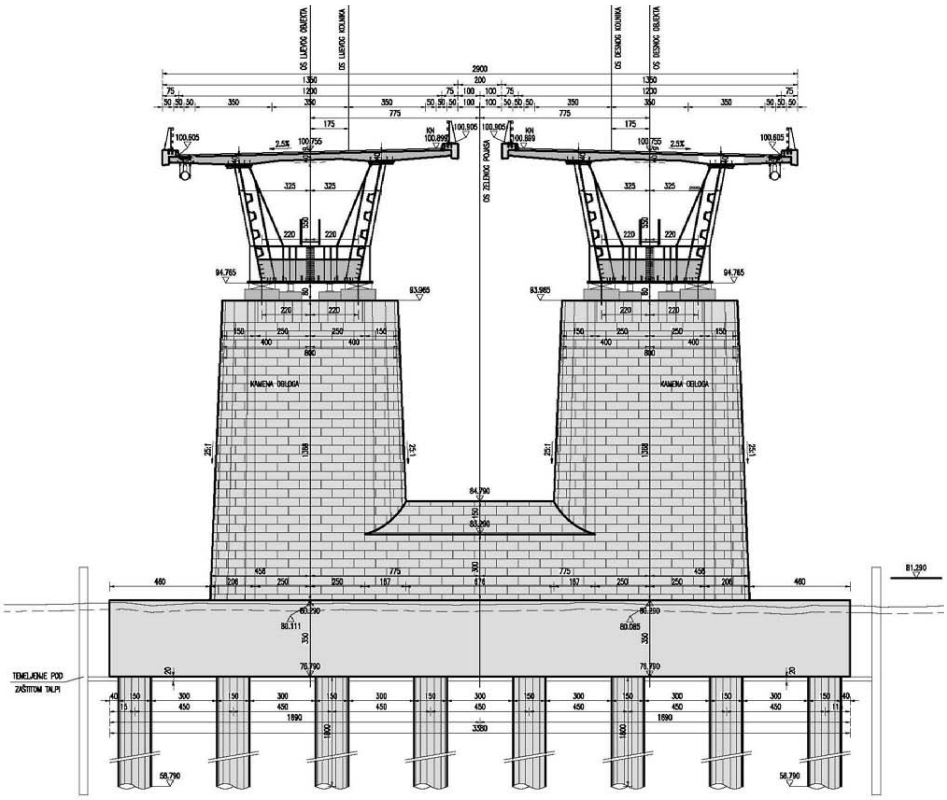
Ilustracija 6. Pogled i situacija mosta "Svilaj" (Glavni projekt, IPZ d.d., Zagreb 2010.)

4.1. Općenito o mostu "Svilaj"

Glavnim projektom definirano je tehničko rješenje mosta (lijevi i desno objekt) čiji rasponski sklop predstavlja kontinuirana greda preko sedam polja s dvostruko spregnutim poprečnim presjekom sastavljenim od čeličnog sanduka i betonske donje i gornje (kolničke) ploče. Ukupna širina lijevog i desnog objekta iznosi 13,50+2,0+13,5=29,0 m.

Ukupna duljina objekta iznosi 640,0 m. Čelični polu-sanduk promjenjive je visine od 3.300 mm do 5.500 mm, a cijeli most predstavlja jednu dilatacijsku cjelinu kod koje se prijelazne naprave nalaze samo na upornjacima

Opisano projektno rješenje, nameće tehnologiju izgradnje mosta, odnosno predviđeno je da se prilazne konstrukcije montiraju dizalicama s terena, dok bi se glavni otvor montirao konzolno s plovnog objekta metodom slobodne konzolne gradnje. Kasnije bi se na licu mjesta na pomičnoj skeli betonirala ploča kolnika.



Ilustracija 7. Presjek stupa S4 (Glavni projekt mosta, IPZ d.d., Zagreb 2010.)

Vrijednost radova, prema projektantskoj procjeni, iznosi 26 milijuna eura, a predviđeni je rok izgradnje 2 godine.

Ilustracija 8. Simulacija izgleda dovršenog mosta (Glavni projekt mosta, IPZ d.d., 2010.)

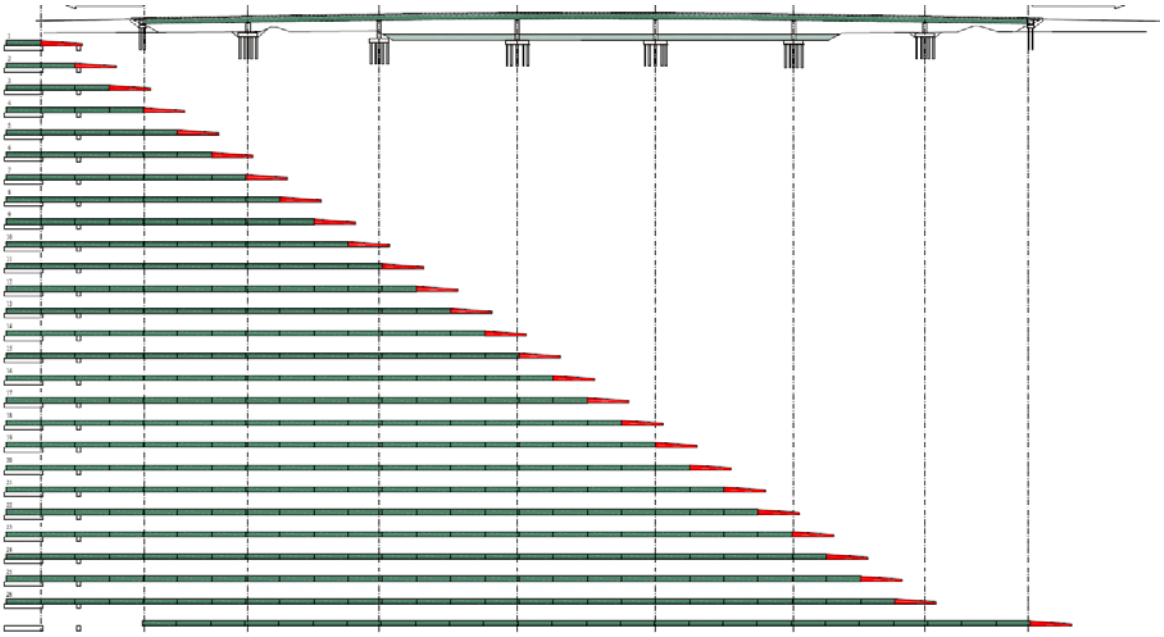
4.2. Primjena koncepta u fazi nabave

Minimalni tehnički uvjeti bili bi dani u dokumentaciji za nadmetanje u formi idejni projekta na slijedeći način:

- tip rasponske konstrukcije - spregnuta čelično-betonska konstrukcija,
- veličina središnjeg raspona - minimalno 90 m uvjetovano zahtjevima polovnosti rijeke Save na lokaciji mosta,
- prometni profil - 3 vozne trake minimalne širine 3,50 m bez zaustavne trake za zaštitnim prometnim pojasom minimalne širine 0,5 m i pješačkom stazom minimalne širine 0,75 m za svaki smjer,
- minimalni projektirani vijek građevine - 100 godina,
- postavljanje svih potrebnih instalacija ,
- rok izgradnje objekta 2 godine,
- minimalno trajanje garantnog roka na nekonstruktivne elemente 2 godine (10 za konstruktivne).

U studiji slučaja u ovom radu, analiziraju se dvije varijante projektnog rješenja koje bi hipotetski dali potencijalni ponuditelji.

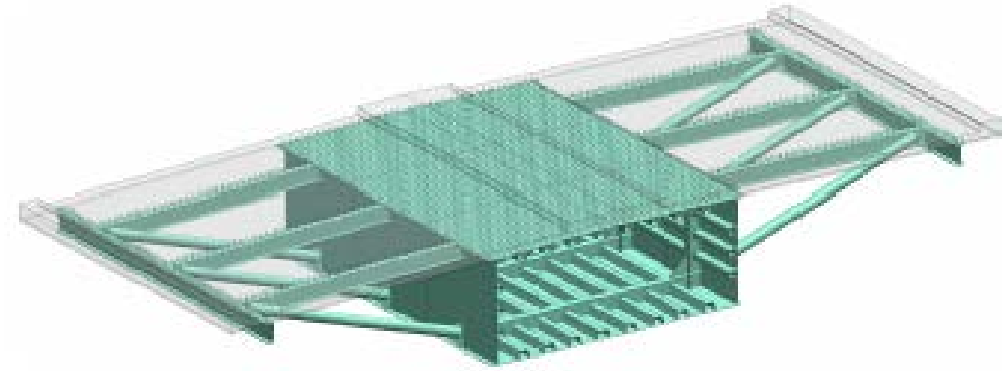
Ponuda ponuditelja označenog kao A, pretpostavljala bi izvedbu objekta prema postojećem projektnom rješenju i prethodno opisanom metodom izgradnje. Ponuditelj B, s druge strane predlaže rješenje koje podrazumijeva izgradnju jednoga objekta umjesto dva zasebna, a koji bi zadovoljavao traženi minimalni prometni profil. Središnji raspon bi, prema njegovom projektnom rješenju, bio duljine 100 m. Ponuditelj projektno rješenje prilagođava vlastitoj raspoloživoj tehnologiji te predlaže izgradnju objekta metodom uzdužnog potiskivanja samo sa jedne obale rijeke Save.



Ilustracija 9. Faze izgradnje mosta sukladno predloženoj tehnologiji izgradnje metodom uzdužnog potiskivanja ponuditelja B (Projektni biro Pointing d.o.o., Maribor, Slovenija 2011.)

Odabirom alternativnog projektnog rješenja, ponuditelj B nudi naručitelju nižu u cijenu te nešto kraći rok izgradnje u odnosu na ponuditelja A. Predloženo rješenje uzrokuje naručitelju

nešto veće troškove održavanja u projektiranom vijeku trajanja objekta. Uzrok većih troškova je složeniji poprečni presjek objekta, a povećanje troškova se u najvećoj se mjeri odnosi na zaštitu od korozije izloženih površina čeličnog sanduka mosta. Iz navedenog razloga ponuditelj nudi nešto duži garantni period za objekt.



Ilustracija 10. Poprečni presjek i izgled segmenta u prostoru konstrukcije gornjeg ustroja mosta sukladno projektnom rješenju ponuditelja B (Projektni biro Pointing d.o.o., Maribor, Slovenija 2011.)

U skladu s navedenim, bitni elementi ponuda hipotetskih ponuditelja dani su slijedećoj tablici:

Tablica 1. Prikaz bitnih elemenata ponuda dva hipotetska ponuditelja pri nabavi radova na izgradnji mosta "Svilaj" preko rijeke Save

PONUDITELJ	A	B
Cijena izgradnje u EUR, bez PDV-a	25.222.905,43	24.913.541,87
Ugovorni rok	24 mjeseci	23 mjeseci
Trajanje garantnog perioda	2 godine	3 godine

Detaljnom analizom svih tehničkih elemenata ponuda, utvrđene su razlike troškova redovnog održavanja objekta po pozicijama definiranim standardom redovnog održavanja autocesta (Mlinarević, Klarić, 2007), te su prikazane u tablici u nastavku kako slijedi:

Tablica 2. Troškovi redovnog održavanja koje su ovisni od odabira projektnog rješenja

Br. pozicije	Naziv i opis radova	Tražena Učestalost izvođenja radova
3.2.1.2.	Čišćenje komora mosta	1 x godišnje
3.3.1.14.a	Zaštita izloženih površina čelične konstrukcije gornjeg ustroja mosta	1x svakih 25 godina
3.3.1.15.a	Zaštita čelične konstrukcije u komorama mosta	1 x svakih 50 godina

Ostali troškovi redovnog održavanja objekta definirani su također navedenim standardom redovnog održavanja. Za potrebe ovog rada mogu se smatrati približno jednakima i procijeniti u fiksnom iznosu za ponude oba hipotetska ponuditelja.

4.2.1. Analiza troškova redovnog održavanja za projektirani vijek trajanja građevine

U tablici u nastavku dan je primjer izračuna troškova za jednu od pozicija koja je mjerodavna za evaluaciju ponuda.

Na prikazani način moguće je napraviti izračun i ostalih troškova prema pozicijama iz standarda redovnog odražavanja autocesta, a koji su ovisni o izboru projektnog rješenja objekta, te su relevantni za određivanje parametara ekonomski najpovoljnije ponude.

Tablica 3. Izračun troškova zaštite izloženih površina čelične konstrukcije gornjeg ustroja mosta

Opis	Jed. mjere	Normativ	Jed. cijena (eur)	Ukupna cijena
Priprema podloge - maksimalni učinak radne grupe 20 m 2 / h				
Radna snaga - priprema podloge				
Rukovatelj posebnih strojeva	h	0,0500	6,93	0,35
Pomoćni radnik	h	0,0500	5,10	0,26
Radnik - manipulacija platforme	h	0,1000	5,10	0,51
Strojevi i vozila - priprema podloge				
Pumpa Hammelmann HDP124, sa svom opremom i materijalom potrebnim za izvođenje radova na pripremi podloge	h	0,0500	154,05	7,70
Bojanje - maksimalni učinak radne grupe 2,0 m2/sat				
Radna snaga - bojanje				
Radnik - manipulacija platforme	h	1,0000	5,10	5,10
Radnik - bojanje	h	0,5000	6,93	3,47
Pomoćni radnik -bojanje	h	0,5000	5,10	2,55
Strojevi i vozila-bojanje				
Uređaj za bojanje i kompresor	h	0,5000	16,74	8,37
Materijali-bojanje				
Temeljna boja, među-premaz, pokrov, razrjeđivač, pomoćni materijal	m^2	1,0000	2,59	2,59
Ukupno rad+ materijal:	eur/m^2			30,90

Budući da je projektirani vijek trajanja građevine 100 godina, možemo odrediti visinu troškova redovnog održavanja i upravljanja u tom periodu svedenih na sadašnju vrijednost, odnosno na vrijednost 2015. godine. Pri tome se pretpostavlja da je primijenjena diskontna stopa jednaka stopi inflacije u razmatranom periodu.

Tablica 4. Usporedni izračun troškova redovnog održavanja ponuditelja A i ponuditelja B u projektiranom vijeku trajanja objekta

	Ponuditelj A (eura)	Ponuditelj B (eura)
Čišćenje komora mosta	291.563,24	182.227,03
Zaštita izloženih površina čelične konstrukcije gornjeg ustroja mosta	1,722.339,79	2.111.727,01
Zaštita čelične konstrukcije u komorama mosta	785.315,22	982.552,48
Svi ostali troškovi redovnog održavanja i upravljanja neovisni od izbora projektnog rješenja	4.500.000,00	4.500.000,00
UKUPNO	7.299.218,25	7.776.506,52

4.2.2. Vrednovanje ponuda

Vrednovanje je ponuda u skladu s relativnim modelom i prema formuli sa težinom kriterija određenih na temelju analize vrijednosti troškova na dovršenim sličnim projektima Hrvatskih autocesta d.o.o.:

$$B(i) = \frac{C_{\min}}{C(i)} \cdot 66 + \frac{T_{\min}}{T(i)} \cdot 30 + \frac{R_{\min}}{R(i)} \cdot 3 + \frac{G(i)}{G_{\max}} \cdot 1 \qquad (1)$$

$B(i)$ - broj bodova za ponudu *i*,

$C_{\min}$ - najniža ponuđena cijena ponude,

$C(i)$ - cijena ponude koja se ocjenjuje,

$T_{\min}$ - iznos najnižih troškova redovnog održavanja i upravljanja za ponudu,

$T(i)$- iznos troškova ponude koja se ocjenjuje,

$R_{\min}$ - najkraći ponuđeni rok dovršetka objekta,

$R(i)$ - rok dovršetka objekta ponude koja se ocjenjuje,

$G_{\max}$ - najdulje ponuđeno trajanje garantnog perioda,

$G(i)$ - trajanje garantnog perioda iz ponude koja se ocjenjuje,

Važno je naglasiti da je navedena formula ilustrativne prirode, te služi samo za prikaz analize mogućnosti primjene koncepta, dok bi se za konkretnu nabavu morala provesti detaljnija analiza težine kriterija ovisno o specifičnosti svakog projekta koji bi se na ovakav način ugovarao.

Prema istoj, ekonomski najpovoljnijom ponudom može se smatrati ona koja je postigla najveći broj bodova, a analiza obje ponude dana je u idućoj tablici kako slijedi:

Tablica 5. Vrednovanje ponuda ponuditelja A i ponuditelja B

	Ponuditelj A (bodovi)	Ponuditelj B (bodovi)
Cijena izgradnje	65,188	66,000
Troškovi održavanja i upravljanja	30,000	28,159
Rok izvođenja radova	2,875	3,000
Trajanje garantnog perioda	0,667	1,000
UKUPNO BODOVA (od 100)	98,660	98,159

Iz analize proizlazi da je ekonomski povoljnija ponuda ponuditelja A, te bi se u slučaju primjene koncepta ona i izabrala.

U skladu sa prikazanim vrednovanjem ponuda, evidentno je da je u ovom slučaju povoljnijom za naručitelja ocijenjena ponuda s većom cijenom same izgradnje objekta, što se ne podudara s dosadašnjom praksom izbora. Primjenom ovakvog pristupa sagledavaju se svi elementi ponuda i u projektiranom vijeku trajanja građevine naručitelj postiže najbolju vrijednost za novac.

5. Zaključak

Na temelju provedene analize može se zaključiti da je *buildability / constructability* koncept primjenjiv na javne naručitelje infrastrukturnih projekata, budući da za primjenu koncepta ne postoje zakonske ili druge prepreke. Primjenom koncepta naručitelji bi mogli postići veću vrijednost za novac na projektima izgradnje, a posredno i mjerljivu korist za druge sudionike u projektu obzirom da je koncept usmjeren na optimalno iskorištavanje raspoloživih resursa u pogledu tehnologije i osoblja te prethodno stečenih znanja i kompetencija.

Ovakav pristup omogućio bi veću fleksibilnost javnih naručitelja pri definiranju projektnih ciljeva povezanih sa velikim infrastrukturnim projektima. Pritom je najvažnije pravilno odrediti kriterije, metode odabira i vrednovanja ponuda projektnih rješenja pojedinih izvođača radova u fazi nabave, uvažavajući principe *buildability-a /constructability-a*. Time se u znatnoj povećava transparentnost postupka, odnosno umanjuje mogućnost pogodovanja pojedinim izvođačima radova u fazama nabave i kasnije izvođenja radova, jer su "pravila igre" svim potencijalnim ponuditeljima unaprijed poznata.

Primjenom *buildability/constructability* koncepta mogu se kod naručitelja u znatnoj mjeri umanjiti utjecaji najčešće prisutnih rizika pri realizaciji infrastrukturnih projekata, koji su uglavnom posljedica neodgovarajuće ili manjkave projektne dokumentacije. U tom se slučaju javna nabava i ugovaranje radova provodi na osnovu manje ili više razrađenog projektnog zadatka ili idejnog projekta. Pritom su svi rizici vezani uz projektiranje i projektnu dokumentaciju prebačeni u domenu odgovornosti izvođača radova. Primjenom *constructability / buildability* koncepta moguće je u velikoj mjeri eliminirati i eventualne manipulacije u načinu definiranja dokumentacije za nadmetanje. To je posebno karakteristično za nabavu radova čije izvođenje zahtijeva primjenu usko specijaliziranih tehnologija koje najčešće nisu dostupne svim potencijalnim ponuditeljima.

Ukoliko bi javne investicije u izgradnju infrastrukturnih objekata polazile od principa *buildability / constructability* koncepta, poduzećima izvođača radova bilo bi omogućeno da odbace nerentabilne tehnologije, da se fokusiraju na razvoj i prihvaćanje novih tehnologija te da usmjere politiku upravljanja vlastitim potencijalima s ciljem dodatnog smanjenja troškova poslovanja.

Prepreke primjeni *buildability / constructability* koncepta kod javnih naručitelja prepoznate su i zajedničke u svijetu i u Republici Hrvatskoj. Jedna od najvećih prepreka je nevoljkost uvođenja promjena u odnosu na ustaljene principe rada. U tu je svrhu kod nositelja javnih investicija na razini države, javnih poduzeća, javnih institucija i lokalne samouprave potrebno razviti svijest o prepoznatim alternativnim modelima upravljanja infrastrukturnim projektima i koristima koje njihovom primjenom mogu ostvariti svi sudionici projekta, što zahtjeva ulaganje određenih financijskih sredstava u dodatnu edukaciju osoblja u sustavu javnih naručitelja.

Osim dodatne edukacije osoblja potrebno je dodatno razraditi sustav prikupljanja i obrade relevantnih podataka o dovršenim projektima i projektima u tijeku. To je preduvjet za ispravno vrednovanje projektnih rješenja u ranim fazama projekata. Stečena iskustava, uočene manjkavosti te koristi ostvarene odabirom alternativnih projektnih rješenja, osnova su poboljšanja sustava na koji se *buildability / constructability* koncept oslanja.

Model javne nabave građevinskih radova po kriteriju ekonomski najpovoljnije ponude u Republici Hrvatskoj nedovoljno je poznat. Odabir izvođača po kriteriju ekonomski najpovoljnije ponude zahtijevao bi od nadležnih tijela koje kontroliraju postupke javne nabave definiranje odgovarajućih smjernica za provedbu takvog odabira, a sve s ciljem izbjegavanja netransparentnosti u postupcima i sprječavanja zastoja i kašnjenja u ranim fazama projekta kao posljedice moguće pogrešne interpretacije pravila pri provođenju postupaka.

Već je naglašeno da je za potpunu implementaciju *buildability/constructability* koncepta potrebno da se kod javnih naručitelja, razviju spoznaje o principima koncepta i osobitostima njegove primjene. Međutim, primjena koncepta zahtjeva da se u takvim sustavima provedu prikladne organizacijske promjene.

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Utjecaj upravljanja projektima na kvalitetu u graditeljstvu Bosne i Hercegovine i Hrvatske

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Sažetak

Suvremena kompanija egzistira pod uticajem brojnih faktora koji potiču, kako iz vanjske okoline, tako i iz interne cjeline kompanije. Razvoj tržišnih odnosa i udovoljenje rastućim zahtjevima potrošača za boljim, funkcionalnim, komplementarnim proizvodima, informacijama i uslugama, što u stvari predstavlja kvalitet, ciljevi su i politika kompanija, i preduslov za razvoj iste u vremenu i zadovoljenje društvenih potreba. Do kraja prošlog vijeka organizacije su počele da uviđaju da je stvar potrebe primjena upravljanja projektima, a ne njihov slobodni izbor. Do željene kvalitete se može doći na dva načina implementacijom jednog od sustava upravljanja kvalitetom ili jednostavno okretanje ka kvaliteti u svim aspektima poslovanja kompanije. U oba slučaja, jedan od prvih koraka je analiza ključnih faktora kvalitete. Pokazaće se rezultati analize anketa provedenih u Bosni i Hercegovini i Hrvatskoj na temu upravljanje projektima, ključnih faktora kvalitete, faze projekta i međusobne razlike u stajalištu učesnika u projektu. Vidjeće se da pojedini učesnici u BiH i RH nemaju isto rangiranje za određene faktore, pa tako npr. Investitori u BiH najviše rangiranim faktorom kvalitete smatraju "podrška top menadžmenta", dok u RH smatraju da je to "kontinualno poboljšanje". Osnovna svrha rada je pokazati kako upravljanje projektima utječe na kvalitet projekta.

Ključne riječi: graditeljstvo; projekat; upravljanje projektima; ključni faktori kvaliteta; Bosna i Hercegovina; Hrvatska

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1. Uvod

Savremeno preduzeće egzistira pod uticajem brojnih faktora koji potiču, kako iz vanjske okoline, tako i iz interne cjeline preduzeća. Kako bi pravovremeno odgovorilo na sve izazove tržišta ono mora unaprjeđivati kvalitetu svojih proizvoda, procesa i raditi na edukaciji zaposlenika. Neophodno je razumijeti pojam kvalitete, jer kvaliteta je postala jedan od ključnih imperativa današnjice koju žele i kupci i prodavaoci i zaposlenici unutar organizacije. Pojam kvalitete ima različita značenja za različite ljude. Kvaliteta projekta definisan je kao ispunjenje dogovorenih zahtjeva za projekat (IPMA, 2006.) .

Svi sudionici u gradnji teže postizanju zadovoljavanja svojih potreba, naplati potraživanja i osiguranju profita. Jasno je da se kvaliteta u građevinskom projektu može promatrati sa stajališta kvalitete same građevine koja se očituje u njezinoj funkcionalnosti, ekonomičnosti, estetici i sigurnosti. Možemo posmatrati građevinski projekat ovisno na mogućnost zadovoljavanja potreba svih sudionika u gradnji ili kao suprotnost nedostacima i šteti.

Upravljanje kvalitetom je postalo jako bitno u projekatu izgradnje, većina aktera su zabrinuti sa kvalitetom svojih projekata, upravljanja kvalitetom na pravi načim može olakšati uspjeh projekta i organizacijske održivosti (Husin et al., 2008.).

Upravljanje projektima se može poboljšati kroz proces upravljanja kvalitetom. Pravilno upravljanja projektima može olakšati ostvarivanje kvaliteta projekta, a samim tim i organizacijske održivosti (Ogwueleka, 2013.).

Bez podrške vrha menadžmenta upravljanje projektima neće biti usvojeno. Za njih upravljanje projektima ne predstavlja gotovo ništa ili jako malo što za posljedicu ima nedostatke u projektima. Istraživanja pokazuju da male i srednje kompanije čine 99,8% svih kompanija u EU, generišu 56% BDP-a i zapošljavaju 70% od privatnog vlasništva. Rezultati su pokazali su da u malim i mikro kompanijama nema tendencije korištenja poznatih alata i tehnika upravljanja projektima (Turner et al., 2010.).

Iskustva kompanija koje su uvele sustav kvaliteta ukazuju na sljedeće prednosti: troškovi poslovanja se snižavaju i so 50%, produktivnost se povećava do 50%, profit se povečava od 30-50%. Unutrašnje prednosti od uvedenog koncepta upravljanja kvalitetom su: unapređenje očekivanja kupca, unapređenje dokumentacije, unapređenje procesa, unapređenje motivacije zaposlenih, razvoj kvaliteta proizvoda, unapređenje poslovanja, povećanje efikasnosti, smanjenje škarta, dok u vanjske prednosti spadaju: zadovoljenje zahtjeva kupca, rast profita, povećanje konkurentnosti, unapređenje proizvoda, razvoj marketimg imiđa, razvoj odnosa sa dobavljačima, povećanje prodaje, smanjivanje žalbi kupaca, povećanje prodaje na inostranom tržištu (Joiner, 2007, Čačkalo, 2008.).

U praksi su malo i skoro nikako dostupni podaci o utjecaju upravljanja projektima na kvalitet kako u regionu, tako i u svijetu uopće. Učesnici u građenju (Investitor, Izvođač/ podizvođač, Projektant, Voditelj projekta, Konsultant), kao i krajnji korisnici projekta će imati izravne koristi od istraživanja ovog međusobnog utjecaja. Na vrlo jednostavan način će moći sagledati na osnovu nivoa na polju upravljanja projektima preko faktora kvaliteta, dal' zadovoljavaju određene određene postavljene ciljeve u smislu zadovoljavanja kvaliteta projekta ili faze projekta.

Metodologija istraživanja je bila sljedeća: analiza i sinteza pregleda literature, pravljenje i slanje anketnog upitnika, analiza rezultata obavljene ankete, diskusija i donošenje zaključaka za sljedeće korake istraživanja. Istraživanje se provelo u Bosni i Hercegovini i Hrvatskoj u građevinskom sektoru, što predstavlja osnovu za dalja istraživanja koja idu u pravcu formiranja modela koji će se moći lako primjenjivati u praksi, a pokazaće uticaj upravljanja projektima na kvalitet.

Ovaj rad će prikazati pregled literature o saznanjima o projektu, fazama projekta i upravljanju projektom, takođe i o kvaliteti i upravljanju kvalitetom. Sljedeće će se predstaviti istaživačka pitanja na koja će se na kraju rada i odgovoriti. Nakon toga će se objasniti istraživanje provedeno u građevinskim kompanijama u BiH i Hrvatskoj kroz metodologiju istraživanja, na kraju će se predstaviti rezultati i koraci koji sljede u daljem nastavku istraživanja.

2. Pregled literature

2.1. Projekat i faza projekta, upravljanje projektom

Projekt je svaki jednokratni ljudski poduhvata koji ima jasno definisan cilj, te se izvodi se po fazama, unutar zadanog vremena i uz trošenje ili iskorištavanje određenog broja različitih i ograničeno raspoloživih resursa (Radujković, 2000.). Organizacija Project Management Institute (PMI, 2007.) definiše projekat kao vremenski određeno nastojanje da se proizvede jedinstven proizvod, usluga ili rezultat. Jasno je vidljivo iz predhodne definicije da je projekat privremena aktivnost, što znači da projekat ima svoj početak i kraj, projektom je stvoren jedinstven poizvod. Međunarodni standard kvalitete ISO definiše projekat kao jednokratan proces koji se sastoji od skupa koordiniranih i kontrolisanih aktivnosti sa poznatim početkom i krajem, čijim relizovanjem ostvaruje se cilj u skladu sa specifičnim potrebama, u uslovima ograničenja vremena, troškova i resursa (ISO, 2009.). International Project Management Association (IPMA, 2006.) definiše projekt kao poduhvat ograničenog vremena i troškova kojim se realizuje skup tačno definisanih produkata u skladu sa postavljenim ciljevima, priznatim standardima kvaliteta i potrebama naručitelja.

Prema PRINCE 2 (Chin et al, 2012.) (glavne osobine ove metode su definisana struktura upravljanja projektom, fleksibilne tačke odluke, sustav planiranja resursa, skup kontrolisanih procedura, fokusiranost na proizvode kroz cijeli projekt) faze projekta su iniciranje, pokretanje, usmjeravanje, kontrola, upravljanje isporukama i finalizacija.

Faze prema vrsti poslova koji se odvijaju u projektu po PMI-u (PMI, 2007.) su :

- Koncipiranje – definisanje projekta, identifikacija potreba i mogućnosti, određivanje alternativa i organizacije projekta;
- Planiranje – izrada pripremnih planova i skica, detaljno projektovanje i izrada kompletnog plana;
- Izvršenje ili izvođenje – izvršenje i koordinacija svih aktivnosti i resursa da bi se završio projekat;
- Završna ili konačna – završne aktivnosti i zadaci da bi se ostvarili projektni ciljevi.

Upravljanje projektom je održavanje ravnoteže između projektih ciljeva, plana i resursa. Upravljanje projekta predstavlja primjenu znanja, vještina, alata i tehnika u realizaciji aktivnosti projekta kako bi se ispunili svi zahtjevi jednog projekta. Upravljanje projektima se izvršava kroz primjenu i integraciju procesa upravljanja projektima koji obuhvataju određene faze. Projekt menadžer je odgovorna osoba za postizanje projektnih ciljeva (PMI, 2013.).

2.2. Kvaliteta, kritični faktori kvalitete

Kvaliteta je kao i ljepota - u oku promatrača. Kvaliteta je subjektivan fenomen. Ona je emocionalni doživljaj koji nastaje kao rezultat percepcije i očekivanja. Kvaliteta se različito

definiše od strane zainteresovanih strana u projektu, jer pojam kvaliteta za projektanta, krajnjeg korisnika ili društva uopšte nije isti.

Kvaliteta sa stajališta potrošača je stupanj vrijednosti proizvoda ili usluge koji zadovoljavaju određenu potrebu, i kada te proizvode ili usluge upoređuju sa konkurencijom na tržištu. Proizvođači, s druge strane, u pravilu definiraju i mjere kvalitetu kao stupanj sukladnosti prema određenom standardu koji propisuje na koji se način određeni proizvod mora proizvesti da bi bio korektan. Kvaliteta sa stajališta tržišta je stupanj do kojeg određena roba ili usluga zadovoljava određenog kupca u odnosu na istovrsnu robu ili uslugu konkurencije.

Očigledno je da je posljednjih dvadesetak godina kvaliteta kao osobina proizvoda/usluga postao izuzetno tržišno zastupljen i promovisan. Kao takav isti je danas dobio primarno mjesto među pokazateljima tržišne uspješnosti jedne organizacije ispred brojnih mjerljivih parametara kao što su produktivnost, rentabilnost, likvidnost, uposlenost kapaciteta isl. Brojni su oni koji ovaj fenomen povezuju sa intenzivnim trendom promjene odnosa kupca prema kvalitetu. Da bi ostali u tržišnoj utakmici i proizvođači su se morali prilagoditi takvom shvatanju. Istraživanja pokazuju da je danas uobičajeno da 80-90 % kupaca/korisnika na prvo mjesto karakteristika proizvoda stavljaju kvalitetu. Zbog toga ne čudi da se posljednji vijek smatra "vijekom kvaliteta", a kvalitet najznačajnijim fenomenom našeg doba (Flyvbjerg, 2013.) .

Do željene kvalitete se može doći na dva načina: prvim, koji predstavlja implementaciju jednog od sustava upravljanja kvalitetom, kao što su: ISO 9000, TQM (Total Quality Managament), Six Sigma, Kaizen, 5S, Metodologija dvadeset ključeva ili drugim, koji podrazumijeva jednostavno okretanje ka kvaliteti u svim aspektima poslovanja organizacije. U oba slučaja, jedan od prvih koraka je analiza kritičnih faktora (Yung et al., 2010.).

U pojedinim slučajevima faktori kvalitete su povezani ili upoređeni sa faktorima koji utiču na upravljanje sigurnošću građevinskih projekata, ali nije se našla bilo kakav podatak o uticaju ovih faktora u različitim fazama građevinskog projekta. Takođe se nije našao podatak o mogućoj vezi upravljanja projektima sa njegovim fazama i podfazama i faktorima koji utiču na upravljanje kvalitetom građevinskog projekta. Nakon pregleda, analize i selekcije svih faktora kvalitete došlo se do njih 11 (F1 - Planiranje i kontrola, F2 - uključenost, timski rad..., F3 - stručnost, znanje..., F4 - usmjerenost na kupca..., F5 - podrška top menadžmenta, F6 – komunikacija, F7 - kontinualno poboljšanje, F8 - koordinacija među sudionicima, F9 - politika kvaliteta, F10 - dostupnost resursa, F11 - dobavljačevo upravlanje kvalitetom) koji su analizirani u istraživanju koje je provedeno u BiH i Hrvatskoj.

2.3. Uspjeh, kritični faktori uspjeha

Krajnji cilj menadžera projekta ili programa je da bude uspješan, i iz tog razloga (IPMA, 2008.) uspjeh projekta se definiše kao "cjenjenje rezultata projekta od strane različitih zainteresovanih strana", naglašavajući da ova definicija predstavlja veći izazov od "da ostvari isporučive rezultate projekta unutar datog vremena i budžeta", što samo predstavlja njegov dio. U literaturi je prisutno različito percipranje uspjeha projekta od onog tradicionalnog da se uspjeh mjeri prema učinku kroz vrijeme, novac i kvalitet do toga da se uspjeh mjeri kroz postizanje opštih ciljeva projekta (Cooke-Davies, 2002.). Uspjeh ili neuspjeh bilo kojeg projekta u velikoj mjeri utječe na performanse projekta (troškove , vrijeme , i kvalitet).

Kritični faktori uspjeha predstavljaju ograničeni broj područja čiji će zadovoljavajući rezultati osigurati uspješne konkurentne performanse za pojedinca, odjel ili organizaciju. Isto tako, kritični faktori uspjeha mogu se odrediti i kao one karakteristike proizvoda koje posebno

cijeni i vrednuje određena skupina i prema čemu organizacija u njima mora nadmašiti konkurenciju (Johnson, 2005.). Postoji razlika u kategorizaciji kritičnih faktora uspjeha, postoji razlika i u broju istih. Obično se njihov broj kreće u intervalu između pet i osam, a sadržajno, to su faktori koji imaju izravan i jak uticaj na efikasnost, efektivnost i održivost organizacije ili programa, odnosno projekta.

Uspjeh projekta je složen i višeznačan pojam i on se mijenja tokom životnog cilusa projekta i proizvoda (Jugdev, 2005.).

Nakon pregleda i analize literature došlo se do saznanja da različiti autori u različitim istraživanjima definišu i kriterije uspjeha i kritične faktore uspjeha (različit broj faktora ili grupa faktora) ili samo kritične faktore uspjeha. Kritični faktori uspjeha prema Hyväri-u su: misija, podrška upravljanju, raspored projekta, konsultacije klijenta, osoblje, tehnički zadatak, prihvatanje klijenta, praćenje i povratne informacije, komunikacija, rješavanje problema (Hyväri, 2006.), Dang smatra da su to: procedure, karakteristike projekta, okoliš, atmosfera rada na projektu, strategija, učesnici vezani za projekat (Dang et al., 2012.).

3. Metodologija istraživanja

Nakon pregleda literature i definisanja osnovnih kritičnih faktora kvalitete, sprovedeno je anketiranje u BiH i Hrvatskoj, a nakon toga je izvršena analiza rezultata, stvaranje zaključaka kao i formiranje modela koji će pokazati koji faktori, u kojim trenucima, tj. u kojim fazama, se trebaju uzimati u obzir, a da bi moglo mjeriti da li se određena područja projekta upravljaju dobro, a da se ostvaruje zadana kvaliteta. U anketama smo uzimali u obzir faze koncipiranja, definisanja i planiranja, izvođenja i monotoringa i kontrole, uticaj faktora koji su anlizirani u nastavku imaju primarni uticaj u navedenim fazama, tako da isti nisu analizirani za fazu zatvaranja projekta.

Podaci dobijeni analizom literature, anketnim upitnicima korišteni su za analiziranje i dokazivanje hipoteza koje su postavljene. Pri tome je korišteni neparametrijski Kruskal-Wallisov test (kako bi se utvrdilo da li je tri ili više uzorka pripada istom skupu ili osnovnimskupovima, u pogledu ispitivane osobine, koji imaju jednake aritmetičke sredine).

Jedan dio anketnog upitnika je sadržavao pitanja koja su vezana za kritčne faktore upravljanja kvalitetom, čija se važnost ocjenjivala prema Likertovoj skali ocjenjivanja (1 – nisam upoznat, 2 – nije važno,..., 6 – najvažnije), zatim se svakom pojedinom kritiči faktoru kvalitete dodjeljivala faza projekta (koncipiranje, definisanje, izvođenje, monotoring i kontrola) za koju se smatralo da je najvažiji. Anketni upitnik je putem e-maila poslan i to pomoću web aplikacije - docs.google.com- i to u periodu april – oktobar (BiH: april-juli, HR: septembar-novembar) na 3156 adresa u BiH i Hrvatskoj, 154 je bilo ispunjenih anketnih upitnika, 611 ispitanika nisu dobili mail (zbog ne postojeće adrese ili sl.), 2391 ispitanika nije popunilo anketu. Anketa se satojala iz pet dijelova, prvi dio sadrži opšta pitanja, drugi i treći (po fazama projekta) sadrži pitanja o upravljanju projektima, kvalitetu i uspjehu projekta, četvrti analizira faktore koji utiču na upravljanje kvalitetom i peti analizira kritične faktore uspjeha. Rezultati su analizirani neparametrijskom analizom varijanse sa rangovima (1), a da bi se ispitalo da li postoji razlika između perspektiva ispitanika korisio se ne parametrijski Kruskal-Waillisovim test, ako bi se pojavile značajnije razlike za nivo važnosti 0,05 u perspektivama između uzoraka koristili smo Mann-Whitneyevim neparametrijski test koji pokazuje koji se par/ovi populacije razlikuju i koji je identičak kao parametirjski t -test koji uzima u obzir dva uzorka , zatim su provjereni u programu za statistiku SPSS 16.0, nakon toga je je urađeno rangiranje kritičnih faktora upravljanje kvalitetom iz percepcije Investitora,

Izvođača/poizvođača, Projektanta/Voditelja projekta/koordinatora (Wysocki, 2006) (Vukomanović et al., 2012.)

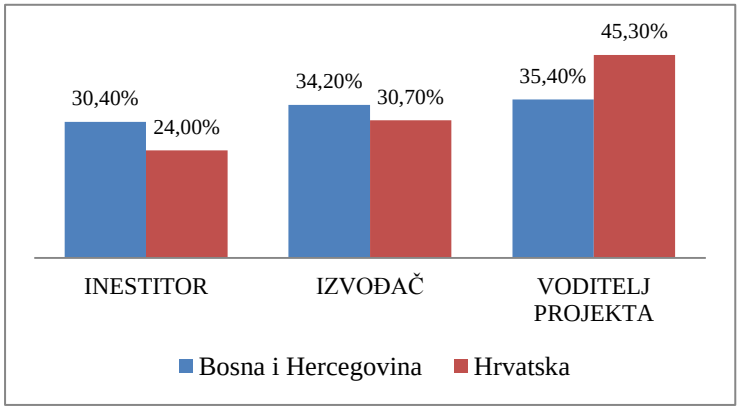
Gdje je: ∑w – suma ocjena datih pojedinom faktoru; A – max. data ocjena za pojedini faktor; N – ukupan broj ispitanika.

$$RII = \frac{\sum w}{A \times N} \qquad (1)$$

RII se kreće u intervalu 0 ÷ 1, kada se koristi ordinarna skala ocjenjivanja pri istraživanju mnogi istraživači zagovaraju ovaj način rangiranja, što je RII veći to to se smatra važniji faktor kvalitete.

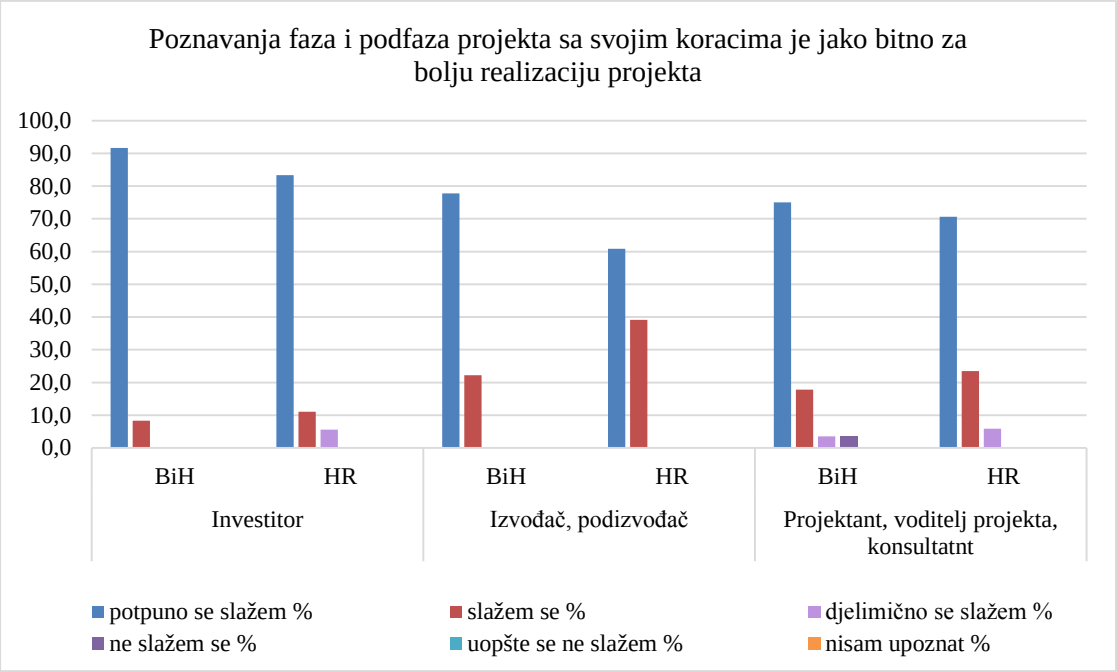
4. Analiza i diskusija rezultata istraživanja

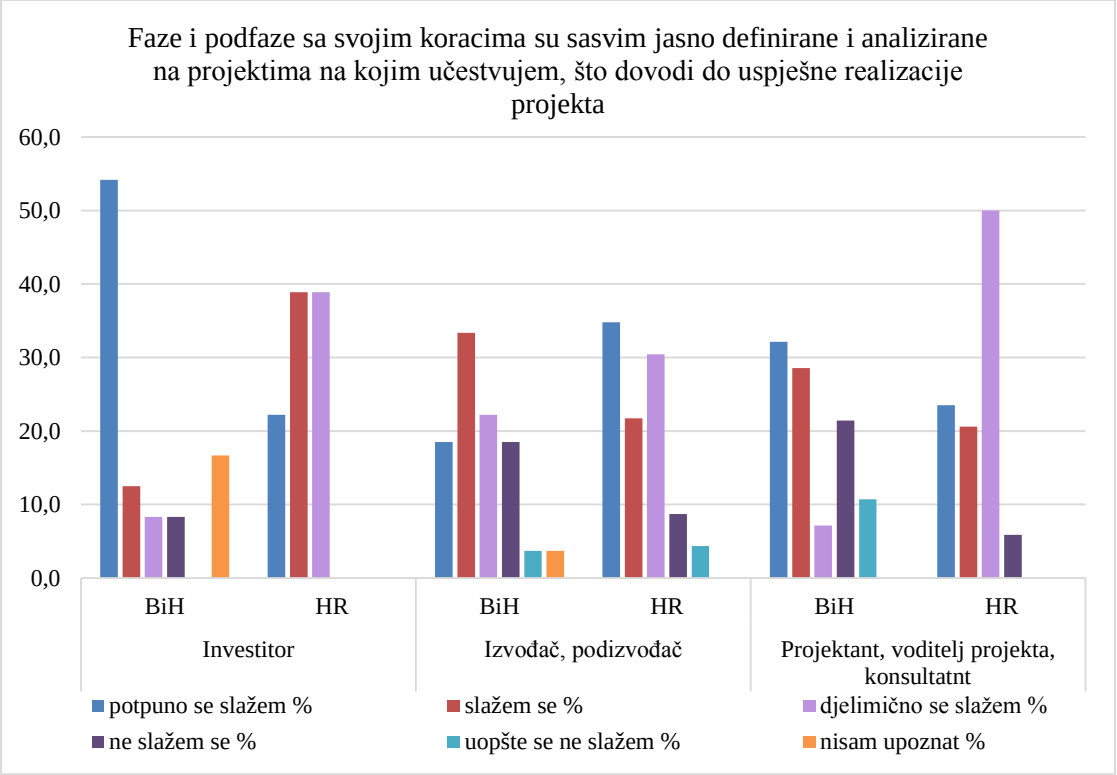
Od 154 primjenih i ispunjenih anketnih upitnika, 79 je bilo iz Bosne i Hercegovine i 75 iz Hrvatske. Na slici 2 je prikazan procentualni udio ispitanika po grupama Investitor, Izvođač/podizvođač – u nastavku teksta Izvođač, Projektant/voditelj projekta/konsultant – u nastavku teksta Voditelj projekta u BiH i HR koji su ispunili anketni upitnik, (Ilustracija 1).



Ilustracija 1. Učešće ispitanika po grupama

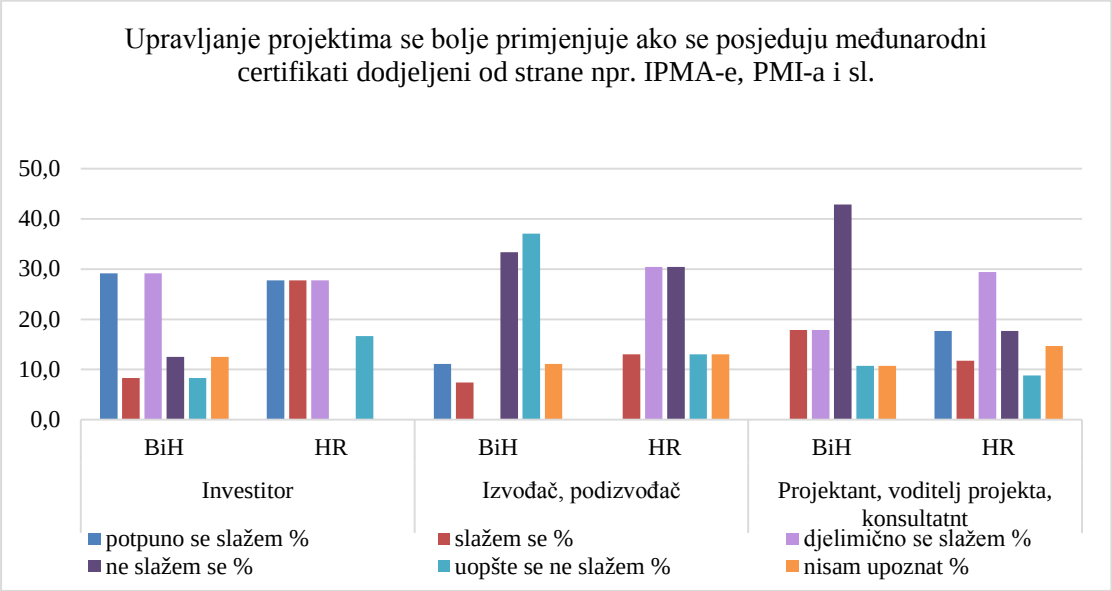
Sljedeći grafikoni 1. i 2. prikazuje kako predhodno navedene grupe shvataju i praktikuju upravljanje projektima, značaj kvaliteta u Bosni i Hercegovini i Hrvatskoj. Vidljive su razlike u odgovorima između grupa ispitanika na istom području, kao i između dvije države. Rezultati pokazuju da zavisno koliko su pojedine grupe ispitanika uključene u faze projekta generalno, tako su koncipirani i odgovori. Zanimljivo je da u Hrvatskoj tek 27,8% Investitora i 17,6% Voditelja projekata u potpunosti slaže da se upravljanje projektima bolje primjenjuje

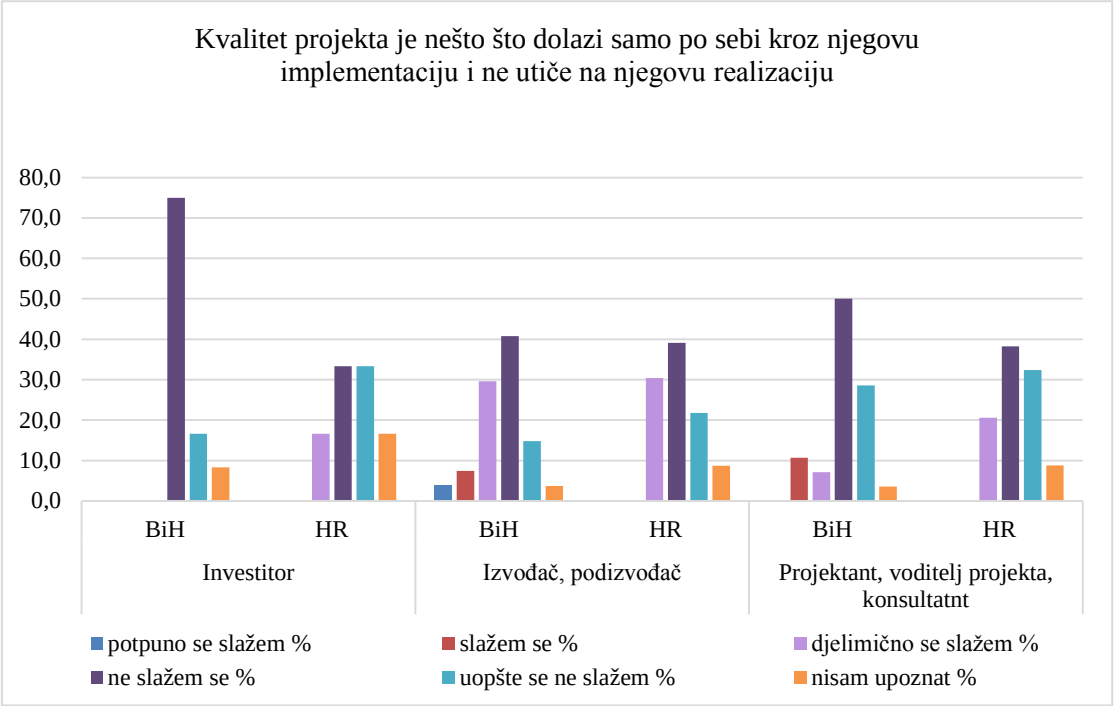




Grafikon 1. Rezultati anketiranja u Bosni i Hercegovini i Hrvatskoj

ako se posjeduje neki od međunarodnih certifikata iz upravljanja projektima, dok se u Bosni i Hercegovini Investitori 29,2% u potpunosti slažu sa tim, razlog tome je nedovoljno poznavanje prednosti i mogućnosti koje nosi certificiranje sa sobom.sa konstatacijom da su faze i podfaze sa svojim koracima su sasvim jasno definirane i analizirane na projektima na kojim učestvujem, što dovodi do uspješne realizacije projekta 42,9% Voditelja projekata u BiH se ne slaže, 54,2% Investitora se u potpunosti slaže, u HR 38,9% Investitora se slaže i djelimično slaže, dok 50% Voditelja projektima se djelimično slaže.





Grafikon 2. Rezultati anketiranja u Bosni i Hercegovini i Hrvatskoj

Rezultati istraživanja su pokazali da svi učesnici u BiH i Hrvatskoj (tablica1) smatraju da je najvažniji faktor uspjeha koordinacija među učesnicima, ostala rangiranja su međusobno različita pa tako u BiH, Investitori smatraju da su najvažniji faktori podrška top menadžmenta (RII=0,868), planiranje i kontrola (RII=0,861), stručnost, znanje (RII=0,854), koordinacija među učesnicima (RII=0,847), Izvođači: dostupnost resursa(RII=0,833), komunikacija (RII=0,821), koordinacija među učesnicima (RII=0,815), dobavljačevo upravlanje kvalitetom (RII=0,802), Voditelji projekta: Koordinacija među učesnicima (RII=0,851), stručnost, znanje... (RII=0,839), komunikacija (RII=0,839), planiranje i kontrola(RII=0,821). Razlika u perspektivama se javljala kod faktora "podrška top menadžmenta", i to između investitora i izvođača i investitora i voditelja projekta.

Tablica 1. Rangiranje kritičnih faktora kvalitete RII – Bosna i Hercegovina, Hrvatska

Faktor kvalitete	**Svi učesnici**		**Investitor**		**Izvođač...**		**Voditelj projekta ...**	
	BiH	HR	BiH	HR	BiH	HR	BiH	HR
Planiranje i kontrola – F1	0,808	0,847	0,861	0,806	0,747	0,833	0,821	0,877
Uključenost, timski rad... – F2	0,783	0,804	0,806	0,824	0,790	0,761	0,756	0,824
Stručnost, znanje... – F3	0,823	0,860	0,854	0,815	0,778	0,833	0,839	0,902
Usmjerenost na kupca... – F4	0,736	0,758	0,736	0,731	0,753	0,746	0,720	0,779
Podrška top menadžmenta – F5	0,783	0,771	**0,868**	0,806	0,728	0,768	0,762	0,755
Komunikacija – F6	0,827	0,847	0,819	0,815	0,821	0,833	0,839	0,873
Kontinualno poboljšanje – F7	0,764	0,824	0,736	**0,833**	0,759	0,812	0,792	0,828
Koordinacija među učesnicima – F8	**0,838**	**0,893**	0,847	**0,833**	0,815	**0,906**	**0,851**	**0,917**
Politika kvaliteta – F9	0,770	0,773	0,736	0,778	0,784	0,783	0,786	0,765
Dostupnost resursa – F10	0,793	0,813	0,806	**0,833**	**0,833**	0,797	0,744	0,814
Dobavljačevo upravlanje kvalitetom – F11	0,766	0,744	0,778	0,685	0,802	0,783	0,720	0,750

Tablica 2. Rangiranje kritičnih faktora uspjeha RII – Bosna i Hercegovina, Hrvatska

Faktor uspjeha	**Svi učesnici**		**Investitor**		**Izvođač...**		**Voditelj projekta ...**	
	BiH	HR	BiH	HR	BiH	HR	BiH	HR
Misija – FU1	0,757	0,744	**0,854**	0,806	0,722	0,638	0,708	0,784
Planiranje realiziranja projekta – FU2	0,795	0,820	0,778	0,796	0,796	0,790	0,810	**0,853**
Sudionici u projektu – FU3	0,806	0,791	0,806	0,750	0,821	0,790	0,792	0,814
Komunikacija – FU4	0,816	**0,847**	0,826	0,815	0,827	**0,877**	0,798	0,843
Prihvatanje i konsultacije – FU5	0,821	0,798	0,826	0,750	0,840	0,812	0,798	0,814
Praćenje i povratne informacije – FU6	**0,827**	**0,847**	0,799	**0,833**	**0,858**	0,862	**0,821**	0,843
Podrška top menadžmenta – FU7	0,762	0,764	0,771	0,815	0,747	0,739	0,768	0,755

Tablica 2 prikazuje da ispitanici u BiH i HR najvažnijim faktorom uspjeha smatraju praćenje i povratne informacije (RII=0,827; 0,847), dok u HR smatraju da je to i komunikacija, ostala rangiranja su međusobno različita među ispitanicima u BiH, Investitori misiju rangiraju kao prvu, komunikaciju i prihvatanje i konslutacije kao drugu. U Hrvatskoj

Investitori (RII=0,833) praćenje i povratne informacije stavljaju na prvo mjesto isto kao i Izvođači (RII=0,858) i Voditelji projekata (RII=0,821) iz BiH.

5. Zaključak

Pokazane su razlike među grupama ispitanika koje učestvuju na projektu u svim postavljenim pitanjima, a tako i među ispitanicima istih grupa između BiH i HR. Poražavajuća je činjenica da čak 29,2% Izvođača u BiH i 30,4% u HR djelimično se slaže ili nije sigurno da je kvalitet projekta nešto što dolazi samo po sebi kroz njegovu implementaciju i ne utiče na njegovu realizaciju što pokazuje koliko se kvalitet projekta smatra kao nešto što je neophodno analizirati, osigurati, pratiti i poboljšati.

U ovom istraživanju smo dokazali da postoje razlike u rangiranju pojedinih ključnih faktora kvalitete između Investitora, Izvođača i Voditelja projekta, projektanta. Takođe smo pokazali za ključni faktori uspjeha nisu isto rangirani u BiH i HR od strane ispitanika. Jedan od razloga je i njihovo nejednako poznavanje i shvatanje važnosti upravljanja projektom i kvaliteta uopšte. Takođe razlike su vidljive između navedenih učesnika u projektima u Bosni i Hercegovini i Hrvatskoj, al' interesantno je su četiri prva rangirana faktora kvalitete od strane svih učesnika jednaka i u BiH (koordinacija među učesnicima; komunikacija; stručnost, znanje...; planiranje i kontrola) i u RH (koordinacija među učesnicima; stručnost, znanje...; komunikacija; planiranje i kontrola) su jedntaki. Razlike osim između grupa učesnika u projektima se takođe vidljive i između država BiH i HR, što pokazuje da shvatanja važnosti faktora kvaliteta, faktora uspjeha i upravljanja projektima još uvijek nije isto u navedenim područjima.

Dobijeni rezultati istraživanja će se uključiti u prijedlog modela koji će za svaku fazu projektata preko nivoa upravljanja projektom, moći pomoću zaostajućih pokazatelja izvršenja (KPO) i uticaja ključnih faktora kvalitete doći do "quality gate-a" te faze, koji su ujedno i pokazatelji za istu (dal' bi se trebalo nešto mjenjati ili popravljati).

Koristi od ovog istraživanja će imati učesnici u građenju Investitori, Izvođači/podizvoči, Projektanti/Voditelji projekata/Konsultanti kao i krajnji korisnici istih, jer će se moći poboljšati kvaliteta projekata kroz upravljanje projektima što je jedan od ključnih zahtjeva krajnjeg korisnika.

Ovo istraživanje se može proširiti na način da se u u isto uključe sve zainteresirane strane u projektu (stakeholderi), da se proširi "krug" ispitanika npr. na krajnje korisnike. Takođe isto se može prošititi na duži vremenski period, jer poznato je da životni ciklus građevinskog projekta traje i nakon završetka njegove izgradnje. Mogućnost proširenja ovog istraživanja i međusobnog poređenja na druge privredne grane osim građevinarstva bi bilo jako interesantno. Takođe bi bilo interesantno istraživanje vršiti na samo javnim projektima ili jako velikim projektima na širem regionu Evrope, uključujući i druge zemlje osim Bosne i Hercegovine i Hrvatske.

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Primjena nove regulative na procjene vrijednosti nekretnina u Republici Hrvatskoj

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[a]Međimurje-investa d.o.o., Hrvatska

Sažetak

U Republici Hrvatskoj je 2014. godine donesena Uredba o procjeni vrijednosti nekretnina objavljena u Narodnim novinama broj 74/2014 kao i pripadajući Pravilnik o metodama procjene vrijednosti nekretnina objavljen u Narodnim novinama broj 79/2014. Ove će 2015. godine, prema najavi Ministarstva graditeljstva i prostornoga uređenja, biti donesen Zakon o procjeni vrijednosti nekretnina. Na taj način će se doprinijeti pravnoj sigurnosti za investitore, kupce i vlasnike nekretnina. U radu će biti obrađene troškovna i prihodovna metoda, a na konkretnim primjerima će se prikazati izračun vrijednosti nekretnina. Obradit će se primjeri procjene vrijednosti nekretnina istih veličina ali različitih obilježja u svrhu izračuna mogućih raspona vrijednosti.

Ključne riječi: procjena vrijednosti nekretnina; troškovna metoda; prihodovna metoda

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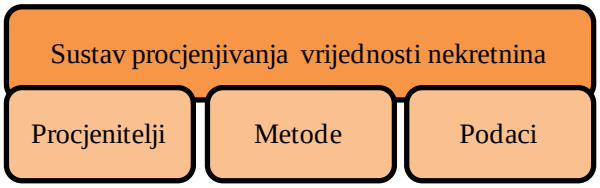
1. Uvod

Do donošenja Uredbe o procjeni vrijednosti nekretnina (Uredba) objavljene u Narodnim novinama broj (NN br.) 74/14 i pripadajućeg Pravilnika o metodama procjene vrijednosti nekretnina (NN br. 79/14 – Pravilnik), u Republici Hrvatskoj nije bilo regulirano područje procjenjivanja vrijednosti nekretnina propisom ili nekim drugim pravnim aktom. Moglo bi se reći da je to područje bilo prepušteno poslovnoj praksi. Procjenitelji su za izradu procjene tržišne vrijednosti nekretnina uglavnom koristili Uputstvo o načinu utvrđivanja građevinske vrijednosti ekspropriranih objekata iz 1984. godine. Utvrđivanje vrijednosti nekretnina je od osamostaljenja Hrvatske 1991. godine bilo regulirano posebnim propisima, ali samo za posebne slučajeve koji su navedeni u nastavku. Tako je 1992. godine donesena Uredba o načinu utvrđivanja cijene stana i garaže (NN br. 35/92, 72/92, 83/93 i 110/93) koja je bila povezana s prodajom stanova na kojima postoji stanarsko pravo. Vezano na Zakon o naknadi za imovinu oduzetu za vrijeme jugoslavenske komunističke vladavine (NN br. 92/96, 39/99, 42/99, 92/99, 43/00, 131/00, 27/01, 65/01, 118/01, 80/02 i 81/02) odnosno denacionalizaciju, doneseno je nekoliko pravilnika, i to Pravilnik o mjerilima za utvrđivanje vrijednosti oduzetih poduzeća (NN br. 107/99, 76/00, 25/03, 36/03 i 33/06), Pravilnik o mjerilima za utvrđivanje vrijednosti oduzetog poljoprivrednog zemljišta, šuma i šumskog zemljišta (NN br. 18/04) i Pravilnik o mjerilima za utvrđivanje naknade za oduzeto građevinsko zemljište i poslovni prostor (NN br. 204/03 i 3/04). Svakako da izračuni vrijednosti koji su izrađeni ili se izrađuju prema navedenim pravilnicima sadrže brojne specifičnosti, koje nisu primjenjive u uvjetima tržišnog gospodarstva, niti se mogu koristiti kao uzor za procjenu vrijednosti nekretnina u uobičajenim okolnostima. Međutim, iz njih je vidljivo da su primjenjivane, u izvjesnom smislu, glavne metode procjene vrijednosti nekretnina. (Belaj i Rajčić, 2008.)

Iako se u nizu zakona pojavljuju pojmovi tržišne vrijednosti nekretnine, tržišne cijene zemljišta i tržišne vrijednosti zemljišta, tek je donošenjem Zakona o prostornom uređenju (NN br. 153/13), koji se primjenjuje od 01.01.2014. godine, u članku 196. stavak 6. ovlaštena Vlada Republike Hrvatske za donošenje uredbe kojom će se za potrebe provedbe istog i drugih zakona urediti način procjene vrijednosti nekretnina, način prikupljanja podataka i njihova evaluacija, a Ministarstvo graditeljstva i prostornoga uređenja za donošenje pravilnika kojim se razrađuju metode procjena nekretnina i druga pitanja s tim u vezi.

Tako je 2014. godine donesena navedena Uredba s pripadajućim Pravilnikom, koja se odnosi na sve nekretnine u Republici Hrvatskoj neovisno u čijem su vlasništvu, osim ako posebnim zakonom nije propisano drukčije. Na taj se način po prvi puta uređuje područje procjenjivanja vrijednosti nekretnina kao multidisciplinarni postupak tržišnog vrednovanja prema zadacima naručitelja, koji provode ovlašteni sudski vještaci za procjenu nekretnina i ovlašteni sudski procjenitelji. (Uredba, 2014.)



Ilustracija 1. Tri temeljna stupa u procjenama vrijednosti nekretnina

Tržišna vrijednost nekretnine je propisana kao procijenjeni iznos za koji bi nekretnina mogla biti razmijenjena na dan vrednovanja, između voljnog kupca i voljnog prodavatelja, u transakciji po tržišnim uvjetima nakon prikladnog oglašavanja, pri čemu je svaka stranka postupila upućeno, razborito i bez prisile. (Uredba, 2014.)

Temeljno pravilo za procjenu vrijednosti nekretnine, zemljišne čestice (neizgrađene i izgrađene), jest procjena koristi koja se može ostvariti njezinim korištenjem. Ako je riječ o izgrađenoj građevnoj čestici, tada se govori o koristi koja se može ostvariti njezinim gospodarenjem. Izračun, odnosno procjena realne tržišne vrijednosti nekretnine ubraja se u kompleksne zadaće stručnjaka za procjenu tržišne vrijednosti nekretnina jer je tržište nekretnina s mnogo nepoznanica te niza posebnih i osobnih odnosa. (Krtalić, 2009.)

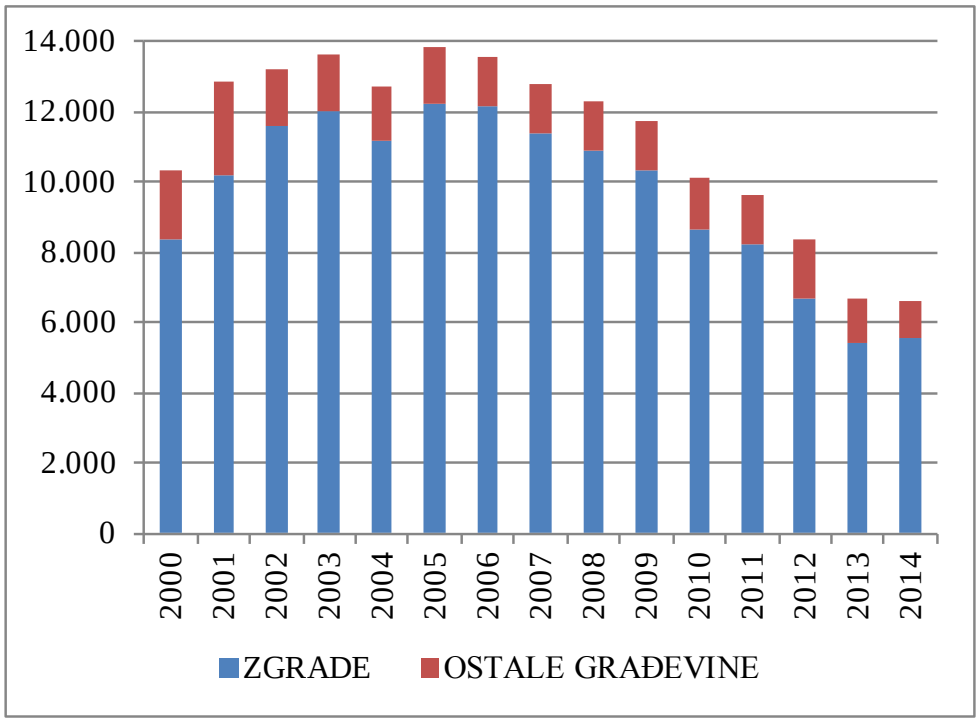
Tržišna vrijednost nekretnine se ne koristi samo u prometu nekretnina, već i u drugim postupcima kao što je utvrđivanje vrijednosti zaloga, osiguranja imovine, razvrgnuća

suvlasničkih zajednica, ulaganja i povećanja vrijednosti nekretnina, provođenje postupka uređenja građevinskog zemljišta putem urbane komasacije, izvlaštenja, kao i drugih poslova glede zemljišnih čestica.

Još prije više od 100 godina, poznati njemački stručnjak za procjenu nekretnina, arhitekt Franz Wilhelm Ross pisao je: „Istinita vrijednost jedne nekretnine (posjeda), može se potvrditi tek onda ako, tijekom njezinoga korištenja bude stavljena na tržište nekretnina, i ako nakon promjene nekoliko vlasnika, pod uvjetom da je primjereno održavana, njena vrijednost ostane postojana.“ (Krtalić, 2009.)

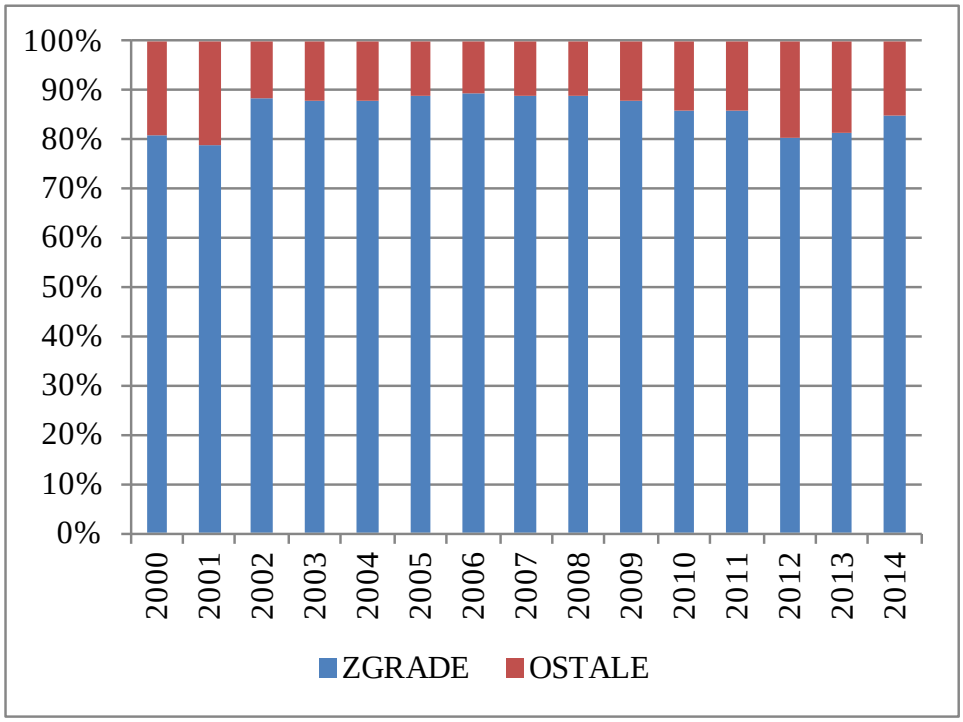
2. Stanje tržišta nekretnina u Hrvatskoj

U nastavku je prema podacima Državnog zavoda za statistiku izrađena analiza stanja tržišta nekretnina u Hrvatskoj. Naime, kako je gospodarstvo u Hrvatskoj još uvijek u recesiji nastaloj kao posljedica globalne krize tako je i stanje tržišta nekretnina stagniralo, može se reći i unazadovalo. Na Ilustracijama 2. i 3. je prikazan broj izdanih odobrenja za građenje za razdoblje od 2000. do 2014. godine za zgrade i za ostale građevine. Zgrade se odnose na stambene, u kojima je 50% ili više ukupne korisne podne površine namijenjeno za stambene



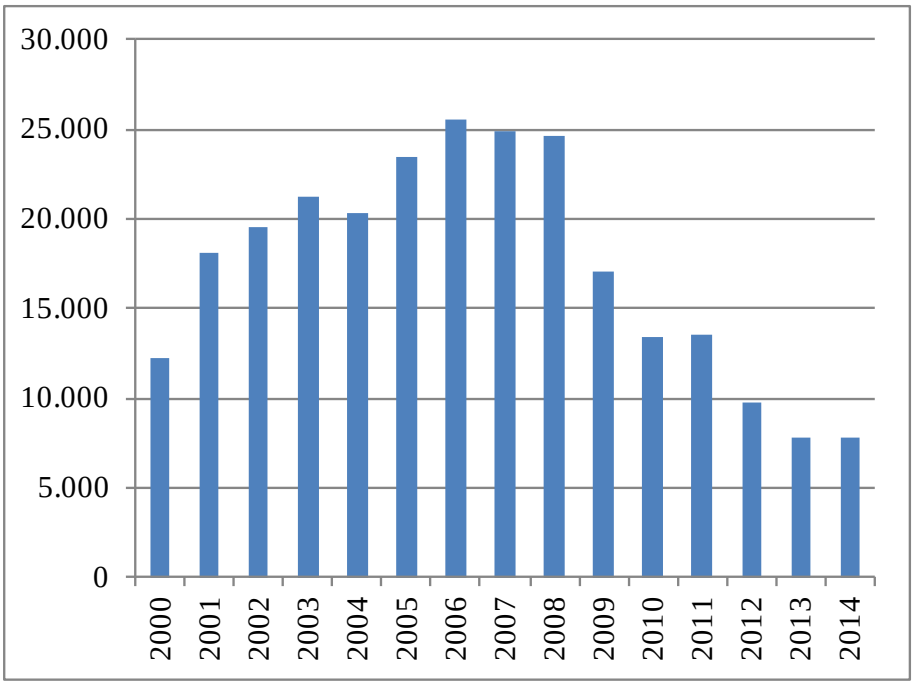
svrhe, i na nestambene. Ostale građevine su sve građevine koje nisu zgrade kao što su npr. ceste, pruge, cjevovodi, mostovi, brane, sportski tereni itd. Vidljivo je značajno opadanje tog broja s 13.818 u 2005. godini na samo 6.589 u 2014. godini, što predstavlja pad za 52%. (www.dzs.hr)

Ilustracija 2. Broj izdanih odobrenja za građenje

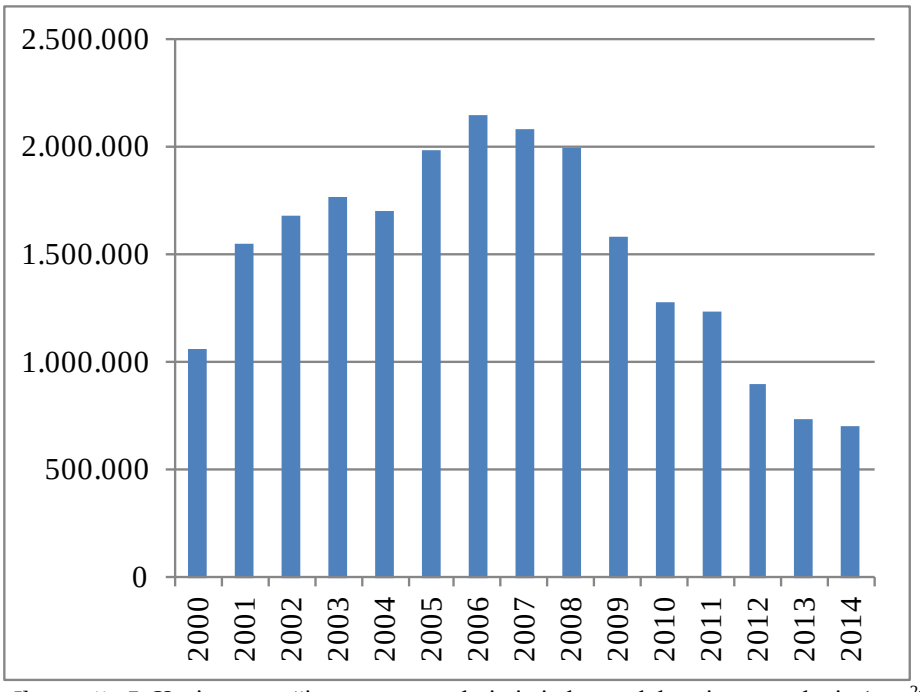


Ilustracija 3. Učešće zgrada i ostalih građevina u odobrenjima za građenje

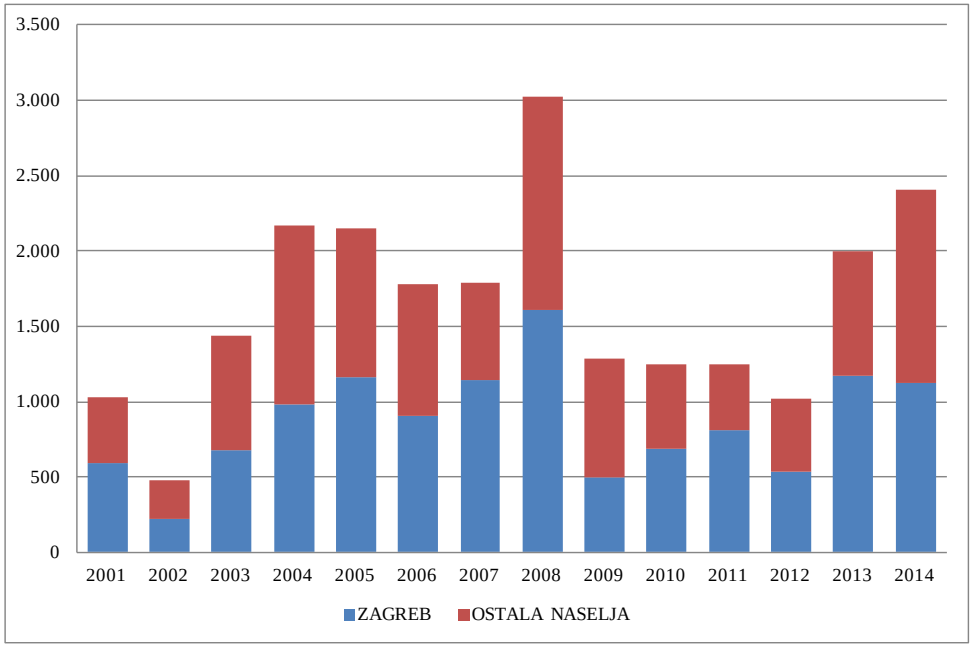
Na Ilustracijama 4. i 5. je prikazan broj stanova i ukupna površina stanova za koje su izdana odobrenja za građenje. Tako je s broja stanova od 25.517 u 2006. godini vidljiv značajan pad na 7.743 u 2014. godini, što predstavlja pad za 70%. Analizirajući korisnu površinu stanova radi se o padu s 2.150.055 m^2 na 705.309 m^2, odnosno za 67%. Kako je od izdavanja odobrenja za građenje potrebno prosječno dvije godine do završetka, odnosno isporuke novih stanova, u 2008. godini je taj broj bio najveći, što je prikazano na Ilustracijama 6. i 7. Vidljivo je također da je u gradu Zagrebu najveći broj završenih stanova u odnosu na ostala naselja u Hrvatskoj. (www.dzs.hr)



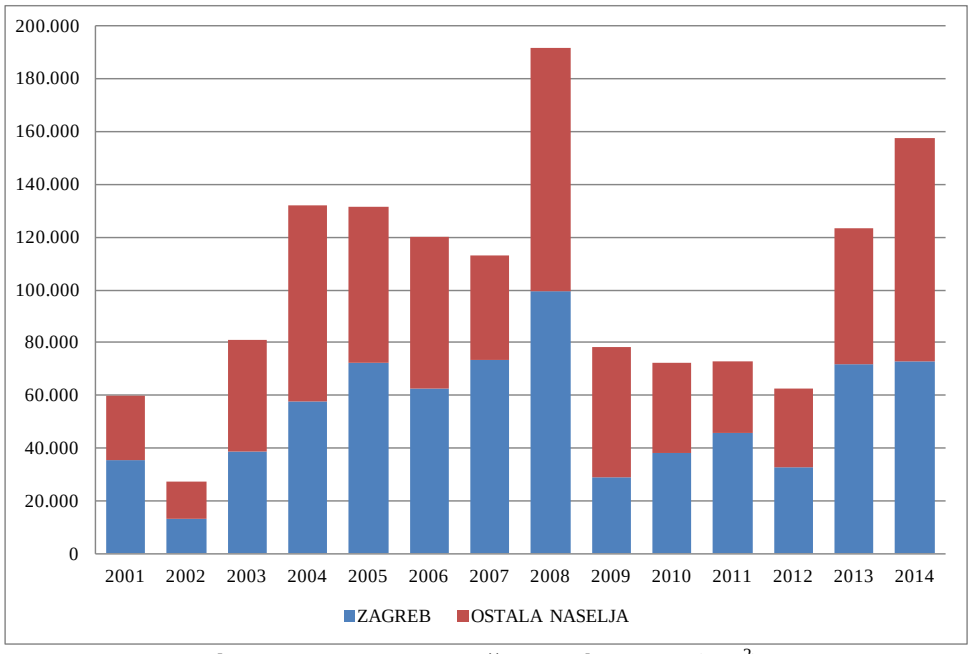
Ilustracija 4. Broj stanova za koje je izdano odobrenje za građenje



Ilustracija 5. Korisna površina stanova za koje je izdano odobrenje za građenje (u m^2)

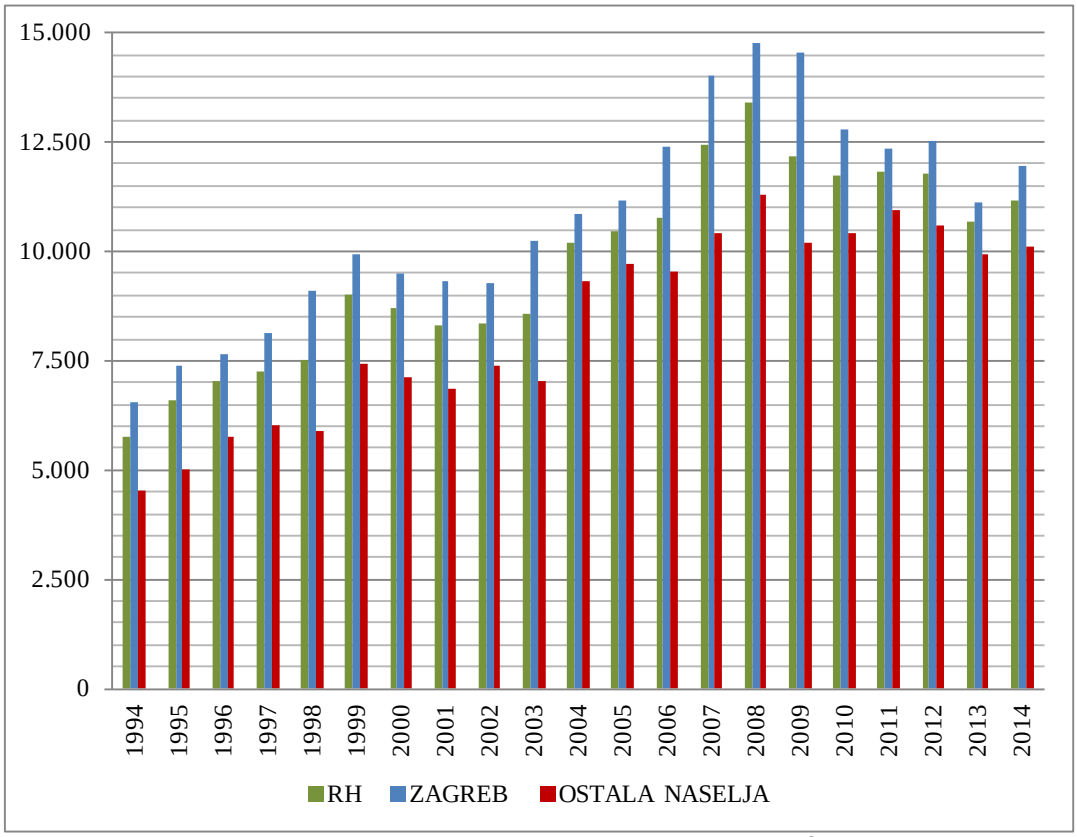


Ilustracija 6. Broj novih stanova



Ilustracija 7. Korisna površina novih stanova (u m^2)

Na Ilustraciji 8. je prikazana prosječna cijena stanova za razdoblje od 1994. do 2014. godine, prema kojoj je vidljiv značajan porast za grad Zagreb od 2002. godine s 9.296 kn/m^2 na 14.770 kn/m^2 u 2008. godini, odnosno za 59%, a na razini cijele Hrvatske je taj porast s 8.366 kn/m^2 na 13.399 kn/m^2, odnosno za 60%. Nakon globalne gospodarske krize nastale 2008. godine slijedi značajan pad prosječne cijene stanova. Tako je za grad Zagreb ta cijena najniža bila u 2013. godini i iznosila je 11.104 kn/m^2, što je pad za 25% u odnosu na 2008. godinu. Na razini cijele Hrvatske je taj pad nešto manji i iznosi 20% u odnosu na 2008. godinu, odnosno prosječna cijena je iznosila 10.662 kn/m^2. (www.dzs.hr)



Ilustracija 8. Prosječna cijena novih stanova (u kn/m^2)

Ne može se sa sigurnošću reći da li bi uređivanje područja procjenjivanja vrijednosti nekretnina ranije upozorilo na nerazmjeran porast ponude broja stanova u odnosu na potražnju na tržištu, odnosno u odnosu na kupovnu moć građana ili kupaca, ali je značajan napredak da se to područje počelo uređivati. Samo donošenje Uredbe, a ove godine i Zakona o procjeni vrijednosti nekretnina, neće urediti područje procjenjivanja vrijednosti nekretnina, ukoliko se sustavno neće pristupiti izradi baza podataka o kupoprodajnim cijenama koje trebaju voditi jedinice lokalne i područne (regionalne) samouprave. U svrhu provedbe Uredbe, podaci o kupoprodajnim cijenama i ugovorenim cijenama zakupa i/ili najma mogu se pribavljati iz evidencije posredovanja u prometu nekretnina ili iz isprava o kupoprodaji nekretnina koje su uložene u zbirku isprava zemljišnoknjižnog odjela. Podaci ne smiju biti stariji od 4 godine u odnosu na dan vrednovanja, osim ako je drugačije traženo u zadatku za izradu procjene vrijednosti nekretnina. Za sada je na području Republike Hrvatske samo Grad Zagreb ustrojio bazu podataka tj. registar pomoćnih podataka, odnosno zbirku kupoprodajnih cijena. Trenutno je prilikom izračuna vrijednosti nekretnine, zbog nedostatka organiziranih zbirki kupoprodajnih cijena za ostala područja države, potrebno provesti istraživački rad.

3. Metode procjene vrijednosti nekretnina

Uredbom su propisane 3 metode procjene vrijednosti nekretnina, i to:

- poredbena metoda
- prihodovna metoda
- troškovna metoda.

Metoda se odabire prema vrsti procjenjivane nekretnine uzimajući u obzir postojeće običaje u uobičajenom poslovnom prometu i druge okolnosti pojedinog slučaja u odnosu na raspoložive podatke. Izračun vrijednosti kao prosjek rezultata dobivenih po nekoliko metoda ili ponderiranjem rezultata nije dozvoljeno. Ukoliko se koristi više propisanih metoda, jedna je uvijek osnovna, dok ostale služe za potporu i provjeru rezultata.

Poredbenom metodom se utvrđuju tržišne vrijednosti neizgrađenih kao i izgrađenih zemljišta, koja su navedena u nastavku:

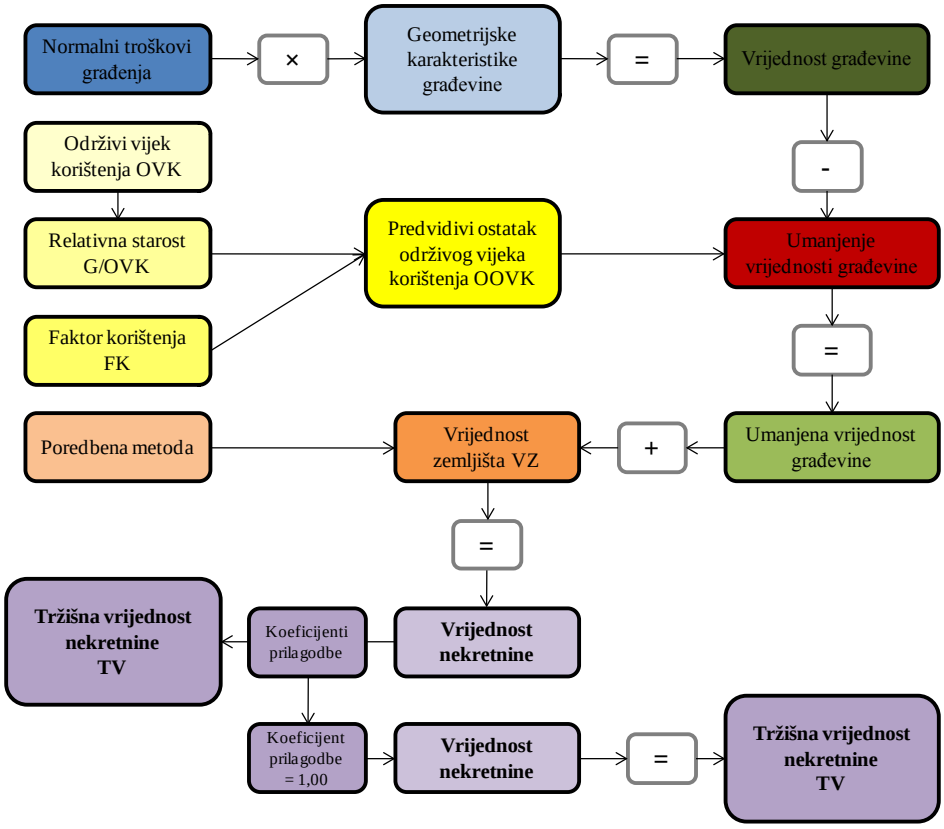
- samostojeće, poluugrađene i ugrađene obiteljske kuće
- obiteljske kuće u nizu
- stanovi
- garaže kao pomoćne građevine
- garažna parkirna mjesta
- parkirna mjesta
- poslovni prostori.

Prihodovnom metodom se utvrđuju tržišne vrijednosti izgrađenih građevnih čestica na kojima se nalaze najamne nekretnine, gospodarske i druge nekretnine svrha kojih je stvaranje prihoda.

Troškovnom metodom se utvrđuje tržišna vrijednost izgrađenih građevnih čestica na kojima su izgrađene zgrade javne namjene i druge građevine svrha kojih nije stvaranje prihoda, a posebno kod samostojećih, poluugrađenih i ugrađenih obiteljskih kuća koje prema svojim obilježjima nisu usporedive. Troškovna metoda je primjerena i kod procjene vrijednosti šteta i nedostataka na građevinama te naknadnih ulaganja u građevine. (Uredba, 2014.)

4. Troškovna metoda

Troškovna metoda (*eng. Cost Approach*) je do današnjeg reguliranja područja procjene vrijednosti nekretnina u Hrvatskoj bila za procjenitelje uobičajena metoda obzirom da je 1984. godine bila propisana Uputstvom o načinu utvrđivanja građevinske vrijednosti ekspropriranih objekata (Uputstvo) te su se na taj način procjenjivale vrijednosti nekretnina u većini slučajeva. Na Ilustraciji 9. je prikazan tijek izračuna vrijednosti troškovnom metodom prema Uredbi i Pravilniku.



Ilustracija 9. Tijek izračuna troškovnom metodom

4.1. Umanjenje vrijednosti prema Uputstvu iz 1984.

Prema Uputstvu iz 1984. godine umanjenje vrijednosti nosive konstrukcije zbog starosti i trošnosti građevine (U_1) računalo se prema formuli Vlade Vernera, ing:

$$U_1=0{,}80 \times (n/N) \times ((n+N)/2N) \times P_u \text{ za } n \leq N \qquad (1)$$

gdje su: *n – starost*
N – prosječni vjerojatni vijek trajanja
P_u – postotak učešća cijene građenja nosive konstrukcije u ukupnoj cijeni građenja

Umanjenje vrijednosti svih ostalih elemenata (U_i) koji se odnose na pojedine cjeline, sklopove ili dijelove zgrada, ugrađene građevinske materijale, elemente i opremu, odnosno koji se ne odnose na nosivu konstrukciju je linearno prema Izrazu 2.

$$U_i = n/N \times P_{u,i}\ ,\ i=2\ldots n \qquad (2)$$

gdje su: *n – starost*
N – prosječni vjerojatni vijek trajanja
$P_{u,i}$ – postotak učešća ostalih elemenata u ukupnoj cijeni građenja

Ukupno umanjenje jednako je zbroju svih umanjenja pomnoženo sa cijenom građenja ekvivalentne zgrade (N_G):

$$U=\Sigma U_i \times N_G\ ,\ i=1\ldots n \qquad (3)$$

Sadašnja vrijednost (SG) se dobiva umanjenjem nove građevinske vrijednosti (N_G) za izračunata umanjenja (U) prema formuli:

$$SG = N_G - U \qquad (4)$$

4.2. Procjena predvidivog ostatka održivog vijeka korištenja prema Pravilniku iz 2014.

Novim Pravilnikom propisuje se procjena predvidivog ostatka održivog vijeka korištenja (OOVK) primjenom faktora korištenja (FK) kao stupnja uporabivosti, koji navodi u kojoj mjeri zgrada odgovara i dalje može odgovarati zahtjevima za suvremenim uvjetima stanovanja i rada, tj. u kojoj mjeri trajno i gospodarski može ispunjavati svrhu korištenja. To je u suštini broj godina u kojima je građevinu moguće još gospodarski koristiti dopuštenim načinom korištenja, a može se produžiti održavanjem, rekonstrukcijom i osuvremenjivanjem, odnosno bitnim poboljšanjem uvjeta uporabe, osobito u pogledu povećanja energetske učinkovitosti ili se može i skratiti izostankom navedenih mjera ili neprikladnim aktivnostima. U FK matrici je potrebno ocijeniti od 1 do 5 (s time da je 1 najbolja a 5 najlošija ocjena) slijedeće elemente:

- lokacija/tržište (A)
- zgrada općenito (B)
- stanje zgrade (C).

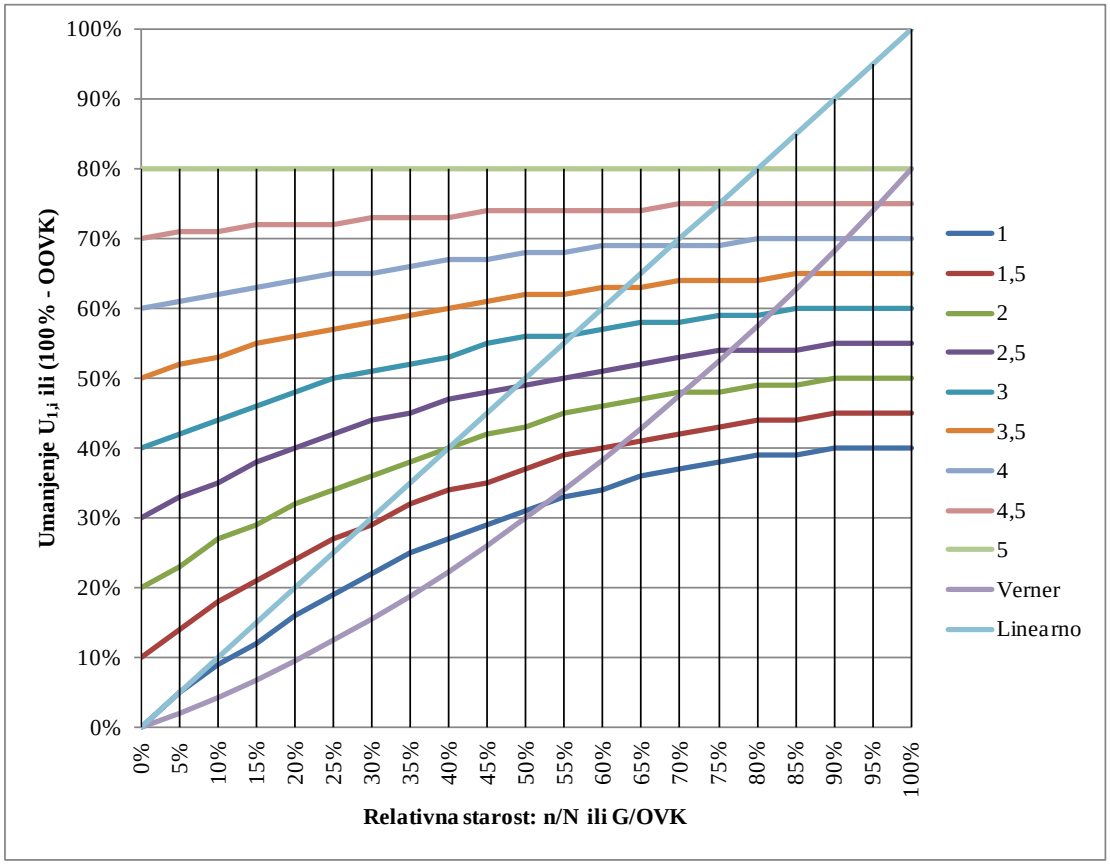
Prema najlošijoj klasifikaciji faktora korištenja, odnosno prema procijenjenoj daljnjoj uporabivosti građevine od gospodarskog očekivanja i građevinskih datosti te relativnoj starosti, koja je jednaka omjeru starosti (G) i održivog vijeka korištenja (OVK), odabire se predvidivi ostatak održivog vijeka korištenja (OOVK) u postotku (%).

Na Ilustracijama 10. i 11. je grafički prikazano Vernerovo umanjenje (Izraz 1.) i umanjenje prema faktorima korištenja (FK). Vidljivo je da obje metode ostavljaju trajnu korist od 20% građevine, odnosno najveće umanjenje iznosi 80%. Naravno da linearno umanjenje omogućuje u cijelosti umanjenje vrijednosti, odnosno 100%. Ranije se prema Uputstvu takav izračun koristio za umanjenje svih ostalih elemenata koji se ne odnose na nosivu konstrukciju. Oznaka starosti je ranije bila *n* a sada *G*, dok je prosječni vjerojatni vijek trajanja ranije imao oznaku *N*, a sada je to održivi vijek korištenja *OVK*. I ranije Uputstvo i sadašnji Pravilnik propisuju za građevine i građevinske elemente održivi vijek korištenja (OVK), odnosno prosječni vjerojatni vijek trajanja. Na priloženim Ilustracijama 10. i 11. je vidljivo da je do relativne starosti oko 50% Vernerovo umanjenje puno manje od onih prema faktorima

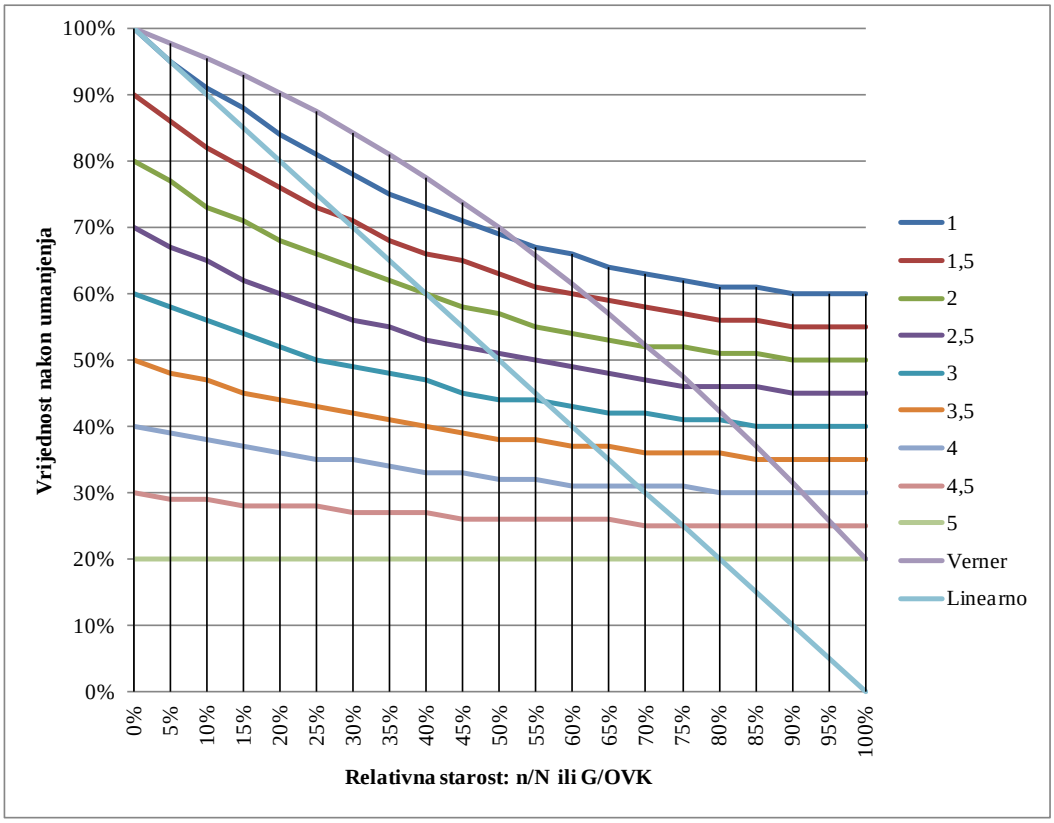
korištenja (FK), dok je u rasponu relativne starosti do preostalih 100% to umanjenje prema Verneru puno veće, da bi prema najlošijoj klasifikaciji faktora korištenja (FK) 5 ta umanjenja iznosila maksimalnih 80% od početne vrijednosti. Vidljivo je također da zgrada relativne starosti 0% (nova zgrada) prema faktorima korištenja (FK) ima raspon umanjenja vrijednosti od 0% do 80%. Kako se odabire najlošije klasificirani faktor korištenja (FK) prema ocjenjenoj lokaciji/tržištu (A), zgradi općenito (B) i stanju zgrade (C), odnosno najveća vrijednost od parametara A, B i C, tako nova zgrada na lošoj lokaciji imati značajno manju daljnju uporabivost.

Tablica 1. FK matrica

Parametri koji se ocjenjuju	**A lokacija/tržište**	**B zgrada općenito**	**C stanje zgrade**	**Odabrani FK**
Raspon ocjena	1	1	1	maksimum (A, B, C)
	1,5	1,5	1,5	
	2	2	2	
	2,5	2,5	2,5	
	3	3	3	
	3,5	3,5	3,5	
	4	4	4	
	4,5	4,5	4,5	
	5	5	5	



Ilustracija 10. Raspon umanjenja vrijednosti građevine



Ilustracija 11. Raspon vrijednost građevine nakon umanjenja

5. Prihodovna metoda

U prihodovnoj metodi (*eng. Income Capitalization Approach)* se vrijednost utvrđuje temeljem prihoda koji se postižu na tržištu (održivi prihodi). Prihodovna vrijednost se može utvrditi na temelju:

- opće prihodovne metode (tzv. dvotračna prihodovna metoda)
- pojednostavljene prihodovne metode (tzv. jednotračna prihodovna metoda)
- prihodovne metode na temelju periodički različitih prihoda.

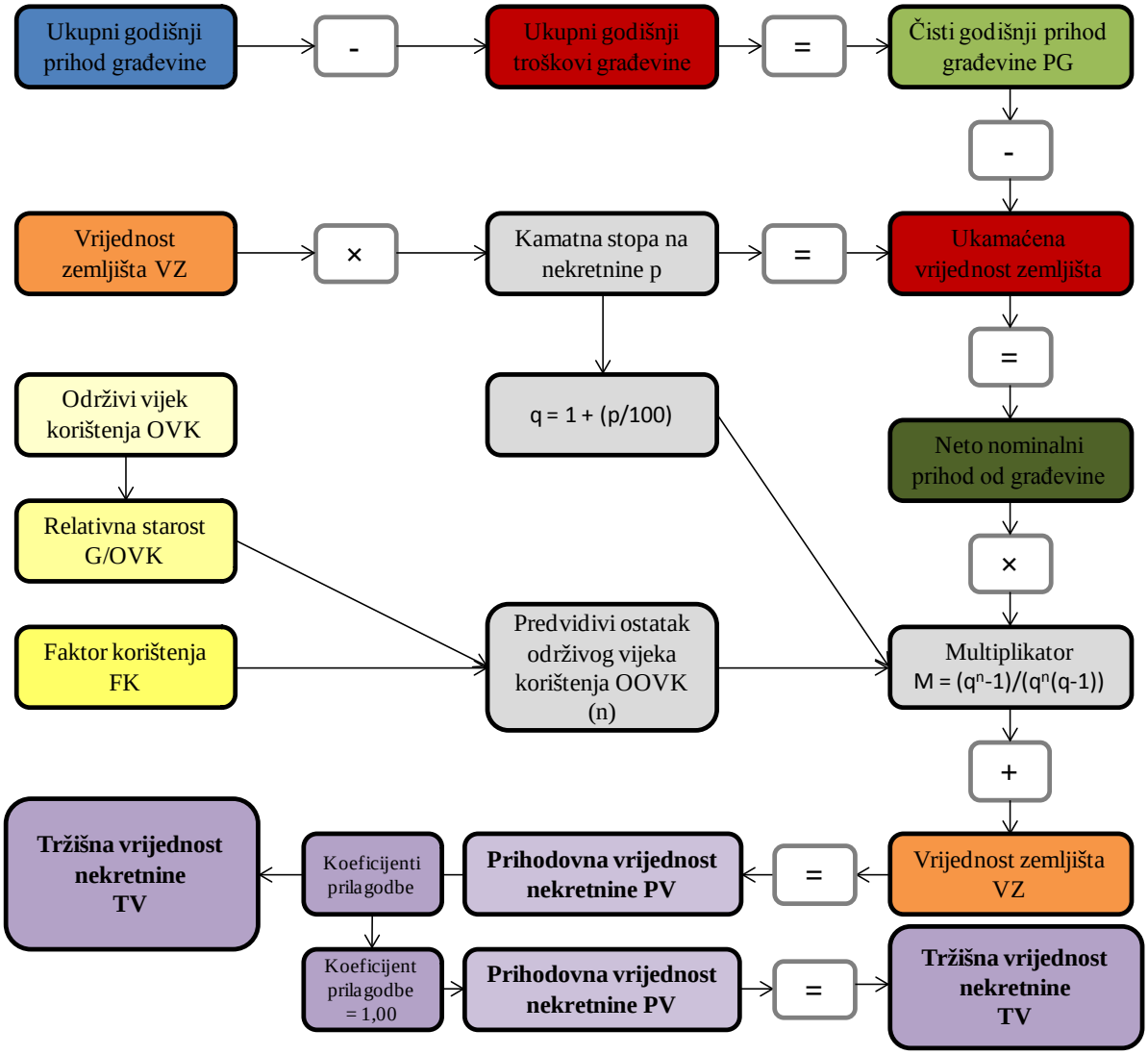
U radu će biti obrađen primjer izračuna prihodovne vrijednosti općom prihodovnom metodom, prema kojoj se vrijednost utvrđuje temeljem postignutih prihoda na tržištu iz utvrđene vrijednosti zemljišta uvećane za kapitaliziranu razliku čistog prihoda (razlika između ukupnog godišnjega prihoda i troškova gospodarenja) i odgovarajućeg ukamaćivanja vrijednosti prema općenitom izrazu:

$$PV = (PG - VZ \times p) \times M + VZ;\ M = (q^n-1)/(q^n(q-1));\ q = 1 + (p/100) \qquad (5)$$

gdje su:
PV – prihodovna vrijednost nekretnine
PG – čisti godišnji prihod građevine
VZ – vrijednost zemljišta
M – multiplikator
p – kamatna stopa nekretnine (stopa kapitalizacije)
n – predvidi ostatak održivog vijeka korištenja građevine (OOVK)

Stope kapitalizacije (kamatne stope na nekretnine) su stope kojima se prosječno kapitalizira tržišna vrijednost različitih vrsta nekretnina, osobito nekretnina namijenjenih stanovanju, komercijalnih nekretnina i nekretnina mješovite namjene.

Troškovi gospodarenja nekretninom odnose se na troškove upravljanja i održavanja te pogonske (režijske) troškove. Osim toga, treba uzeti u obzir rizik gubitka najamnine ili zakupnine. Na Ilustraciji 12. je grafički prikazan tijek izračuna vrijednosti nekretnine prihodovnom metodom.



Ilustracija 12. Tijek izračuna prihodovnom metodom

Na Ilustraciji 13. je prikazan raspon multiplikatora (M) ovisno o predvidivom ostatku održivog vijeka korištenja (OOVK) i odabranoj kamatnoj stopi na nekretnine (stopa kapitalizacije p). Određivanje OOVK je opisano u točki 4.2. U Pravilniku su dane orijentacijske vrijednosti stope kapitalizacije prema namjeni:

- stambena namjena: od 2,0% do 5,0%
- poslovna namjena: od 4,5% do 8,0%
- posebna namjena: od 6,0% do 7,0%.

Nekretnine stambene namjene su obiteljske kuće i višestambene zgrade, međutim Uredbom je određeno da se za takvu vrstu nekretnina koristi poredbena metoda. Obzirom da u Hrvatskoj nije razvijen sustav tržišnog najma stambenih prostora, već su takve nekretnine uglavnom u vlasništvu korisnika, iste se neće procjenjivati prihodovnom metodom.

U nekretnine poslovne namjene svrstavaju se:

- poslovni prostori i zgrade
- trgovački centri
- robne kuće
- javne garaže
- skladišne hale
- benzinske crpke

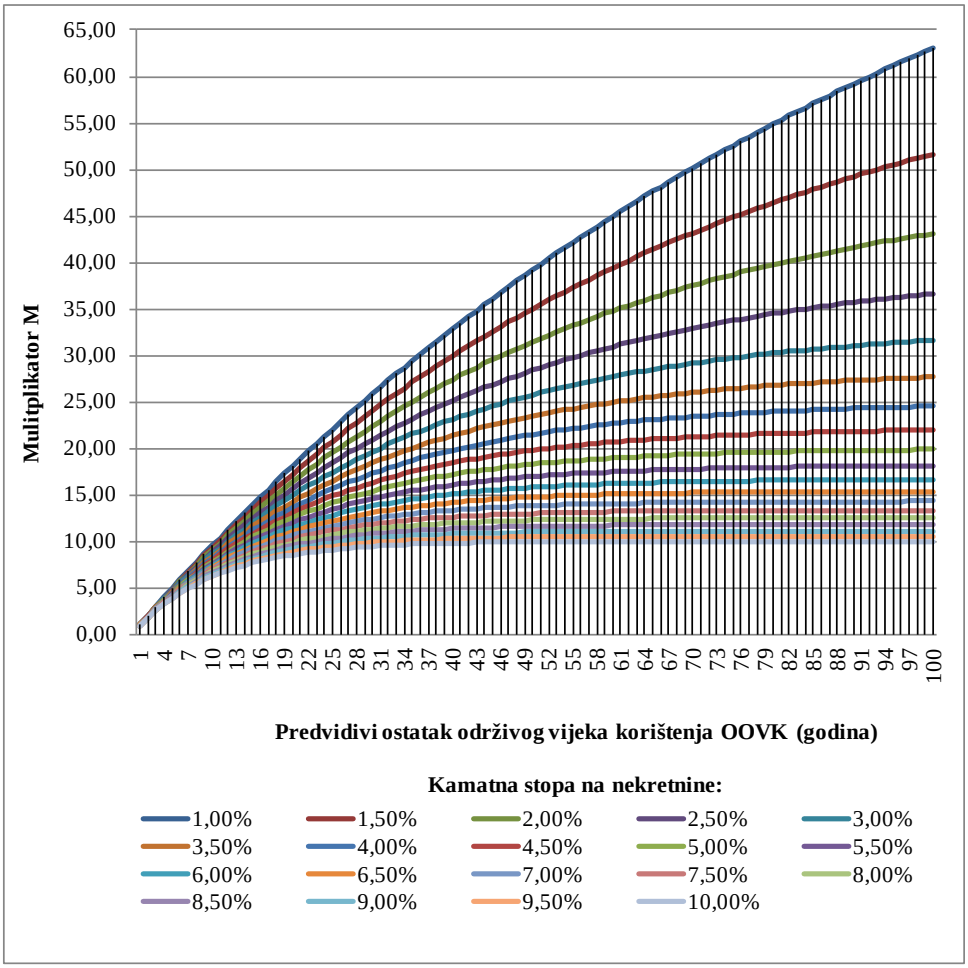
- logistički centri
- proizvodne građevine.

Nekretnine posebne namjene odnose se na slijedeće građevine:

- hoteli
- gastronomija
- rehabilitacija
- domovi
- klinike
- sport
- rekreacija
- zabava.

Obzirom da u Hrvatskoj nije razvijeno područje sustavnog praćenja i javne objave tržišnih stopa kapitalizacije, u Pravilniku su za dane orijentacijske stope moguće prilagodbe od prosječnih podataka ovisno o slijedećim parametrima:

- položaj nekretnine: od -1,0% do 1,0%
- kvaliteta građevine: od -0,5% do 1,0%
- rizik naplate najamnine/zakupnine: od -0,5% do 1,0%
- gospodarska situacija: od -0,5% do 1,0%
- razvojni potencijal nekretnine: od -2,0% do 0,0%.



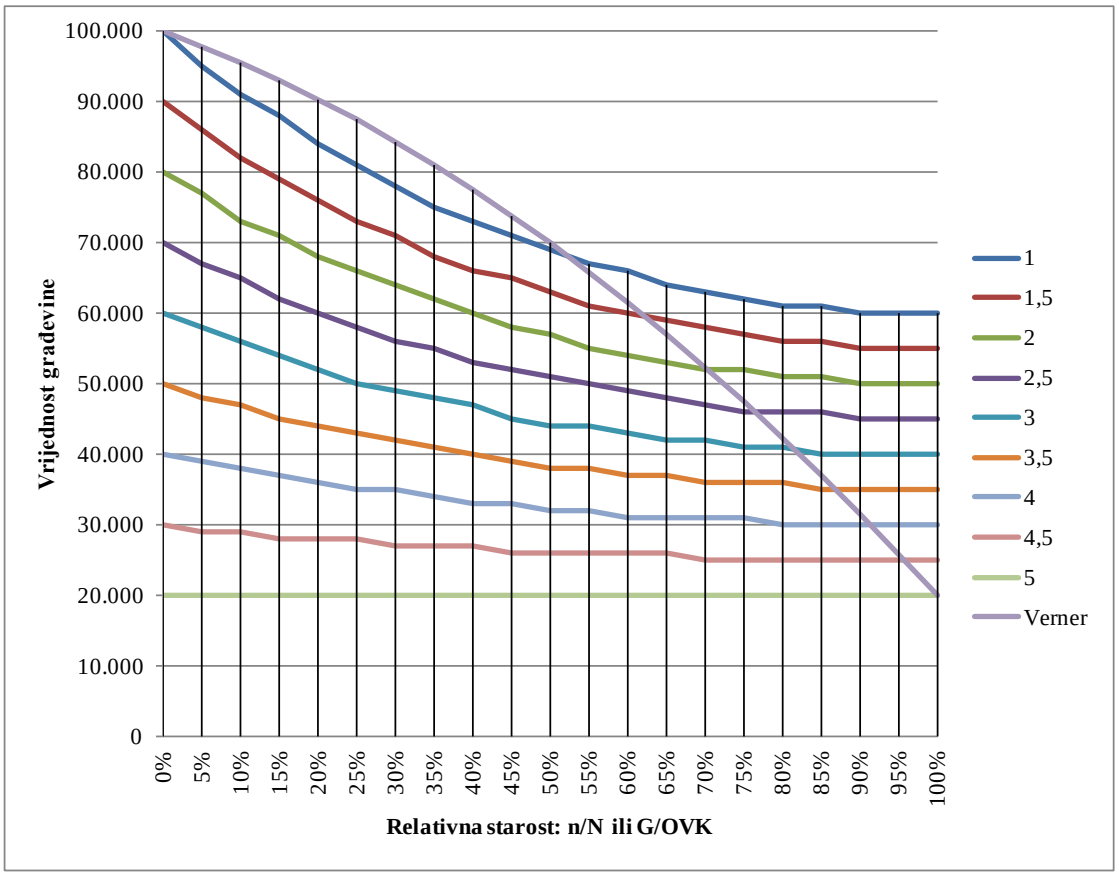
Ilustracija 13. Raspon vrijednosti multiplikatora

6. Primjeri troškovne i prihodovne metode

6.1. Troškovna metoda

Za konkretan primjer će se prikazati raspon vrijednosti nekretnine primjenom troškovne metode. Za građevinu je utvrđeno da prema normalnim troškovima građenja i geometrijskim karakteristikama njena vrijednost iznosi 100.000 novčanih jedinica. Na Ilustraciji 14. je

prikazan raspon vrijednosti građevine prema Vernerovom izrazu te prema predvidivom ostatku održivog vijeka korištenja (OOVK) i faktorima korištenja (FK). Za novu građevinu, odnosno relativne starosti 0% je prema Verneru vrijednost jedinstvena, dok je prema postupku faktora korištenja (FK) iz Pravilnika taj raspon od 20% do 100%, odnosno nova građevina može imati vrijednosti u tom rasponu. Primjena Vernerove formule je u primjeru prikazana samo za nosivu konstrukciju. Ovisno o ostalim elementima neke građevine, a koji se ne odnose na nosivu konstrukciju, moguće je izraditi detaljniju analizu prema učešćima svih ostalih grupa radova (obrtnički, završni i instalaterski) u ukupnoj vrijednosti. Nadalje, ukoliko relativna starost iznosi 100% tada prema Vernerovom izrazu građevinska vrijednost iznosi 20%, dok prema postupku faktora korištenja (FK) taj raspon iznosi od 20% do 60% od početne vrijednosti. Radi se o tome da je umanjenje vrijednosti građevine prema Verneru samo dio strukture troškovne metode, koju tek treba svesti na tržišnu vrijednost, dok se prema postupku faktora korištenja (FK) radi o stupnju uporabivosti, koji navodi u kojoj mjeri zgrada odgovara i dalje može odgovarati zahtjevima za suvremenim uvjetima stanovanja i rada, tj. u kojoj mjeri trajno i ekonomično može ispunjavati svrhu korištenja zgrade. Tako dobivena vrijednost predstavlja konačnu tržišnu vrijednosti, ukoliko nije potrebna prilagodba, kao što je prikazano u tijeku izračuna troškovnom metodom na Ilustraciji 9. Stoga je potrebno vrlo pažljivo i argumentirano ocijeniti lokaciju/tržište (A), zgradu općenito (B) i stanje zgrade (C).

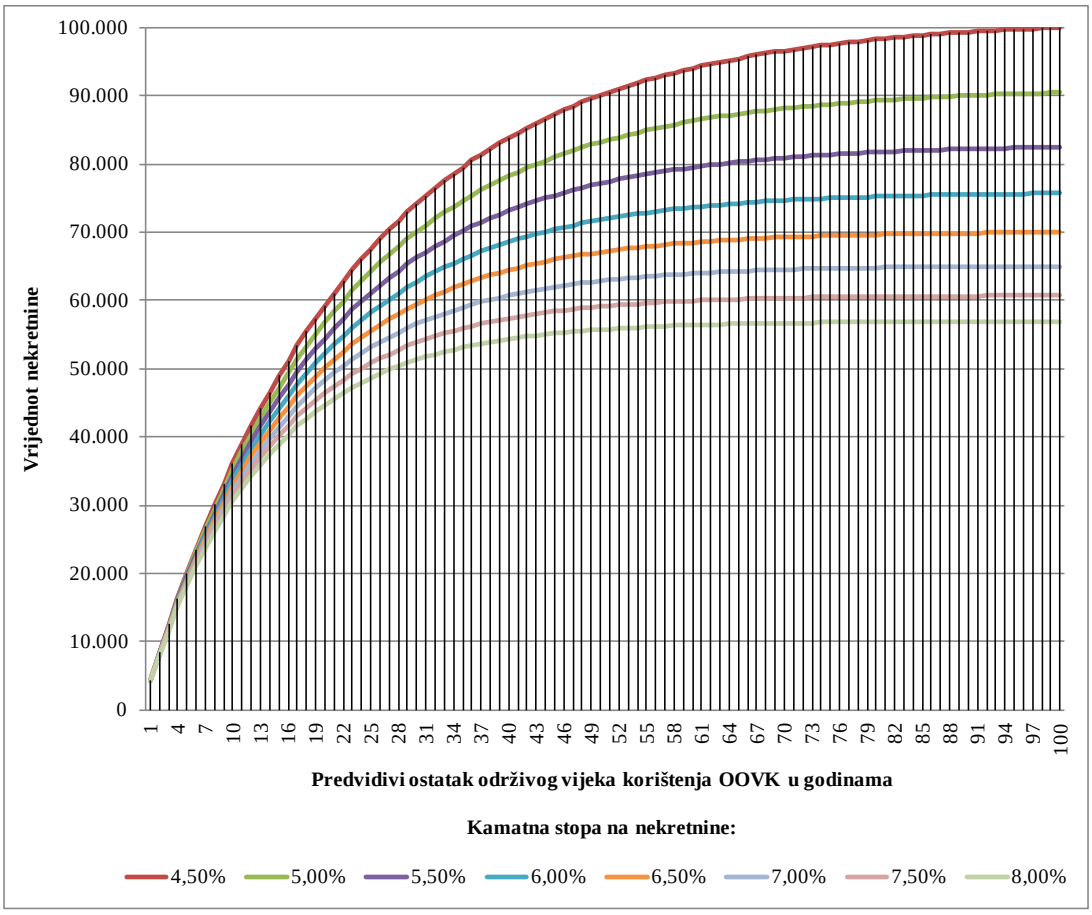


Ilustracija 14. Raspon vrijednosti nekretnine za primjer troškovne metode

6.2. Prihodovna metoda

Za konkretan primjer će se prikazati raspon vrijednosti nekretnine primjenom prihodovne metode, koja ovisi o stopi kapitalizacije (p) i predvidivom ostatku održivog vijeka korištenja (OOVK). Na Ilustraciji 15. je prikazan raspon vrijednosti za nekretninu poslovne namjene, koja maksimum postiže primjenom najmanje vrijednosti stope kapitalizacije (p) pri najvećoj vrijednosti predvidivog ostatka održivog vijeka korištenja (OOVK). Za čisti godišnji prihod od pretpostavljenih 4.555 novčanih jedinica, vrijednost nekretnine primjenom multiplikatora iznosi maksimalnih 100.000 novčanih jedinica. Za građevinu s najmanjim ocjenama A, B i C, koje su rezultirale najvećim OOVK, ovisno o primijenjenoj stopi kapitalizacije (p), raspon

vrijednosti iznosi između 56.902 i 100.000 novčanih jedinica. Za najmanju stopu kapitalizacije (p_{min}), ovisno o OOVK raspon vrijednosti nekretnine je teoretski između 4.374 i 100.000 novčanih jedinica. Međutim, ukoliko je OOVK minimalan, nije za očekivati da takva nekretnina stvara prihode jer je stupanj uporabivosti minimalan (ili možda uopće nije moguć) pa je potrebno primijeniti troškovnu metodu ili pak je potrebno dodati odbitke, ukoliko se primjenjuje prihodovna metoda, radi dovođenja nekretnine u primjeren stupanj uporabivosti. Iz grafičkog prikaza na Ilustraciji 15. je vidljivo da je primjenom veće stope kapitalizacije (p) značajnije umanjenje vrijednosti nekretnine kod manjeg OOVK u odnosu na ostale stope.



Ilustracija 15. Raspon vrijednosti nekretnine za primjer prihodovne metode

U Tablici 2. je prikazano umanjenje vrijednosti nekretnine u ovisnosti stope kapitalizacije (p) i OOVK. Tako je npr. umanjenje vrijednosti nekretnine za 10% ukoliko OOVK iznosi 50 godina za primijenjenu stopu kapitalizacije (p) od 4,5%. Nadalje, za p=8,0% isti iznos umanjenja vrijednosti za 10% je ukoliko OOVK iznosi 30 godina.

Tablica 2. Umanjenje vrijednosti nekretnine u ovisnosti o OOVK i stopi kapitalizacije

Umanjenje vrijednosti nekretnine za	ukoliko OOVK u godinama iznosi				
10%	50	46	39	34	30
25%	31	28	23	20	18
50%	15	14	12	10	9
75%	6	5	5	4	3
93%	1	1	1	1	1
	za primijenjenu stopu kapitalizacije (p) od				
	4,5%	5,0%	6,0%	7,0%	8,0%

7. Zaključak

Obzirom da se tek po donošenju Uredbe o procjeni vrijednosti nekretnina i pripadajućeg Pravilnika o metodama procjene vrijednosti nekretnine 2014. godine u Republici Hrvatskoj počelo regulirati područje procjenjivanja vrijednosti nekretnina obvezujućim propisom, a 2015. godine će to područje biti regulirano zakonom, može se reći da će se zasigurno olakšati posao procjeniteljima nekretnina. Navedeni propisi uređuju opće poznate i prihvaćene metode procjenjivanja, i to poredbenu, prihodovnu i troškovnu. Uredba, a ove godine i zakon uređuju način procjene vrijednosti nekretnina, način prikupljanja podataka i njihovu evaluaciju. Cilj ovog rada je bila usporedba dosadašnje troškovne metode, koja se temeljila na Uputstvu iz 1984. godine, i današnje prema Uredbi i Pravilniku, kao i izrada raspona vrijednosti nekretnina istih veličina u različitim okolnostima prema lokaciji/tržištu, zgradi općenito i stanju zgrade. Isto tako je prikazan i raspon vrijednosti nekretnina primjenom prihodovne metode te utjecaj faktora korištenja (FK) i kamatnih stopa na nekretnine (stope kapitalizacije) na raspone vrijednosti. Navedenim propisima se tek započelo što se u drugim zemljama provodi već duže vrijeme (u nekim zemljama i više desetljeća) s rezultatom vrlo razvijenih sustava praćenja tržišta nekretnina (baza podataka odnosno zbirka kupoprodajnih cijena) radi utvrđivanja realnih tržišnih vrijednosti.

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Uputstvo o načinu utvrđivanja građevinske vrijednosti ekspropriranih objekata, Narodne novine broj 52/1984

Uredba o procjeni vrijednosti nekretnina, Narodne novine broj 74/2014

FIDIC Uvjeti ugovaranja za postrojenja i projektiranje i građenje (izdanje 1999.g):

Značajke ugovora i određeni aspekti primjene u Hrvatskoj

Ivan Bogdan[a], Časlav Dunović[a]*, Boris Uremović[a]

[a]Tehničko veleučilište u Zagrebu, Hrvatska

Sažetak

Prikazuju se neke od osnovnih značajki projekata uvjeta ugovora prema modelu Međunarodne federacije savjetodavnih inženjera (FIDIC – Federations Internationales des Ingenieurs-Conseils), specifično Uvjeta ugovaranja za postrojenja i projektiranje i građenje za elektrotehničke i strojarske građevinske i inženjerske radove po projektima izvođača (izdanje 1999.g). Daje se naglasak na određenim postupcima i procedurama koje se trebaju uzeti u obzir kod vođenja projekata i planiranja aktivnosti a koje često uzrokuju nesuglasice i sporove prilikom provedbe u Hrvatskoj. Problematika primjene FIDIC-a u Hrvatskoj je prikazana s obzirom na određene problemime i odnose sa regulativom koji nastaju u provedbi ugovora. Na primjeru Priručnika procedura nadzora opisana je mogućnost upotrebe određenih alata koji mogu pomoći stranama u provedbi ugovora. Ukazuje se na potrebu usavršavanja naših inženjera u pravnim aspektima vođenja projekata koji su izuzetno značajan faktor uz sve ostale tehničke zahtjeve građevinske struke.

Ključne riječi: FIDIC; Uvjeti ugovora; Postrojenja; Primjena

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1. Uvod

Sa približavanjem ulaska Republike Hrvatske u Europsku Uniju i korištenjem pred-pristupnih fondova (ISPA, IPA), a potom i Strukturnih i Kohezijskih fondova, došlo je do raširenije upotrebe FIDIC uvjeta ugovora (ponajviše tzv. „Crvene“ i „Žute“ knjige) kod provedbe infrastrukturnih projekata.

Jedan od uvjeta financiranja iz pristupnih fondova EU je korištenje autonomne regulative FIDIC-a kod ugovaranja radova, tako da je već od 2008.g sve veći broj infrastrukturnih projekata u Hrvatskoj ugovoren po principu FIDIC uvjeta ugovaranja, naročito u izgradnji cesta te sektorima odvodnje i pročišćavanja otpadnih voda i gospodarenju otpadom. Natječajna dokumentacija kod tih ugovora je uvjetovala visoke zahtjeve ponuditeljima u smislu referenci i davanja bankarskih garancija čime je praktično ograničeno sudjelovanje domaćih tvrtki u natječajima. Zbog relativno uskog domaćeg tržišta naše tvrtke nisu imale potrebne reference ni financijsku snagu biti samostalni izvođači, već se rješenje tražilo u suradnji (konzorciji, joint venture-i) sa inozemnim tvrtkama koje su najčešće davale know-how, tehnologiju te upravljanje projektima. Slabost naših inženjera kako u izvođačkom dijelu tako i u savjetodavnom je najviše izražena u dijelu koji je vezan za upravljanje projektima prema FIDIC-u, pa su redovito glavne uloge predstavnika izvođača i inženjera preuzimali strani konzultanti sa višegodišnjim iskustvom. Naši inženjeri su kod izvođača najčešće preuzimali uloge glavnih inženjera gradilišta, inženjera gradilišta i voditelja radova, a kod FIDIC Inženjera bili imenovani nadzornim inženjerima prema Zakonu o gradnji i Zakonu o arhitektonskim i inženjerskim poslovima i djelatnostima u prostornom uređenju i gradnji. Ne treba zanemariti ni činjenicu što je u provedbi ugovora financiranih iz IPA fondova službeni jezik engleski što je bio dodatni uteg jer je FIDIC terminologija formalni pravni rječnik uglavnom stran našim inženjerima.

Međutim, takva situacija je u određenom smislu utjecala na postepeno educiranje u praksi te su naši inženjeri i tvrtke dobijali potrebna znanja koja se kasnije mogu primjeniti kako na domaćem tako i na međunarodnom tržištu čineći ih konkurentnijima. S obzirom da je danas Hrvatska dio Europske Unije može se očekivati pojačana prisutnost i konkurencija stranih tvrtki na našem tržištu, a što će dodatno zaoštriti situaciju u nuđenju i ugovaranju poslova. S druge strane članstvo u Europskoj Uniji omogućava da naša operativa i projektne organizacije lakše traže poslove na stranim tržištima što može omogućiti zaposlenost i kontinuitet rada. Naravno da će sposobnost upravljanja projektima i znanja stečena u provedbi FIDIC ugovora izravno utjecati i na uspjeh na stranim tržištima.

U 2013.g FIDIC-ovi Uvjeti ugovora („Crvena“ i „Žuta“ knjiga, izdanja 1999.g) su doživjeli prve službene prijevode na hrvatski jezik. Očekuje se daljnja i sve šira primjena navedenih uvjeta ugovaranja za radove na izvedbi infrastrukturnih objekata u RH a samim time i sve veća educiranost naših inženjera graditeljstva u primjeni i provedbi projekata ugovorenih tim uvjetima ugovora. Planiranje aktivnosti u ugovoru prema FIDIC-u se u praksi pokazuje kao veoma zahtjevno naročito sa stanovišta administracije ugovora, postupanja u slučaju vantroškovničkih radova, izmjena opsega radova, potraživanja, te rješavanja sporova kroz ugovorne mehanizme. Manjak praktičnog iskustva naših tvrtki u usporedbi sa stranim savjetodavnim inženjerima i tvrtkama koje se već duži niz godina u inozemnoj praksi bave provođenjem projekata prema FIDIC-u je značajna, a uglavnom se očituje činjenicom da tvrtke propuštaju prilike osiguranja maksimalne dobiti iz dobivena posla i sklopljenog ugovora.

2. Općenito o „Žutoj knjizi“

Slika 1. FIDIC ¨Žuta knjiga¨ (Izdanje 1999)

Raširenost općih uvjeta FIDIC ugovora u međunarodnoj praksi čini te ugovore nezaobilaznima kod izvođenja građevinskih radova. Uvjeti ugovora FIDIC-a primjenjuju se ako su ih ugovorne stranke uključile u njihov međusobni ugovor. Preporučeni su ili čak zahtjevani od strane međunarodnih financijskih institucija, Europske unije, EIB-a, EBRD-a, itd. Ti su uvjeti ugovora sastavljali stručnjaci koji su nastojali postići pravednu ravnotežu odnosa sudionika u gradnji i na taj ih način učiniti prihvatljivima u širim međunarodnim okvirima. Rezultat su dugotrajnog razvoja započetog još u 1950-im godinama te su prošli kroz dugu evoluciju. FIDIC-ovi uvjeti ugovora su proizašli iz anglo-saksonskog pravnog sustava (Common law) te koriste izraze i tumačenja engleskih ICE modela ugovora. Razvoj FIDIC-a je uspio uskladiti načela engleskog prava građenja koje je u početnim uvjetima ugovora bilo dominantno, s načelima europskih kontinentalnih pravnih sustava. Time su se FIDIC uvjeti uspjeli nametnuti kao svojevrsno „međunarodno“ pravo građenja. Ti uvjeti ugovora pružaju mnogobrojne primjere raznih rješenja za pojedina pitanja koja se postavljaju kod ugovora o građenju, a za koja naši propisi nemaju uvijek spremne odgovore. U Hrvatskoj se do današnjeg dana nije uspjelo u sastavljanju (standardizaciji) takvih uvjeta ugovora koji bi bili generalno prihvaćeni kod sklapanja ugovora o građenju. Iz tih razloga se primjena FIDIC-ovih uvjeta ugovora čini razumljiva kod radova u Hrvatskoj, naročito kad u njima učestvuju strani izvođači. U Hrvatskoj su se za sada najviše upotrebljavala FIDIC-ova izdanja iz 1999.g, naročito tzv. „Crvena“ i „Žuta“ knjiga.

U rujnu 1999.g. FIDIC je izdao kompletno novu seriju uvjeta ugovora koji nadopunjuju ili zamjenjuju već postojeće publikacije. Nova serija ugovora su popularno nazvani „Izdanja u duginim bojama“ (Rainbow editions), s obzirom na različite boje korica svake knjige.

Jedna od četiri izdane publikacije koja je tema ovog članka je:

- FIDIC Uvjeti ugovaranja za postrojenja i projektiranje i građenje za elektrotehničke i strojarske građevinske i inženjerske radove po projektima izvođača.

Zbog svoje boje korica kolokvijalno je nazvana nova „Žuta knjiga“. Žuta knjiga je napisana za upotrebu kod svih građevinskih i inženjerskih radova zajedno sa isporukom i montažom opreme, u kojima projektiranje radi izvođač. Najčešće se koristi kod ugovaranja građevina kod kojih je dominatna ugradnja opreme u odnosu na opseg građevinskih radova (npr. industrijska postrojenja).

Žuta knjiga se sastoji od sljedećih dijelova:

- Općih uvjeta,
- Smjernica za pripremu Posebnih uvjeta,
- Obrazaca za Pisma ponude, Sporazuma i Sporazuma za rješavanje sporova.

Ugovor koji se temelji na FIDIC-u se sastoji dijelom od Općih i Posebnih uvjeta ugovora. Ugovorne strane ne moraju mijenjati Opće uvjete da bi ih prilagodile svojim zahtjevima već se to čini aplicirajući izmjene i dopune kroz Posebne uvjete ugovora. Posebni uvjeti nadopunjuju Opće uvjete a ako postoji neslaganje između njih obvezujući su i imaju prednost

pred Općim uvjetima. FIDIC-ovi Opći uvjeti ugovora su detaljno izbalansirani ugovori sa stanovišta raspodjele odgovornosti te štite projekat a ne određenu stranku u ugovoru.

Značajke Žute knjige i posebnosti u odnosu na ostale knjige su:

- Izvođač je odgovoran za projektnu dokumentaciju,
- Ugovorna cijena je paušalna i fiksna,

Plaćanja se vrše prema dinamici plaćanja utvrđenoj u ugovoru.

Izvođač je dužan projektiranje izvršiti u skladu sa dijelom ugovorne dokumentacije koja se zove Zahtjevi Naručitelja i dio je tender dokumentacije, uz ostalu dokumentaciju poput raznih nacrta, elaborata, studija itd. Izvođač preuzima obvezu projektiranja, izgradnje, obavljanja svih potrebnih ispitivanja i otklanjanja nedostataka u radovima. Nakon dovršetka radovi moraju odgovarati svrsi za koju su namijenjeni i koja mora biti opisana u Zahtjevima Naručitelja. Izvođač mora izvršiti sve radove koji su opisani ugovorom i sve radove koji su (iako nisu navedeni u Ugovoru) potrebni za stabilnost, dovršetak ili sigurno i pravilno upravljanje radovima. Zahtjevi Naručitelja definiraju opseg projekta za koji je odgovoran izvođač te moraju dati kriterije kojih se projektanti moraju pridržavati. Zadani kriteriji mogu uključivati dimenzije, geometriju zgrada, pravilnike, zahtjeve zaštite okoliša, tehničke specifikacije i razne norme. Potrebno je izbjeći detaljno uvjetovanje tehnologije izvedbe jer se taj dio odgovornosti mora prebaciti izvođaču. Izvođač je dužan dati generalni opis tehnologije koju misli primjeniti u projektu i odgovoran je za uspjeh i rezultate. Smatra se da Zahtjevi Naručitelja moraju dati specifične uvjete koje postrojenje u konačnici mora zadovoljiti istovremeno ostavljajući izvođaču slobodu da sam odabere put kojim želi ići da postigne tražene rezultate.

Projektnu dokumentaciju izrađuje kvalificirani projektant kojeg predlaže izvođač a odobrava inženjer u ugovoru.

Izvođač također preuzima sljedeće obaveze:

- Izraditi sve Projekte izvedenog stanja,
- Izraditi sve Priručnike za održavanje i upravljanje postrojenjem,
- Provesti obuku operativnih djelatnika naručitelja.

FIDIC-ovi uvjeti ugovora se također mogu promatrati kao priručnici koji daju upute za vođenje projekta jer određuju pravila ponašanja stranaka. Knjige daju upute strankama u pogledu izvještavanja, pravila komuniciranja, zahtjeva za vremensko planiranje te procedura u slučaju potraživanja i sporova.

Uvjeti ugovora koje je dao FIDIC u Žutoj knjizi, a i u svim ostalim modelima ugovora, čine samo jedan dio „Ugovora“. Dio dokumentacije koja čini ugovor dolazi slijedom procesa natječaja koji može uključivati pregovore i razmjenu dokumentacije. Sam proces natječaja za ugovor prema Žutoj knjizi traži visoku razinu stručnosti od strane naručitelja, izvođača i inženjera.

Posebna pozornost se mora obratiti na sljedeće:

- Opseg projekta,
- Tko je u kojoj fazi uključen u projektiranje,
- Svrha za koju su radovi namijenjeni,
- Kontrola kvalitete i razina zahtijevane kvalitete radova.

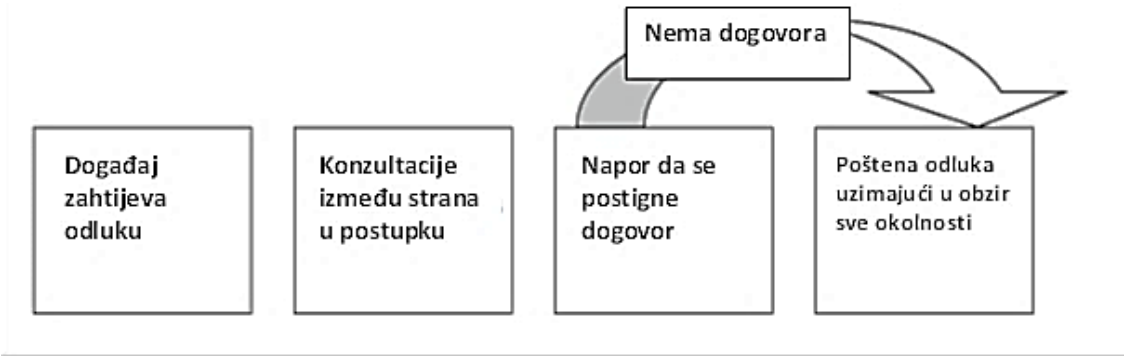
Kompletan Ugovor se sastoji od više različitih dokumenata koji imaju red točno određen red prvenstva i sastoji se od:

- Sporazuma,
- Pisma o prihvaćanju,
- Pisma ponude,
- Posebnih uvjeta ugovora,
- Općih uvjeta ugovora,
- Zahtjeva Naručitelja,
- Priloga,
- Prijedloga Izvođača i svih ostalih dokumenata koji čine dio Ugovora.

Inženjer u FIDIC ugovoru nije ugovorna strana, ali je angažiran od strane naručitelja, provodi dužnosti dodijeljene mu ugovorom i zastupa naručitelja. Inženjer ima ključnu ulogu u administraciji ugovora te preuzima mnoge dužnosti i obaveze, a ima pravo interpretirati ugovor i izdavati objašnjenja i upute u slučaju da postoje proturječnosti. Zbog toga on ima izrazito bitnu ulogu u projektu, ulogu koja traži određeni stupanj nepristranosti i pravičnog

postupanja. Iako je inženjer angažiran od strane naručitelja on se treba ponašati neovisno i donositi odluke u skladu sa svojom profesionalnom prosudbom.

Inženjerove ovlasti kakve su u FIDIC-ovu ugovoru nisu uobičajene u Hrvatskom ugovornom pravu, uzancama ni poslovnim običajima. Inženjer u ugovorima prema FIDIC-u je najčešće pravna osoba (tvrtka) koju putem konzultantskog ugovora angažira naručitelj da obavlja poslove Inženjera na projektu, ali može imati i dodatne funkcije kao što su recimo vođenje projekta i administriranje ugovora. Inženjer najčešće preuzima i funkciju nadzornog inženjera prema Zakonu o gradnji (NN 153/13), odnosno imenuje osobu koja vrši funkciju nadzornog inženjera za investitora prema hrvatskoj građevinskoj regulativi.



Grafikon 1. Procedura donošenja odluka prema čl. 3.5 (Inženjer)

Inženjerova uloga u projektu je dakle tehničke ali i administratorske prirode jer preuzima dužnosti pregleda dokumentacije, nadzora nad kvalitetom radova, praćenje napretka projekta, te vođenja administracije i korespondencije. Mora biti sposoban pružiti adekvatne inženjerske usluge i imati izuzetno dobro poznavanje procedura zatraženih ugovorom, naročito u pogledu izdavanja uputa, izmjena, usklađenja, odgovora na potraživanja i donošenja odluka.

Kada god ugovor zahtijeva od inženjera da se suglasi ili odluči o nekoj stvari on mora konzultirati obje ugovorne strane i ukoliko se ne usuglase tada mora donijeti pravednu odluku u skladu sa ugovorom. Odluke koje donosi ne mogu osloboditi nijednu stranu ugovornih obaveza niti nametnuti neke obaveze kojih nema u ugovoru. Inženjer donosi odluke u slučaju potraživanja, izmjena i usuglašenija. Inženjerova odluka je obvezujuća za stranke u ugovoru i moraju je provesti osim ako se ne revidira u naknadnom postupku rješavanja spora.

2.1. Izmjene i usklađenja kod FIDIC ugovora

U ugovorima o radovima se često u slučaju nepredviđenih i naknadnih radova ulazi u određene pregovore sa izvođačima, a događa se da takva situacija završi i sporovima.U FIDIC ugovoru izmjene i usklađenja su propisane člankom 13. Opisana su prava inženjera, izvođača, naručitelja, te procedure koje treba pratiti u slučaju da se dogovore dodatni radovi, izmjeni način izvedbe radova ili određeni radovi izbace iz provedbe. Inicijativu može preuzeti izvođač ili inženjer. Opseg radova definiran ugovorom u Zahtjevima Naručitelja i Prilozima može tokom ugovora biti izmijenjen da bi se prilagodio specifičnim zahtjevima, situacijama i događajima koji nisu mogli biti predviđeni tokom izrade ponudbene dokumentacije. U praksi je provedba projekata praktički nemoguća bez određenih izmjena.

Kako izmjene utječu ne samo na projektiranje i izvedbu na gradilištu već i na ugovornu cijenu i profit izvođača, posljedice izmjena na izvođača i naručitelja moraju biti jasno definirane u samoj uputi za izmjenom. U FIDIC-ovim ugovorima procedura izmjene u članku 13 predviđa daljnje postupanje u svrhu evaluacije cijene, profita, te produženja roka za dovršetak.

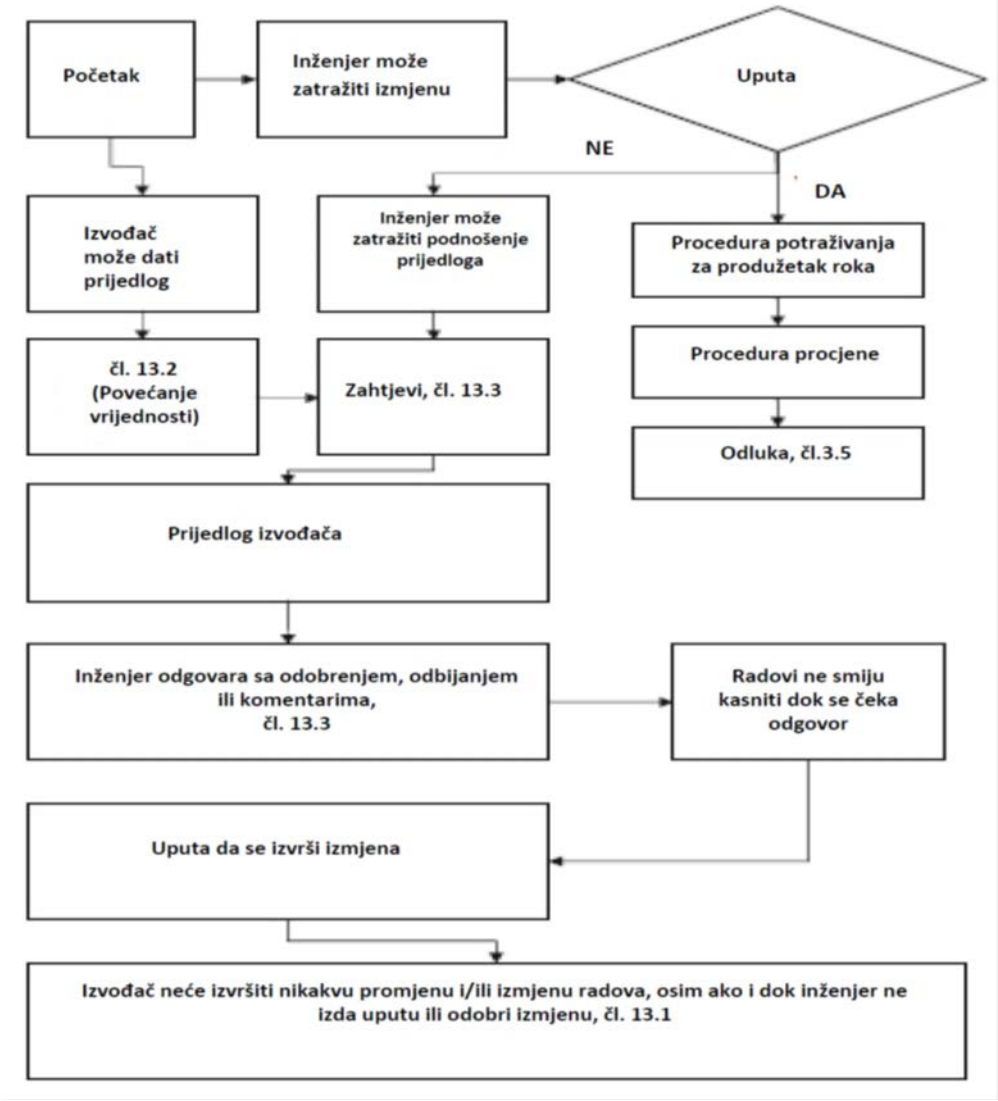
Dodatno plaćanje izvođaču je moguće ako inženjer izda uputu za izmjenom u odnosu prema Zahtjevima Naručitelja ili radovima. Naručitelji zbog toga često ne žele detaljno elaborirati Zahtjeve Naručitelja, već se drže samo okvirnog opisa i ciljeva koje projekt treba ispuniti, tako da onemoguće potrebu za mnogobrojnim izmjenama. FIDIC daje mogućnost inženjeru da inicira izmjenu ili direktnim nalogom (prema čl. 3.3) ili zahtjevom izvođaču da napravi prijedlog (čl. 13.1). Uputu je moguće izdati bilo kada je potrebno da bi se omogućila

daljnja izvedba radova. Međutim, FIDIC onemogućuje inženjeru da izda uputu koja predstavlja izmjenu nakon izdavanje Potvrde o preuzimanju radova.

Inženjer će u nastojanju da smanji rizike koje izmjena može imati na opseg radova, ugovorni rok i cijenu, najčešće zatražiti u skladu sa člankom 13.3 od izvođača da mu dostavi prijedlog izmjene. Izvođač će potom dati razlog zašto ne može ispuniti taj zahtjev ili dostaviti detaljan prijedlog izvršenja izmjene. Takav prijedlog ne predstavlja čvrstu ponudu za izvršenje izmjene. Inženjer može potom dati nalog za izvršenje izmjene nakon čega pristupa proceduri odlučivanja prema čl. 3.5 da bi dogovorio ili utvrdio korekciju ugovorne cijene. Izvođač je obvezi izvršiti svaku izmjenu koju naloži inženjer, osim ako ne da razloge zbog kojih nije u mogućnosti to učiniti (čl. 13.1), međutim ugovor ne pruža brojne mogućnosti u tom pogledu. Inženjer ne može nalogom za izmjenu dati pravo izvođenja nekoj trećoj osobi niti može mijenjati odredbe ugovora stoga izmjene ne mogu radikalno mijenjati opseg radova i obveze koje je izvođač preuzeo ugovorom.

Uputa inženjera izvođaču da izvrši izmjenu je obvezujuća i nije je moguće poništiti, bez obzira koliko može imati dalekosežne posljedice za projekt. Ukoliko ne postoje nejasnoće i greške u ugovornoj dokumentaciji, rizik pojave izmjena je manji. Dobro pripremljena ugovorna dokumentacija smanjuje potrebu za brojnim uputama prema izvođaču i posljedično za izmjenama.

U ugovoru prema Žutoj knjizi izvođač ima određenu slobodu prilikom odabira tehnologije, materijala i metodologije izvedbe radova. inženjer mora pažljivo postupati i analizirati rizike svake upute i izmjene koju naloži izvođaču. U suprotnom su moguće posljedice u financijskom smislu te u produženju rokova dovršetka projekta.

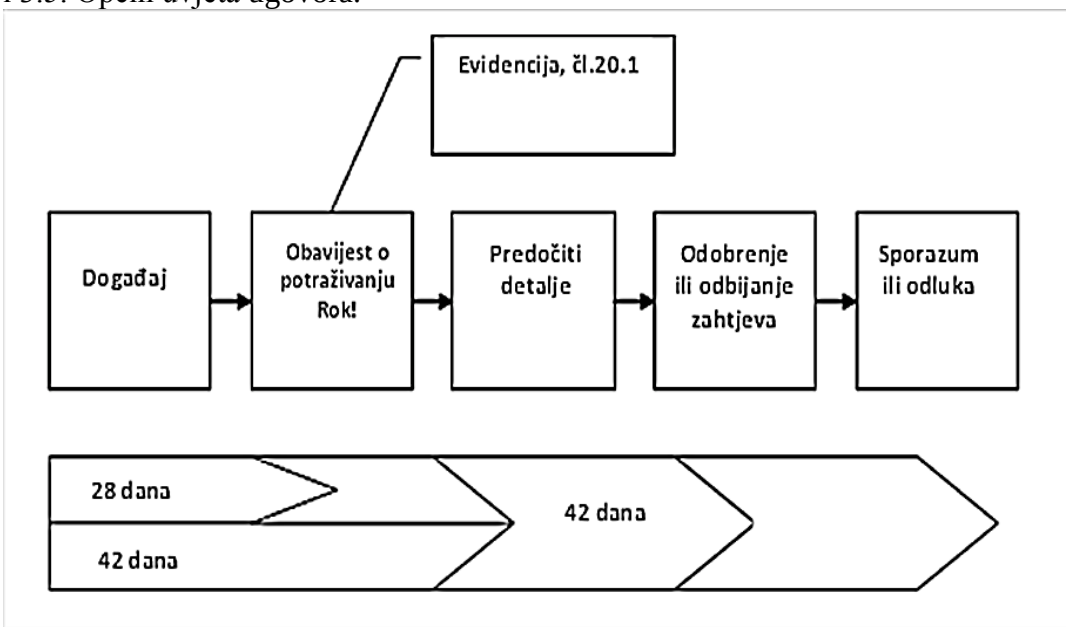


Grafikon 2. Procedura izmjena prema čl. 13

2.2. Potraživanja i sporovi

FIDIC uvjeti ugovora su pravedno balansirani šta se tiče podjele rizika. Zbog toga su procedure obrade potraživanja uključene u ugovor. Svejedno, izvođači često smatraju procedure u FIDIC ugovorima opterećujućima jer nameću striktne odgovornosti i rokove. Izvođač mora dati obavijest o potraživanju i nakon toga sve detalje o potraživanju u zadanim rokovima, a njegovo pravo na novčanu kompenzaciju ovisi o pridržavanju procedura iz ugovora. Razlog nametanja rokova i proceduralnih ograničenja je u nastojanju da se potraživanje obrađuje u realnom vremenu i bez odgađanja. To onemogućuje nepotrebno gomilanje potraživanja na kraju projekata. Drugi razlog je što to omogućuje inženjeru da izda određene upute koje mogu umanjiti financijske i vremenske posljedice ili u potpunosti spriječiti da do potraživanja dođe. FIDIC dakle nastoji da se sva pitanja o predmetnim potraživanjima postave dok su oprema, ljudstvo i svjedoci događaju koji je uzrokovao potraživanje još na gradilištu.

Čvrsto je pravilo da obavijest o potraživanju mora biti dana u roku od 28 dana. Ako izvođač propusti taj rok njegovo pravo na to potraživanje se gubi. Obavijest o potraživanju mora dati osnovne podatke te omogućiti inženjeru da izda potrebne upute ako je to potrebno. Dostavom obavijesti o potraživanju počinje proces odlučivanja koji je opisan u člancima 20.1 i 3.5. Općih uvjeta ugovora.



Grafikon 3. Procedura potraživanja

Inženjer može zatražiti dodatne podatke o potraživanju ali svejedno mora odgovoriti u roku od 42 dana. Nakon šta je odgovorio sa pristankom ili odbijanjem inženjer dalje konzultira obje stranke u nastojanju da dođe do sporazuma. Ako do sporazuma ne dođe inženjer donosi pravednu odluku u skladu sa ugovorom te pismeno obaviještava stranke. Odluka inženjera o potraživanju je obvezujuća za obe stranke osim ako se ne revidira na Vijeću za rješavanje sporova ili Arbitraži. Potraživanja mogu nastati u bilo kojem trenutku prije dovršetka radova ili čak i poslije toga. Postupanje sa potraživanjima traži organizacijske, tehničke, financijske i pravne vještine. Nažalost, praksa i literatura koja obrađuje tu temu (Baker-et-al, 2009.) pokazuje da:

- Postupanje sa potraživanjima se najčešće radi na Ad hoc bazi,
- Izvođačeva evidencija nije na razini da omogući detaljan uvid i podupre potraživanja,
- Građevinski dnevnici, radne liste i operativni planovi često ne sadrže potrebne informacije za odlučivanje o potraživanjima,
- Neke aspekte potraživanja je nemoguće točno definirati čak i uz dobro vođenu evidenciju na gradilištu.

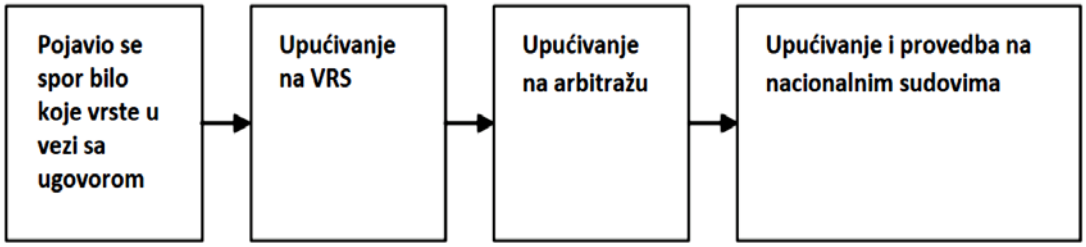
Iz navedenih razloga nije začuđujuće što se često događa da se stranke ne usaglase u pravima na potraživanja i odluče svoja prava tražiti dalje u postupku rješavanja sporova.

Međutim, kada god je to moguće preporučljivo je sporove riješavati nagodbom jer je proces rješavanja sporova dugotrajan i skup. Većina međunarodnih uvjeta ugovora zbog te činjenice sadrži odredbe koje strankama omogućuju da izbjegnu sporove, poput Sporazumnog rješavanja spora (FIDIC Uvjeti ugovaranja za postrojenja i projektiranje i građenje, prvo izdanje, čl. 20.5). Kako su sudski i arbitražni procesi skupi razvijene su alternativne metode rješavanja sporova koje su obvezujuće za stranke prije nego šta se slučaj prijavi na sud ili arbitražu. Neki od alternativnih metoda su „mirenje“ ili „posredovanje“ te posebna povjerenstva za rješavanje sporova (Dispute Review Board ili Dispute Adjudication Board).

FIDIC je u svim svojim izdanjima iz 1999.g usvojio DAB ili hrv. Vijeće za rješavanje sporova (VRS). Ako nastane spor stranke mogu isti prijaviti na VRS koji ima pravo pregledati i revidirati bilo koju uputa, odluku, potvrdu ili mišljenje dano od strane inženjera na ugovoru.

Postoje dvije vrste VRS-a u FIDIC izdanjima iz 1999.g, a razlikuju se u trajanju imenovanja - stalno vijeće i ad-hoc vijeće. Stalno vijeće se imenuje prije nego izvođač počne izvoditi radove i prisutno je tijekom cijelog vremena trajanja ugovora. Takvo vijeće redovito posjećuje gradilište i rješava tekuća pitanja kako se ona pojave. Ad-hoc vijeće se imenuje svaki puta kada se pojavi spor. Obje vrste vijeća mogu se sastojati od jednog ili tri člana koje imenuju ugovorne strane.

U principu svaki spor mora proći proces odlučivanja na VRS-u prije nego može biti upućen dalje na arbitražu.



Grafikon 4. Proceduralni koraci kod sporova

Stranka koja podnosi spor VRS-u dužna je to učiniti pismenim putem uz primjerak drugoj strani i inženjeru. Šta se tiče samog sadržaja podneska, FIDIC objašnjava da je potrebno da podnesak uključuje obrazloženi stav stranke sa svim detaljima slučaja, potrebne premise i zaključke na kojem se stav stranke zasniva, te detaljno obrazloženje odluke koju stranka želi da VRS donese (The FIDIC Contracts Guide - First Edition, 2000.g).

VRS je opunomoćen da:

- Utvrdi postupak koji će se primjeniti u rješavanju spora;
- Oduči o svojoj juridistikciji i obujmu spora koji mu je dostavljen;
- Odluči o postupku saslušanja i o tome da li su potrebna. Također može odlučiti o prihvaćanju izjava stručnjaka i pravnih savjetnika;
- Odluči o naplati zateznih kamata, privremenim mjerama i mjerama osiguranja;
- Pregleda i revidira sve potvrde, odluke, mišljenja i presude inženjera koje se odnose na spor.

VRS pritom može provesti istražne radnje, odbiti prisusutvo osobama angažiranima od stranaka na saslušanju a može postupati i bez prisustva bilo koje strane.

Ovisno o roku za odluku i svim relevantnim faktorima, VRS mora:

- Postupati nepristrano i pošteno prema naručitelju i izvođaču i svakome dati šansu da se izjasni o slučaju;
- Primjeniti postupak koji je adekvatan sporu i izbjegavati nepotrebna kašnjenja i troškove.

Sva korespodencija i dokumentacija vezana za spor mora biti dostavljena na traženje VRS-a. Uobičajeno je, iako ne obavezno, da VRS zatraži saslušanje. Takva saslušanja su najčešće manje formalna nego saslušanja prilikom arbitražnog ili sudskog postupka. U slučaju da je zatraženo saslušanje mogu se pratiti sljedeće procedure procedure koju treba pratiti od podnošenja spora do donošenja odluke (The FIDIC Contracts Guide - First Edition, 2000.g):

Procedura do saslušanja:

1. Prvi podnesak stranke koja obavještava o sporu,
2. Odgovor druge stranke na prvi podnesak,

3. Drugi podnesak stranke koja obavještava o sporu,
4. Drugi odgovor stranke koja ne obavještava o sporu (nije nužan),
5. Formalno saslušanje.

Procedura saslušanja:

1. Usmena prezentacija stranke koja je podnosi spor,
2. Usmena prezentacija druge stranke,
3. Kratki odgovor prve stranke,
4. Kratki odgovor druge stranke,
5. VRS upućuje pitanja strankama i inženjeru.

Procesna pravila daju način koji VRS mora usvojiti prilikom donošenja odluke. VRS ne smije tijekom saslušanja davati nikakva mišljenja koja se tiču merituma argumenata koje iznesu ugovorne strane. Odluka koju VRS donese se ne može više mijenjati, te je obvezujuća za strane osim ukoliko i dok se ne revidira u postupku Sporazumnog rješavanja spora ili Arbitraži. Da bi spriječila da odluka VRS-a postane konačna i obvezujuća, bilo koja ugovorna strana mora dati obavijest o nezadovoljstvu u roku od 28 dana od zaprimanja odluke VRS-a. Ako nijedna ugovorna strana nije dala obavijest o nezadovoljstvu, tada odluka VRS-a postaje konačna i obvezujuća za obje ugovorne strane. Bez obzira na pokušaj sporazumnog rješenja spora arbitraža može započeti najranije 56 dana od datuma predaje obavijesti o nezadovoljstvu.

3. Praktična primjena u Hrvatskoj i problematika

Upravljanje ugovorom znači ponajprije kompetentno vođenje administracije, korespodencije s stranama u ugovoru, te udovoljavanje svim rokovima za dostavljanje obavijesti, odgovora i izvještaja o napretku. Izuzetno je bitno prilikom provedbe ugovora staviti na papir sve moguće zahtjeve za dodatnim naknadama, produženjem rokova, otklanjanjem odgovornosti itd. Propusti u tom pogledu mogu uzrokovati značajne financijske gubitke, kako izvođačima tako i naručiteljima.

Postoji čitav niz formalnih obavijesti koje izvođač mora dati na vrijeme, a bez kojih naručitelj i inženjer nisu dužni reagirati. Osim toga obaveza je čuvati ažurnu dokumentaciju i evidenciju sa gradilišta kroz čitavo vrijeme trajanja ugovora. Pri tome se ne smije zanemariti da FIDIC Žuta knjiga predviđa obaveze i odgovornosti u trajanju Razdoblja za obavijesti o nedostacima kao i mogućnost ispitivanja postrojenja nakon dovršetka odnosno preuzimanja radova, a što traži značajan dodatni angažman nakon šta građevinska operativa napusti gradilište.

Ispravno vođenje dokumentacije je preduvjet za dobijanje sporova jer arbitri i suci u VRS-u ili Arbitražnom postupku nemaju izravno saznanje o činjenicama, već se oslanjaju na pisane dokaze. Dakle, vrijedost dobre administracije kod ugovora o građenju se ne smije zanemariti.

Iz navedenih razloga izrazito je bitno na odgovorna mjesta imenovati osobe koje imaju osjećaj za pravni izričaj i za uredno i organizirano vođenje administracije. Iz iskustva sa provođenja ugovora po FIDIC-u može se reći da je upravo taj dio posla jedna od najslabijih strana naših izvođača i savjetodavnih inženjera. Tvrtke savjetodavnih inženjera i izvođači bi kod izobrazbe svog osoblja trebale posebnu pozornost posvetiti tom aspektu. Za posao upravljanja projektima najbolje je imati inženjere osposobljene kako za tehničku, tako i za ugovornu stranu posla.

Naručitelji na FIDIC projektima angažiraju savjetodavne tvrtke da djeluju u funkciji Inženjera u ugovoru o gradnji. Ugovor koji savjetodavne tvrtke sklapaju sa naručiteljem sadrži tzv. Opseg usluga u kojem su iscrpno navedene sve usluge koje naručitelj očekuje da će biti vršene od strane savjetodavnog inženjera. Takve usluge su šireg opsega od pružanja usluge vršenja dužnosti Inženjera na ugovoru naručitelja sa izvođačem i često uključuju upravljanje projektom i financijske usluge.

Jedan od zadataka koji se redovito daje u Opsegu posla je priprema Priručnika procedura nadzora. Takav priručnik treba dati osnovne smjernice ponašanja i procedura u ugovoru koje trebaju slijediti naručitelj, izvođač i inženjer.

Sadržaj Priručnika procedura nadzora najčešće uključuje:

- Rutine provjere, odobrenja, svakodnevni rad (dnevnik), sastanke, izvještavanje, alternativna rješenja, itd.;
- Plan izvještavanja;

- Odobrenja, procedure, formulare i zahtjeve za izvještavanje u skladu sa svom relevantnom važećom zakonskom regulativom;
- Formulare za procedure i zahtjevi za izvještavanje u skladu s FIDIC Uvjetima ugovora;
- Izvještavanje za financijsku kontrolu i upravljanje u skladu i u dogovoru s naručiteljem;
- Komunikacijski kanali s glavnim dionicima;
- Upravljanje dokumentima i distribucija;
- Procedure osiguranja kvalitete i kontrole za aktivnosti nadzora i upravljanje ugovorima.

Priprema priručnika je zahtjevan posao jer treba uzeti u obzir sve standardne procedure ustanovljene u Općim uvjetima FIDIC ugovora i obratiti pozornost na specifičnosti dane u Posebnim uvjetima predmetnog ugovora. Pri tome treba imati na umu da pravni okvir provedbe projekta nameće određene prisilne odredbe koje je dijelom potrebno opisati i u proceduralnom smislu sa naglaskom na odgovornosti ugovornih strana. Takav priručnik treba nastati na osnovu razrađenog sustava osiguranja kvalitete tvrtke savjetodavnog inženjera te se zatim prilagoditi specifičnostima svakog ugovora.

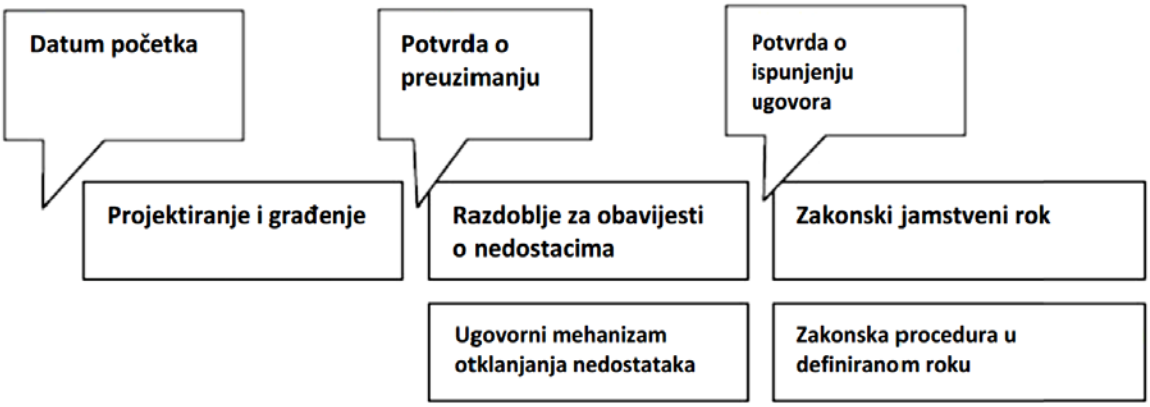
S obzirom na činjenicu da u Hrvatskoj tvrtke izvođača, a i osobe nadzornih inženjera, često nemaju prethodnog iskustva rada na FIDIC ugovorima, takvi Priručnici procedura nadzora mogu dati bitne smjernice postupanja te pomoći ugovornim stranama u nekim dijelovima FIDIC ugovora gdje često dolazi do nesuglasica kao npr. u slučaju obrade plaćanja, odobravanja izmjena, postupanja sa potraživanjima i sporovima, te davanja uputa.

3.1. Provedba FIDIC ugovora u hrvatskom zakonskom okviru

Ugovori se uvijek sklapaju u sklopu nekog pravnog sustava, domaćeg ili stranog. Onaj pravni sustav koji se primjenjuje na neki ugovor se zove „mjerodavnim pravom“. Hrvatski pravni sustav spada u europsko – kontinentalni pravni sustav poznat pod engleskim nazivom „Civil law“. Na ugovore o građenju se kod nas primjenjuju odredbe Zakona o obveznim odnosima. Neka od pravila su prisilne naravi (kogentna) dok druga ovise o slobodnom izboru ugovornih strana (dispozitivna pravila). Prisilna pravila se uvijek primjenjuju bez obzira na dogovor ugovornih strana, dok se dispozitivna primjenjuju u slučaju da ugovorne strane nisu neko pitanje riješile na drugi način ili ga nisu obuhvatile svojim ugovorom.

FIDIC ugovori su nastali na temelju engleskih ICE ugovora o građenju pa su uglavnom preuzeli koncepte anglosaksonskog prava („Common law“). Postepenim razvojem ti su se uvjeti ugovora u određenoj mjeri odvojili od britanskog uzora i približili europskom kontinentalnom pravnom okviru. Bez obzira na tu činjenicu treba imati na umu da neki uvjeti iz FIDIC-a nemaju isto značenje koje im se uobičajeno daje u ugovorima o građenju koji se provode u europskom kontinentalnom pravnom sustavu.

Neki od ugovornih članaka iz FIDIC-a često uzrokuju konfuziju u provedbi ugovora jer iako su koncepti slični ipak postoje određene razlike u pravnim tumačenjima. To je naročito izraženo u nekim osjetljivim periodima provedbe ugovora kao recimo prilikom izdavanja Potvrde o preuzimanju radova te pravnog značenja Razdoblja za obavijesti o nedostacima. Često se događa da kod prijevoda ugovorne dokumentacije na hrvatski jezik prevoditelj prevede termin FIDIC-a mijenjajući mu izvorno značenje iz „Common law“- a. Te situacije treba izbjeći angažiranjem stručnjaka sa iskustvom provedbe FIDIC ugovora već kod koncipiranja natječajne dokumentacije.



Grafikon 5. Tipičan redoslijed glavih događaja u FIDIC ugovoru

U FIDIC ugovoru datum Potvrde o preuzimanju radova označava početak Razdoblja za obavijesti o nedostacima u kojem je izvođač još dužan izvršiti neke radove ako to od njega zatraži inženjer. Razdoblje za obavijesti o nedostacima je zapravo dodatni period u ugovoru u kojem izvođačeva odgovornost za radove još postoji. Zbog toga se smatra da radovi još nisu „prihvaćeni“ odnosno oni postaju prihvaćeni od naručitelja tek izdavanjem Potvrde o ispunjenju ugovora kada počinje teći i zakonski jamstveni rok. Odnos između naručitelja i izvođača prestaje tek predajom i primitkom radova i sastavljanjem „konačnog obračuna“, a to je u FIDIC ugovoru nakon izdavanja Potvrde o ispunjenju ugovora i plaćanja Okončane situacije. Tek nakon toga počinju zakonski jamstveni rokovi i desetogodišnja odgovornost sudionika (izvođača, projektanta i revidenta) za temeljne zahtjeve za građevinu, na osnovi prisilnih propisa iz Zakona o obveznim odnosima (čl. 604-611,633).

U pogledu primjene određenih uvjeta iz FIDIC-a, i to prvenstveno u dijelu standardiziranih isprava, nameće se potreba da se u slučaju primjene hrvatskog prava kroz Posebne uvjete Ugovora, odredi analogija sa srodnim ispravama hrvatskih propisa i to osobito onima koje su nužne zakonske dozvole prema Zakonu o gradnji.

Povezivanje zakonski traženih dozvola poput Uporabne dozvole i stavljanje iste u ugovor kao preduvjet za izdavanje Potvrde o preuzimanju radova, je jedan od primjera koji se moraju detaljno opisati i razraditi u Posebnim uvjetima ugovora, imajući na umu da FIDIC predviđa striktne vremenske rokove stranama u pogledu davanja zahtjeva i izdavanja Potvrde o preuzimanju radova. Ako se to propusti učiniti, tada naručitelj treba biti svjestan da je inženjer dužan izdati Potvrdu o preuzimanju radova odmah nakon uspješnog prolaza na Ispitivanjima po dovršetku postrojenja.

Također, u slučaju da je u toku provedbe ugovora potrebno ishoditi lokacijske ili građevinske dozvole, što je redovito slučaj u ugovorima po Žutoj knjizi, tada je potrebna detaljna razrada odgovornosti strana u postupku te definiranje koja se kašnjenja u slučaju produljenja administrativnih aktivnosti smatraju odgovornošću izvođača, a koja rizikom naručitelja. Praksa kod nas pokazuje da navedeni postupci ishođenja zakonski uvjetovanih dozvola redovito rezultiraju potraživanjima za produženjem rokova.

Jedna od razlika između pravnog sustava na osnovu kojeg je nastao FIDIC i našeg pravnog sustava, je u tumačenju instituta ugovorne kazne. Kod nas se koristi izraz i pravno tumačenje penala (eng. *penalties)* dok je FIDIC usvojio engleski princip ugovorne štete (eng. *liquidated damages*). Karakteristika je instituta ugovorne štete da se unaprijed dogovara procijenjena moguća šteta koja može nastati kašnjenjem izvođača te da se takva ugovorena kazna ne može smanjivati ni povećavati, bez obzira na stvarni iznos pretrpljene štete. Naš pravni sustav je jedan od onih koji ne priznaje apsolutnost visine ugovorne kazne, već je sud dužan ugovornu kaznu smanjiti ako se dokaže da je nesrazmjerna u odnosu na vrijednost stvarne štete.

Kod ugovornog mehanizma postupanja sa sporovima stavka na koje izvođači imaju primjedbe je izrazito nepovoljan propis članka 20.1 prema kojem izvođač u roku od 28 dana „nakon šta je saznao ili je trebao saznati za događaj ili okolnost“ mora dostaviti inženjeru Obavijest o potraživanju inače gubi pravo na naknadu štete (FIDIC Uvjeti ugovaranja za postrojenja i projektiranje i građenje, 1999, str. 60). Prema stajalištu aktualne hrvatske pravne prakse svaki ugovorni rok sam za sebe nužno ne uzrokuje posljedicu gubitka prava, već jedino ukoliko se isti može smatrati bitnim elementom ugovora. Svakako bi u primjeni ugovaranja uvjeta FIDIC-a pomoglo dopunsko ugovaranje odredbi koje bi povezale i harmonizirale odnos uvjeta FIDIC-a sa hrvatskim prisilnim i dispozitivnim propisima, na način da se određeni uvjeti FIDIC-a ne ugovaraju kao obvezujući u dijelu gdje prisilni propisi zakona to ne omogućavaju.

Neki izvođači kod nas smatraju da je upis u građevinski dnevnik dostatan da se može smatrati kao obavijest inženjeru o potraživanju. Međutim, FIDIC uopće ne predviđa vođenje građevinskog dnevnika, već određuje da se komuniciranje između naručitelja, izvođača i inženjera vrši pismenim putem te dostavom poštom ili kurirom na službeno označenu adresu (članak 1.3). Ta su priopćenja puno službenije prirode nego upis u građevinski dnevnik. Upisom u građevinski dnevnik se teško može služiti u iscrpnom objašnjavanju pojedinih pitanja. Zbog toga bi se u građevinski dnevnik trebali unositi samo usmeni sporazumi postignuti tijekom izvođenja radova i biti supotpisani od odgovornih predstavnika ugovornih strana.

Često dolazi i do nesporazuma po pitanju ovlasti određenih osoba u ugovoru koje zastupaju izvođača i inženjera. Naime, osoba imenovana od strane naručitelja da u njegovo ime vrši stručni nadzor nad građenjem prema Zakonu o gradnji, ne mora nužno biti i osoba koja je ovlaštena da zastupa inženjera prema FIDIC-u. Predstavnik inženjera može ustupati ovlasti svojim pomoćnicima i inženjerima na gradilištu, ali to treba biti pisanim putem i u kopiji svim stranama. Takvo ustupanje ovlasti mora definirati da li inženjer na gradilištu ima ovlasti da izvođaču daje specifične upute i u kolikom opsegu. Ustupanje ovlasti inženjera svojim pomoćnicima na gradilištu je posebno ograničeno po pitanju odlučivanja, pa na to treba obratiti posebnu pažnju.

Slična situacija je i kod izvođača koji ima svog imenovanog Predstavnika. Ta osoba ne mora biti ista osoba kao imenovani glavni inženjer ili inženjer gradilišta, pa je bitno ustanoviti koje ugovorne ovlasti imaju osobe koje potpisuju građevinski dnevnik. Jasno je da oni preuzimaju zakonsku odgovornost kod izvođenja radova prema prisilnim propisima građevinske regulative te bi u skladu s tim trebali imati i prikladna ugovorna ovlaštenja.

Zbog svega gore navedenog treba obratiti pažnju kod pisanja natječajne dokumentacije, naročito Posebnih uvjeta ugovora koji bi trebali izmjenama Općih uvjeta ugovora, uklopiti FIDIC u naše pravno okruženje i građevinsku regulativu. Najveći broj potraživanja i sporova koji nastaju prilikom provedbe ugovora, imaju svoj uzrok u greškama u Zahtjevima naručitelja te nedovoljno definiranim ili manjkavim Posebnim uvjetima ugovora.

4. Zaključak

Karakteristične faze projekta koje se pojavljuju prilikom provedbe ugovora prema FIDIC-u često uzrokuju nedoumice i sporove sa ozbiljnim financijskim posljedicama za obje stranke u ugovoru. Zbog toga je potrebna studiozna priprema ugovorne dokumentacije u fazi pripreme natječaja da bi se izbjegli mogući naknadni problemi kao i ažurno vođenje dokumentacije u toku provedbe projekta.

Pravni okvir provedbe nameće određene prisilne odredbe koje je dijelom potrebno opisati i u proceduralnom smislu sa naglaskom na odgovornosti ugovornih strana. Zbog te činjenice kao i velikog broja standardiziranih procedura ustanovljenih u Općim uvjetima FIDIC ugovora veliku pomoć u provedbi mogu dati Priručnici procedura nadzora koje sastavljaju savjetodavne tvrtke u funciji inženjera u ugovoru o gradnji. Pri tome treba imati na umu da neki uvjeti iz FIDIC-a nemaju isto značenje koje im se uobičajeno daje u ugovorima o građenju koji se provode u europskom kontinentalnom pravnom sustavu. Ovlasti inženjera koje zastupaju izvođača i nadzora moraju biti jasno definirane i njihova prava pisanim putem dana na uvid svim stranama.

Provedba ugovora prema FIDIC-u se kod nas pokazuje kao zahtjevan zadatak koji traži maksimalan angažman naših inženjera i stručnjaka, ali isto tako uvjetuje usavršavanje naših inženjera u pravnim aspektima vođenja projekata koji se pokazuju kao značajan faktor, uz sve ostale tehničke zahtjeve građevinske struke. Takva situacija u određenom smislu utječe na postepeno educiranje u praksi te naši inženjeri i tvrtke mogu steći potrebna znanja koja se kasnije mogu primjeniti kako na domaćem tako i na međunarodnom tržištu čineći ih konkurentnijima. Hrvatska je dio Europske Unije što omogućava pojačanu prisutnost i konkurenciju stranih tvrtki na našem tržištu i dodatno zaoštrava situaciju u nuđenju i ugovaranju poslova. Naravno da će sposobnost upravljanja projektima i znanja stečena u provedbi FIDIC ugovora u Hrvatskoj izravno utjecati i na uspjeh naših tvrtki na stranim tržištima.

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Ocjena primjene BIM aplikacija u upravljanju projektom na primjeru modeliranja interpretacija tradicijske arhitekture

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Sažetak

U radu je predstavljena tradicijska arhitektura dalmatinskog zaleđa i mogućnosti njene interpretacije obzirom na konstitutivne građevne dijelove obiteljske kuće. BIM koncept novi je izazov u graditeljstvu čiji se značaj prati i procjenjuje te se razvijaju metode kojima se mjeri učinkovitost novog koncepta izrade projekta i projektne dokumentacije. Kroz pregled literature razmatrani su mogući odnosi prema tradicijskoj gradnji te su definirane razine promjene i načini sagledavanja tradicijskog. Ključno pitanje ovog rada je kakav doprinos informacijskog modeliranja možemo tražiti u interpretaciji tradicijskih oblika. U praktičnom dijelu su izrađeni BIM modeli na temelju postojeće građevine koja je ogledni primjer regionalne arhitekture dalmatinskog zaleđa, a izrađeni modeli predstavljaju pojedine razine interpretacije tradicijske arhitekture promatranog prostora. U radu su prikazani rezultati troškova i vremena izvođenja radova za različite razine interpretacije tradicijske arhitekture te su modeli uspoređeni. Procjena primjene BIM koncepta u varijaciji tradicijskih oblika, tehnologije i materijala dana je na temelju rezultata primjene softwarea Arup BIM Maturity Measure za dimenziju oblikovanja arhitekture s naglaskom na pročelje. Rad rezultatima ukazuje na slabost eksterne podrške za cjelovitije korištenje i iskorištavanje BIM koncepta u promatranom primjeru.

Ključne riječi: tradicijska arhitektura; građevni dijelovi; kamena kuća; modeliranje; BIM

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1. Uvod

Ruralna naselja današnjice izložena su transformacijama koje su povezane s promjenama djelatnosti seoskog stanovništva, promjenama u preferencijama stanovništva no i promjenama u dostupnosti materijala, znanja, vještina i tehnologija. Interpretacija tradicijskih oblika uz zadržavanje i nadogradnju postojećih pouka najpoželjniji je oblik zaštite vrijednosti koje su se stvarale u dugom periodu dok nerazumijevanje i nepromišljanje građevnih oblika stvaraju novu sliku van kontinuiteta. Kamena kuća hrvatskog prostora tema je niza radova koji se bave materijalom, tehnologijom i arhitekturom. U obuhvatnoj knjizi Hrvatsko tradicijsko graditeljstvo autor Živković, 2013 cjelovito razmatra sve tradicijske oblike u Republici Hrvatskoj izdvajajući kuću dalmatinskog zaleđa kao zaseban oblik. Još detaljnije se isti autor bavi kućom dalmatinskog zaleđa u priručniku za obnovu i turističku valorizaciju iz 2015. Autori Šverko et al., 2007 bave se kamenom kućom hrvatskog priobalja ukazujući na pozitivne i negativne primjere interpretacije. Tehnologija i materijal obrađeni su detaljno u knjizi Građenje prirodnim kamenom autora Crnkovića i Šarića, 2013 dok je tehnologija izrade suhozida akcijski prezentirana od strane udruge Dragodid i publicirana u Mediteranskoj kući, 2006. Svijest o vrijednostima kamene kuće na prostoru Hrvatske sve je jača jer se promatra u kontekstu gospodarskog potencijala obalnog prostora. Autentičnost je jedan od važnih atraktora turizma kojemu u prilog treba ići razvoj kako u gradnji tako i u projektiranju i vođenju projekta te eksterne podrške u tehnologiji. Novi koncept BIM-a poslije CAD-a omogućuje i traži jače integriranje svih sudionika i segmenata projekta kroz informacijsko modeliranje. Informacijsko modeliranje tradicijskih elemenata dodatni je izazov zbog potrebe definiranja informacije o vrijednosti pojedinih elemenata te nedostatku upravo tih informacija uslijed nestajanja tehnologija.

2. Tradicijska arhitektura dalmatinskog zaleđa

Pučka ili tradicijska arhitektura nekog područja je arhitektura koja se temelji na lokalnim potrebama, materijalima i vještinama te lokalnim resursima. Ona teži razvoju tijekom vremena kako bi odražavala okolišni, kulturni, tehnološki, ekonomski i povijesni kontekst u kojem postoji. U dalmatinskom zaleđu kuće se često grade u nizovima, a obzirom na vertikalnu dinamiku reljefa javljaju se i kaskadni nizovi. Kuća ovog podneblja se razvijala u svom prizemnom dijelu nizanjem prostorija, a u vertikalnom smjeru nastavljanjem osnovnog oblika. Kuće su građene po jednostavnim geometrijskim tlocrtnim shemama, pravokutnog, rjeđe kvadratnog tlocrta. Dimenzije prostorija su uvjetovane ograničenjima konstruktivnih materijala. Raspon između nosivih zidova ne prelazi 6 metara, jer je dulju drvenu građu za izradu međukatnih i krovnih konstrukcija teže dobaviti, a drvene krovne konstrukcije do navedenog raspona mogu biti vrlo jednostavne. Nagib krova prilagođen je materijalu pokrova i lokalnoj klimi, pa je u pojedinom kraju ili naselju standardiziran, što s jedne strane olakšava i pojeftinjuje gradnju, a s druge strane dovodi do urbanističkog reda i harmonične slike cjeline.

Zdravko Živković, 2013 obrazlaže osnovni tip kuće ovoga kraja te navodi da je u svojemu najvišem dosegnutom obliku ona bila katnica u čijem je suterenu konoba ako je riječ o vinorodnom, ili stoka ako je riječ o stočarskome kraju, s vanjskim izbačenim stubištem koje vodi na kat gdje je prostor za spavanje. U kasnijem razvoju, kada kuća više nije jednoprostorna, prostorija s vatrom, kuhinja, ostaje glavna kućna prostorija, a ognjište se pomiče sa sredine tlocrta prema zidu. U dalmatinskom zaleđu dimnjak nikada nije „zaživio" pa se dim slobodno diže u potkrovlje, a u atmosferu izlazi kroz otvore u krovu i kroz same sljubnice pokrovnih kamenih ploča. Pod kuhinje je katkada bio od zemlje, a češće od kamenih ploča. Iznad kuhinje se u imotskom području javlja strop, drveni grednik i daščana oplata, s otvorom iznad ognjišta kroz koju se diže dim u tavanski prostor gdje se suši meso, a na pročelju se tom prostoru pristupa vanjskim kamenim stubama što je percipirano kao napredak u kulturi kuhinje. Isprva jedinstven prostor na katu uglavnom za spavanje poslije se pregrađuje drvenim pregradama u dvije ili više soba. I na katu kao i u prizemlju su relativno mali prozori, bez stakla, a tek kasnije se javljaju ostakljeni prozori sa škurama. Balatura, vanjski istak sa stubištem je karakterističan element kuće ovog kraja, a jedinstven je i u tome što je akumulirao niz funkcija. Primarna funkcija balature je povezivanje prizemlja i kata kuće po pravilu na južnoj, sunčanoj strani kuće. Ispred vrata konobe ljeti čini hladovinu i tako konobu štiti od prekomjernog zagrijavanja, a zimi predstavlja mjesto okupljanja i društvenog života (Živković, 2013). Ovakva kuća predstavlja graditeljski oblik šire regije te su karakteristični elementi formirali jedinstveni graditeljski sklop po kojima se prepoznaje tradicijska kuća dalmatinskog zaleđa.

Odnos prema baštini različit je u različitim kulturama no istovremeno je u istoj kulturi podložan promjenama sukladno promjenama u svjetonazorima, vodećim idealima i pretežitim ili istaknutim kulturnim vrijednostima. Rapoport, 1999 iznosi četiri moguća stava u odnosu prema tradicijskoj gradnji:

1. Može se zanemariti - kada je tradicijska arhitektura ignorirana.
2. Može se priznati njegovo postojanje, ali zanijekati da je korisno i vrijedno pouke - kada se kuće pored tradicijskih djelomično uklapaju (visina, nagib krova, dio materijala), ali ne prate sve.
3. Može biti kopirano (njegovi oblici,detalji, ispune i tako dalje) - kada se sve kopira.

4. Mogu se izvući više ili manje opće pouke i načela iz njega, kroz korištenje studija okoliš-ponašanje, koncepata, modela i tako dalje. To su te lekcije koje se potom primjenjuju u projektiranju – oblici, materijali i tehnologija se interpretiraju.

2.1. Materijal-kamen

U prošlosti odnosno u tradicijskom načinu građenja kamen je bio nosivi element konstrukcije objekta ili se primjenjivao u veoma debelim pločama za oblaganje dok se danas u suvremenom graditeljstvu kao nosiva konstrukcija koristi uglavnom armirani beton ili blok opeka, a kamen se koristi kao ukrasno zaštitna obloga te konstrukcije u obliku ploča, najčešće debljine 2 do 6 cm. Korištenjem kamena kao kamene obloge on dobiva dekorativno funkcijsku te dekorativno-zaštitnu ulogu. Od arhitektonskog kamena se izrađuju ploče različito obrađenih površina koje se mogu koristiti za vanjska zidna i podna oblaganja te za unutarnja vertikalni horizontalna oblaganja te u prošlosti za pokrivanje krovova. Arhitektonski se kamen koristi i za kamene okvire prozora i vrata, lukove, vijence, prozorske klupčice, u kiparstvu, itd.

Stambene kuće u pravilu su građene priklesanim ili bolje obrađenim kamenom u vapnenom mortu. Debljina zidova proizlazi iz karakteristika materijala, načina zidanja, zahtjeva nosivosti i fizike zgrade (termičke izolacije). Tisućljetnim iskustvom debljina vanjskih zidova tipične stambene kuće ustalila se na jedan lakat do dvije stope (oko 50-65 centimetara). Ta debljina zadovoljava klimatske uvjete, a u konstruktivnom smislu je sasvim dovoljna da ponese nekoliko katova. Ukoliko je zidanje kvalitetno, s konstruktivne strane obično nema problema da se na postojeću visinu doda još jedan kat. Vanjski zidovi su redovito iste debljine, bez obzira nose li samo vlastitu težinu ili još i težinu međukatnih i krovne konstrukcije. Relativno velikom masom zidova postiže se dovoljna toplinska izolacija, čime se štedi energija, ali i smanjuje mogućnost kondenzacije vlage, a time i pojava gljivica. Osim što predstavljaju dobar akumulator topline, kameni zidovi građeni u vapnenom mortu su paropropusni, što znači da kuća "diše".

U pravilu se zidalo kamenom kojeg se vadilo čišćenjem i zaravnavanjem terena za gradnju, pa je o vrsti terena ovisilo i kakva će biti građa zida. Najbolji su se zidovi dobivali od pločastog kamena, a najteže se zidalo oblim kamenima samcima – njih je često trebalo razbiti u komade. Najčešći je bio lomljeni kamen, različitih veličina, dobiven razbijanjem nešto većih komada stijene koji se tijekom zidanja grubo priklesavao da bi se mogao ugraditi u zid.

2.2. Tehnologija izvođenja radova

Konstrukcija od kamena kakve su se izvodile u prošlosti, odnosno, tradicionalni način gradnje kamenom danas je većini ljudi nedostupan zbog čega sve popularnije postaju obloge od dekorativnog kamena. Dekorativni kamen može biti prirodan ili izrađen od umjetnih materijala. Kako dekorativne kamene obloge na prvo mjesto stavljaju izgled kamena, tako se one prirodne izrađuju od površinskog dijela kamena, odnosno, pokušavaju se zadržati prirodna struktura i nijanse prirodnog kamena. Umjetne kamene obloge izrađuju se od različitih materijala, ali pokušavaju što vjernije dočarati izgled prirodnog kamena. Kalupi pomoću kojih se izrađuje umjetni dekorativni kamen lijevaju se prema obliku prirodnog kamena. Umjetne obloge uglavnom su izvrsne kvalitete, postoji širok izbor tekstura i boja, te zadovoljavaju najviše arhitektonske i dizajnerske kriterije.

Kamene obloge moguće je postaviti na bilo koju podlogu: neobrađeni zid, žbuku i sl. Površina na koju se postavlja obloga od kamena mora biti čvrsta, stabilna i čista. Prije postavljanja kamenih obloga potrebno je s podloge odstraniti sve tragove boje, masti ili 30 drugih nečistoća, te oštećene dijelove žbuke. Ako je potrebno, na podlogu se postavlja i impregnacija. Prirodni kamen obično ima glatku pozadinu pa se oko njegovog postavljanja treba više potruditi. Umjetne obloge uglavnom imaju hrapavu i izbrazdanu pozadinu koja olakšava postavljenje i prijanjanje. Nakon pripreme površine na koju se postavlja kamen, priprema se ljepilo. Ljepilo se nanosi na podlogu (jako suhe podloge potrebno je navlažiti jer tad ljepilo bolje prijanja), a zatim se postavlja kamen. Nakon što se ljepilo osuši kamen se fugira i čisti. Ukoliko se pridržava uputa proizvođača kamene obloge, cijeli postupak postavljanja dekorativnih kamenih obloga može izvesti i osoba koja nije „pravi" stručnjak. Umjetne kamene obloge višestruko su jeftinije od pravog kamena, a manji su i troškovi postavljanja, odnosno pripreme podloge za postavljanje umjetnih obloga.

3. Upravljanje projektima i BIM

Ocjena uspješnosti u industriji ako se ona promatra kao širi pojam, oslanja se na tekstove autora Bullen i Rockart, 1981. godine koji faktore uspješnosti dijeli na pet područja:

1. u industriji, npr, karakteristike potražnje, tehnologija zaposleni, obilježja proizvoda itd.,

2. konkurentska strategija i položaj promatrane industrije, a što usmjerava tijek razvoja industrije kroz povijest i pozicioniranje u industriji,
3. okolišni čimbenici kao makroekonomski utjecaji koji utječu na sve aktere unutar industrije, a koji pri tome imaju malo ili nimalo utjecaja, npr. demografski,ekonomski i državne zakonodavne politike itd.,
4. povremeni utjecaji, koji predstavljaju probleme u ograničenom vremenskom razdoblju pri provedbi odabrane strategije, npr. nedostatak menadžerskih stručnost i kvalificiranih radnika.
5. upravljački položaji, odnosno, različite funkcionalne menadžerske pozicije u poslovanju koje imaju svaki svoj generički set povezanih kritičnih faktora uspjeha.

Autori Grunert i Ellegaard, 1992 ključne čimbenike uspjeha navodi za četiri različita načina poimanja:

- kao nužan sastojak u informacijskom sustavu za upravljanje,
- kao jedinstveno obilježje poduzeća,
- kao alat za menadžere da elaboriraju svoje odluke,
- kao opis glavnih vještina i resursa potrebnih da se bude uspješan na određenom tržištu.

U građevinarstvu se razlikuju uspješan projekt i uspješnost vođenja projekta. Autori Vukomanović i Radujković, 2011 navode da je osnovna razlika između ova dva pojma u podjeli odgovornosti. Nad prvim pojmom odgovornost ima sponzor projekta koji može biti vlasnik ili investitor dok nad drugim pojmom odgovornost ima voditelj projekta. Kriteriji uspjeha (KPI – *Key Performance Indicators*) su mjere prema kojima se ocjenjuje uspjeh projekta.

Autori Becerik-Gerber and Rice, 2010 (u Hergunsel, 2011) proveli su istraživanje te utvrdili da se BIM najviše koristi za vizualizacije (63%), zatim za detekciju sudara (60,7%) te redom za projektiranje (60,4%), prikaz modela (42,1%), slaganje cjeline zgrade (40,6%), tijek izvođenja radova (36,2%), programiranje sadržaja (31,9%), procjena na osnovu modela (27,9%), studija izvodljivosti(24,1%), razvoj alternativnih rješenja (23,8%), izravna izrada nacrta (23,2%), analiza lokacije (18,6%), pregled kodiranja (16,4%), upravljanje održavanjem (15,8%), LEED certificiranje (14,6%) i forenzična analiza (1,2%). Daljnja analiza pozitivnih i negativnih utjecaja je promatrana kroz koncept ključnih pokazatelja uspješnosti (KPI).Utjecaj BIM-a na uspješnost projekta je procijenjena kroz KPI rangiranje za pozitivne i negativne procjene (Broquetas, 2010).

Rezultati istraživanja pokazuju da korištenje BIM-a najviše pozitivno doprinosi smanjenju troškova, a zatim su podjednako ocijenjeni pozitivni doprinosi smanjenju vremena, unaprjeđenju komunikacije, koordinacije i kvalitete. Iz pregleda negativnih ocjena korištenja BIM-a može se zaključiti da su uvelike manji nego pozitivni no da su problemi u najvećoj mjeri uočeni za izbor/uporabu programskog paketa. Pri korištenju BIM-a uočen je i utjecaj različitih razina korištenja ovog koncepta.

Nekoliko je različitih klasifikacija ovih razina, a nazivaju se „zrelost BIM-a“ (eng. *BIM Maturity Level*). Na području Velike Britanije primijenjena je podjela na 4 razine.

Razina 0 - osnovni crtež u CAD-u, u 2D formatu, razmjena podataka crtežima na papiru ili digitalnoj podlozi.

Razina 1 - složeni crtež u CAD 2D ili 3D formatu s alatima koji osiguravaju suradnju i okruženje koje pruža mogućnost razmjene podataka sa standardiziranim pristupom strukturi i formatu podataka. Poslovnim podacima se upravlja kroz izdvojene financije i paketima upravljanja troškovima bez integracije.

Razina 2 - naprednije 3D okruženje koje se izdvaja u zasebnu disciplinu "BIM" alata s podacima u prilogu. Poslovnim podacima se upravlja kroz planiranje resursa putem programskog paketa i integriranih sučelja ili putem posrednih programskih paketa. Ova razina BIM može koristiti 4D planiranje izgradnje i/ili 5D informacije troškova.

Razina 3 - potpuno integrirana i kroz suradnički proces omogućena 'web usluga' u skladu s razvijajućim (IFC) standardima. Ova razina BIM će koristiti 4D plan izgradnje, 5D informacije troškova i 6D projekt upravljanje životnim ciklusom zgrade.

Osim institucionalne podrške i razvoja alata u istraživačkom sektoru i samo tržište prati razvoj BIM-a i razvija alate za mjerenje njegove učinkovitosti. Projektna i građevinska tvrtka Arup osnovana 1946. godine sa zavidnim kontinuitetom u realizaciji referentnih objekata te kontinuitetom od 25 godina u korištenju BIM-a usmjerila ih je na razvoj svojih alata. Pod nazivom Arup BIM Maturity Measure (Arup BIM mjera zrelosti) alat je razvijen na Sveučilištu države Penn pod licencom Creative Commons 3.0. Alat služi za mjerenje koliko je BIM implementiran u projekt te koliko je uspješan. Alat je dostupan na mrežnim stranicama te zahtijeva samo podršku u obliku programskog paketa Microsoft Excel 2010. Cilj razvoja ovog alata bio je omogućiti brze usporedbe projekta te omogućiti utvrđivanje trendova i potreba. Alat je koncipiran kroz 11 pitanja za koje se nudi izbor od 6 mogućih odgovora koji su pripisani razinama: ne postoji, početna, upravljana, definirana, mjerena i unaprjeđena.

Ono što je podesivo je razina koju želimo dostići i to za svako pitanje na ljestvici od 0 do 5. Projekt ocjenjujemo kroz izbor odgovora također na ljestvici od 0-5. Pridruženi koeficijenti svakom pitanju predstavljaju težinske kriterije koje su autori alata sublimirali iz dosadašnje prakse projekata koji su koristili BIM. Osnovna podjela na discipline je građenje, infrastruktura i savjetovanje. Discipline u odnosu na koje se projekt ocjenjuje

se grupiraju u primarne i sekundarne te postoji izbor između 31 discipline kao što su arhitektura, audio vizualno, energetska učinkovitost, upravljanje troškovima, upravljanje održavanjem, pročelja, voda, elektro instalacije, rasvjeta, planiranje, logistika itd.

4. Primjena BIM-a u projektu izgradnje kamene kuće

Odabran je primjer kuće dalmatinskog zaleđa iz izvora Živković, 2013 kamena kuća u Vinovu Gornjem te su kroz materijale i tehnologiju elaborirana četiri modela sukladno Rapoportovim, 1999, definicijama odnosa prema tradicijskom. U početnoj elaboraciji tradicijskih elemenata smo postavili sljedeća pitanja:

- geometriji: Koliko sklop slijedi principe kompaktnosti kao instrument zaštite od prevelikog osunčanja i izloženosti vjetru?
- otvorima: Što je dominantno u plaštu – otvori ili zid? Koliki je odnos punog i praznog u vanjskom plaštu izražen udjelima? Jesu li u pravilnom ritmu? Jesu li pojedinačno razmješteni ili u nizu?
- istacima: Postoje li? Da li su naglašeni i koja im je funkcija?
- oblozi zida: Na koji način je korišten kamen – plošno ili volumenski? Kakva je tehnologija korištena?
- krovu – nagibu: Kakav je nagib i koliki je izražen u stupnjevima?
- krovu – pokrovu: Koji pokrov je korišten? Kako pokrov odgovara na izloženost vjetru i osunčanju?

Četvrti Rapoportov stav prema tradicijskoj gradnji koji podrazumijeva primjenu više ili manje općih pouka i načela nije primijenjen za modeliranje jer bi promjene zahtijevale opsežnije proučavanje i elaboraciju planiranih promjena. Za takav pristup potreban je multidisciplinaran tim arhitekata, konzervatora, restauratora, projektanata instalacija i drugih struka. Iz tog razloga razvijena su rješenja za izvorno stanje, kopiranje tradicijskog načina građenja, priznavanje, ali nijekanje pouka te na kraju zanemarivanje svih pouka pučke gradnje kamenom. Kako bi koncepti bili jasniji svakom je dodijeljeno kratko ime:

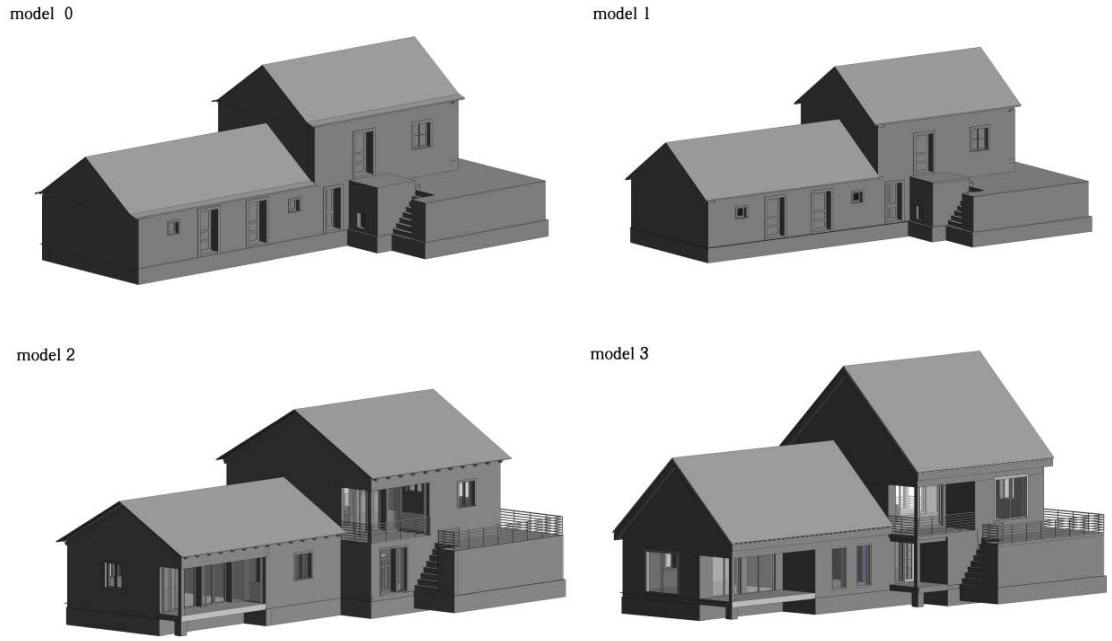
Model 0. Izvorna tradicijska kamena kuća - IZVORNA

Model 1. Pseudo tradicijska kamena kuća - PSEUDO

Model 2. Djelomična tradicijska kamena kuća - DJELOMIČNA

Model 3. Zanemarena tradicija kamene kuće - ZANEMARENA.

Tijekom izrade modela korišten je Autodesk® Revit® Architecture – Building Information Modeling (BIM) softver. Na temelju nacrta i skica početno je definirana geometrija za polazni model. U drugom koraku su mijenjane konstrukcije (temelja, poda, zida, međukatne konstrukcije, krovne konstrukcije i obloge krova) za varijantne modele Pseudo, Djelomična i Zanemarena s pripadajućim promjenama i u geometriji (Slika 1).



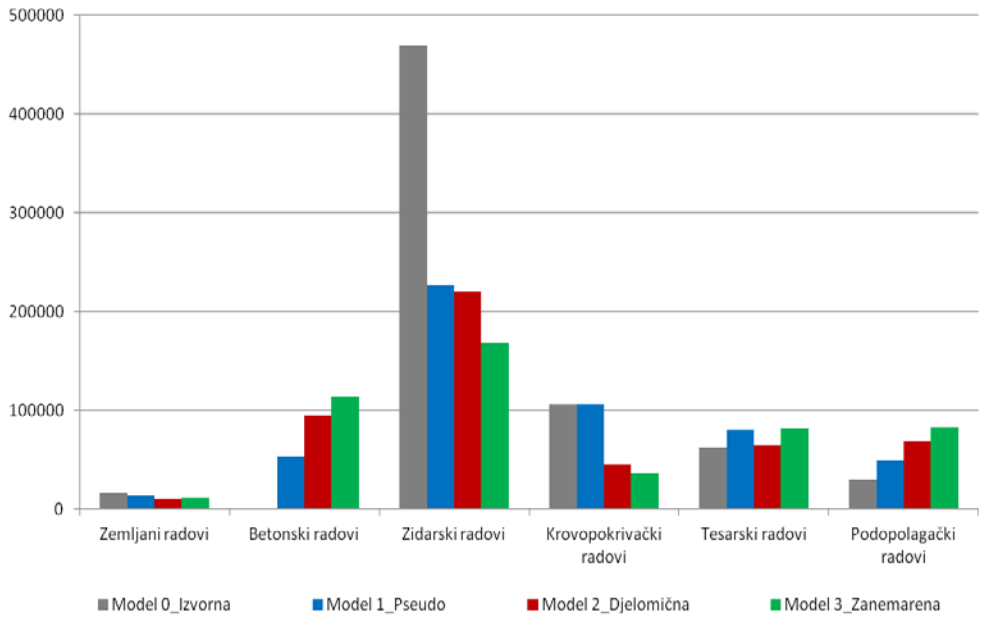
Slika. 1. Prostorni prikaz informacijskih modela kuće dalmatinskog zaleđa Modeli 0,1,2,3

5. Rezultati

Primjenom informacijskog modeliranja u ovom primjeru omogućena je brza izrada varijantnih rješenja te konzekventno i izražavanje podataka za izradu troškovnika i dinamičkog plana kao ključnih dijelova projekta za njegovo vođenje i ocjenu uspješnosti. Usporedbom troškova pojedinih grupa radova po modelima može se potvrditi jasnost i dosljednost arhitektonskih koncepata tj. razlike i gradacija među modelima su potvrđeni i kroz razlike i gradaciju u dimenziji troškova (Slika 2).

Primjenom alata za ocjenu zrelosti BIM-a u projektu dobiven je rezultat koji je ocijenjen kao zadovoljavajući. Ocjenjivao se projekt kao cjelina i njen dio - disciplina arhitekture budući da je bila polazišna za razvoj koncepata. Implementacija BIM-a u cijelom projektu ocjenjena je kroz jedanaest pitanja. Odgovori na jedanaest pitanja odabirom jedne od pet razina upućuju na nisku do srednju razinu BIM-a u ovom projektu. Ostvarena je ocjena 1,22 na razini projekta i ocjena 2,08 u disciplini arhitektura. Ocjena zrelosti BIM-a u dijelu arhitekture veća je za ovu disciplinu te se procjenjuje kao srednja zrelost.

Na razini cjelovitog projekta ističu se tri skupine ocjena:
najviše ocjene (2,4–3) ostvarene su u području izrade 3D modela, vizualizacije i ugovaranja,
srednje ocjene (0,8-1,8) ostvarene su u području planiranja BIM-a, multidisciplinarnosti, te mogućnosti iskorištavanja modela za druga područja (analize, simulacije i slično),
negativne ocjene (0,00) koje ukazuju na odsustvo BIM-a odnose se na vanjske utjecaje kao što su postojanje nacionalnih standarda i normi za klasifikaciju informacija u građevini, zatim projektni početak osnovan na već postojećem obrascu te suradnja s iskusnim BIM stručnjakom.



Slika. 2. Prostorni prikaz informacijskih modela kuće dalmatinskog zaleđa Modeli 0,1,2,3

U disciplini arhitekture ostvarena je prosječna ocjena 2,08 (Slika 3.). Uvidom u pojedinačne ocjene na razini arhitekture uočavaju se najviše ocjene postignute u području izrade 3D modela (2,70), konzistentnosti s 2D crtežima (2,70) te iskorištavanje modela za vizualizaciju (3,50). Budući da je zadatak uključivao izradu i 4D modela, a izrađen je i 5D model, za ove elemente su također ostvarene najveće ocjene (3,50 i 2,80). Prema tome možemo zaključiti da je BIM korišten u zadovoljavajućoj mjeri prema postavljenom zadatku.

1	EIRs	0,80
2	BIM Data Review	2,70
3	BEP	1,80
4	Procurement	2,40
5	CDE	0,00
6	Version, Status	0,00
7	Marketing Strateg	0,00
8	VDRs	3,00
9	Open Standards	1,80
10	BIM Contract	0,90
11	BIM Champion	0,00

3D Model	2,70
Drawings	2,70
LoD	1,00
Reviews	1,00
Data	1,00
Visualisation	3,50
4D (time)	3,50
5D (cost)	2,80
Analysis	2,00
Contractor Use	1,80
FM/OM Use	0,90

Slika. 3. BIM Maturity Measure Ver by Arup

Srednje ocjene u disciplini arhitekture ostvarene su u području analize i mogućnosti korištenja modela prilikom ugovaranja. Budući da zadatak nije obuhvatio ova područja, ostvareni modeli su samo procijenjeni u kojoj se mjeri mogu dalje primijeniti. Procjena je da se modeli moraju malo ili srednje doraditi ukoliko bi se koristili za analize (npr. statička analiza, energetska učinkovitost, osunčanje i slično). Ocjene od 0,8 do 1 u pitanjima o detaljnosti pridruženih informacija, kontinuitetu u multidisciplinarnoj provjeri modela i iskoristivost pridruženih informacija ukazuju na nižu razinu BIM-a u ovim područjima što je posljedica ograničenja zadatka.

6. Zaključak

U radu se analizirao pristup različitim razinama interpretacije tradicijske arhitekture dalmatinskog zaleđa informacijskim modeliranjem 5DBIM modela. U ovom radu je postavljena metodologija na način da se izmjena elemenata tradicijske kamene kuće pratila vizualno, troškovno i vremenski kroz različitu razinu interpretacije tradicijske arhitekture razmatranog podneblja. Iz rezultata ovoga rada možemo zaključiti kako ovakav pristup omogućava brzu izradu varijantnih rješenja, boljem snalaženju prilikom izrade varijanti, kontinuiranoj provjeri dosljednosti primijenjenog teorijskog okvira, a u konačnici i boljoj procjeni rezultata. BIM modeliranje je također omogućilo i brzi prijenos informacija potrebnih za izradu troškovnika i dinamičkog plana, odnosno 5D modela. Primjena BIM koncepta na ovom primjeru ukazuje na to da ovaj novi koncept može svoj doprinos naći i u području promocije tradicijskih vrijednosti arhitekture te njihovo argumentirano zagovaranje. Procjena BIM koncepta kroz preuzetu aplikaciju ukazuje na slabosti okruženja, nedostatak nacionalnih standarda, normi te potrebu za normativnim pristupom prvenstveno na nacionalnoj razini kako bi se omogućilo brzo i učinkovito širenje novog koncepta čije se doprinose snažno zagovara.

Zahvala

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Utjecaj tehničke dijagnostike i održavanja na troškove građevinske mehanizacije

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Sažetak

Članak daje pregled potrebnih postupaka održavanja standardne građevinske mehanizacije. Aktivnosti održavanja provode se ovisno o rezultatima ispitivanja i propisanim obvezama, kao i potrebama njihovog vlasnika. Opisani su mogući oblici organizacije obavljanja tih poslova i odlučivanje o ulaganju u održavanje i obnovu strojeva. Zato se analizira utjecaj održavanja i neodržavanja na učinak i sigurnost rada te direktne i indirektne troškove strojeva.

Ključne riječi: strojevi; održavanje; organizacija; troškovi; učinak; sigurnost

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1. Uvod

Tehničke karakteristike strojeva mijenjaju se tijekom njihovog uporabnog vijeka. Smanjuje im se radna sposobnost, odnosno prosječni učinak i kvaliteta izvedenih radova, te povećava potrošnja goriva i maziva itd. Na to utječu i uvjeti rada i ljudski faktor, dok se negativne posljedice vremena rada strojeva umanjuju s odgovarajućim održavanjem (Ilustracija 1).

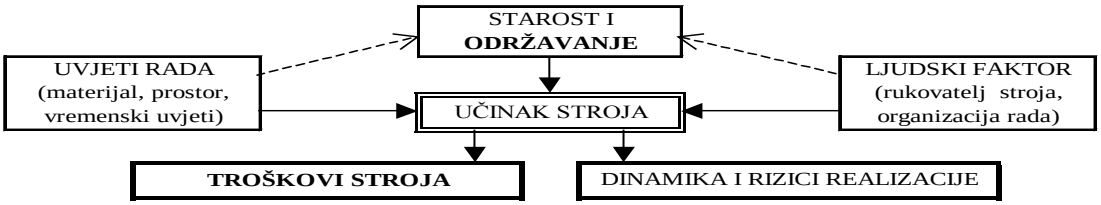
Održavanje se, općenito, definira kao provedba mjera kako bi stroj ili postrojenje dobro funkcioniralo, a pod čim se podrazumijeva dovoljno sigurno i pouzdano obavljanje svih zadataka. Održavanje građevinskih strojeva i postrojenja su pomoćni tehnološki procesi, nužni da osiguraju nesmetano odvijanje glavnih procesa građevinske proizvodnje. Značaj održavanja raste sa složenosti mehanizacije i važnosti projekata na kojima se radi.

Održavanje mehanizacije u poduzećima za izvođenje građevinskih radova ima neke specifičnosti u odnosu na druge djelatnosti, od kojih neke koriste čak i istu vrstu strojeva. Također, postoje razlike između organizacije održavanja strojeva na gradilištima i u centralnim građevinskim pogonima (betonarama, asfaltnim bazama, drobilanama i dr.), gdje je prema uvjetima i organizaciji proizvodnja sličnija industrijskoj.

Mehanizirani radovi, uobičajeno se većim dijelom nalaze na kritičnom putu realizacije građevinskih projekata, te imaju veliki udio u troškovima grubih građevinskih radova, pogotovo u niskogradnji. Uvijek se nastoji što više izbjeći zastoje i opadanje produktivnosti kako se ne bi probio planirani rok i da ne dođe do dodatnih troškova (troškova nekvalitete), a u tome treba pomoći pravilno i pravovremeno održavanje mehanizacije i druge opreme.

Mora se imati u vidu povezanost održavanja mehanizacije sa sigurnosti na radu i stoga podzakonski akti propisuju za to obvezne radnje. Posebno opasni strojevi, kao što su primjerice dizalice, smiju se koristiti samo ako su u mehanički savršenom stanju, pa se moraju kontinuirano pregledavati i održavati.

Ilustracija 1. Utjecaji na učinak i troškove građevinske mehanizacije



2. Zadaci službe održavanja mehanizacije

Održavanjem se uz propisane radne uvjete (sigurnosne zahtjeve) treba osigurati što manje zastoja u radu, odnosno maksimalnu raspoloživost uz minimalne troškove. Cilj je povećati učinak i pouzdanost strojeva sprječavanjem kvarova i njihovim što bržim otklanjanjem, a održavanjem se i produžava ekonomski i tehnički vijek uporabe. Održavanje obuhvaća niz radnji kojima se obavljaju primarni i sekundarni zadaci navedeni u tablici 1.

Tablica 1. Primarni i sekundarni zadaci održavanja građevinskih strojeva

Primarni zadaci	Sekundarni zadaci
1. Nadzor – kontrolni pregledi, podešavanja, čišćenja, pranja i podmazivanja	1. Definiranje zahtjeva glede održavanja kod nabave nove mehanizacije i rezervnih dijelova i potrošnog materijala
2. Tekuće održavanje strojeva, uređaja i postrojenja u uporabi (zamjena istrošenih dijelova, reparacija)	2. Smanjenje buke i postizanje drugih zadovoljavajućih radnih uvjeta (zrak i dr.)
3. Popravci – otklanjanje kvarova	3. Briga za zaštitu okoliša
4. Rekonstrukcija (modifikacija) postojećih strojeva	4. Osiguranje propisanih sigurnosnih mjera

Osim navedenoga u tablici 1, službe održavanja u poduzećima zadužene su i za razradu metodologije održavanja, izradu planova održavanja, iskorištavanje rezervnih dijelova s otpisanih strojeva, obuku zaposlenika koji koriste mehanizaciju itd [Kondić i dr., 2011].

S održavanjem je povezano i uhodavanje novih strojeva i onih koji su bili na remontu, što povoljno utječe na pouzdanost, učinak i njihov uporabni vijek. Razrada strojeva (oko 100 sati) provodi se postepenim opterećivanjem kako bi se postiglo dobro međusobno nalijeganje kontaktnih površina, uz učestaliju dopunu i zamjenu radnih fluida [Todosijević i dr., 2005].

Sposobnost održavanja općenito se tumači kao mogućnost ili vjerojatnost da će neki tehnički sustav na kojem se (u slučaju kvara) obavlja zahvat održavanja biti za određeno vrijeme ponovo doveden u radno stanje, odnosno da se neće kvariti. Na sposobnost održavanja utječu: pristupačnost, preglednost, zamjenjivost i međuzamjenjivost komponenti, kao i opremljenost i stručnost i uvježbanost zaposlenika [Vidaković i dr., 2009]. Zato suvremena građevinska mehanizacija ima niz tehničkih rješenja za brzo i jednostavno održavanje, kao npr. lagani pristup elementima koji se često održavaju, sustave samopodmazivanja, senzore za kontrolu stanja itd.

3. Proces održavanja građevinskih strojeva

Definiranje procesa održavanja mehanizacije sastoji se od određivanja organizacijske strukture i nadležnosti te definiranja programa održavanja za svaki pojedini stroj [Kondić i dr., 2011]. Održavanja mehanizacije obavlja se prema sljedećem redoslijedu:

- pregledi (profilaktičke mjere),
- aktivnosti koje se obavljaju dok još nije nastupio kvar (zamjene dijelova i dr.),
- popravljanje kvarova do kojih dođe pri radu (defekt, lom nekog dijela i dr.).

3.1. Periodični postupci održavanja

Održavanje građevinske mehanizacije u odnosu na nastanak kvarova može biti korektivno i preventivno.

Korektivno održavanje je interveniranje radi otklanjanja iznenadnih kvarova, a pri tome je uvijek bitno otkloniti uzroke koji su doveli do njihovog nastanka. To može biti zamjenom pojedinih dijelova stroja (novim, popravljenim, obnovljenim ili drugim) ili popravcima (podešavanjem, podmazivanjem, čišćenjem i drugim postupcima) [Adamović i dr., 2008].

Preventivno održavanje u pravilu se radi prema nekom utvrđenom planu. Prema tehnološkoj namjeni plansko održavanje obuhvaća razne kontrolne preglede (tehnička dijagnostika), čišćenje i podmazivanje, traženje i otklanjanje slabih mjesta i planske popravke (male, srednje i velike). Ono ima preventivni karakter, jer sprječava neispravnosti i smanjuje pojavu kvarova pri radu.

Kontrolne održavateljske radnje na gradilištu trebaju se obavljati u tri koraka:

- priprema kontrole (pazi se na poštivanje svih mjera zaštite na radu)
- kontrola na nižoj razini (čistoća, provjera da je Priručnik za rad i održavanje u kabini)
- kontrola na višoj razini (provjera i zamjena elemenata stroja prema Priručniku).

Preventivne mjere mogu se poduzimati na osnovu određenog broja sati rada ili kalendarskog roka (tamo gdje je trošenje podjednako i kada se radi i kada se ne radi) ili prema rano upozoravajućim indikatorima mogućih grešaka i zastoja dobivenih provjeravanjem

postojećeg stanja i radnih performansi stroja (tzv. prediktivno održavanje). Potonji način održavanja smatra se najnaprednijim i prevladava u suvremenom poslovanju. Na održavanje mehanizacije prema stanju nadovezuje se proaktivni pristup gdje se tehničkom dijagnostikom uz provjeru ispravnosti i radne sposobnosti istražuje i mjesto, oblik i uzrok kvara. Redovnim pregledima s tehničkom dijagnostikom i održavanjem u skladu s Priručnikom za rad i održavanje stroja pravovremeno, dok još nije došlo do otkaza u radu, locira se i rješava moguće probleme. Tako se smanjuju vlasnički troškovi i troškovi rada [Caterpillar, 2010], obzirom da se izbjegava šteta do koje dolazi kada se rad prekida zbog kvara. Preventivno, a pogotovo prediktivno održavanje u raznim djelatnostima je pokazalo da dovodi do znatnog smanjenja potrebne količine rezervnih dijelova i smanjenja zastoja, te povećanja produktivnosti i dobiti [Adamović i Ilić, 2013].

Suvremeni, vrijedniji strojevi s računalima i GPS-om daju podatke o lokaciji i o broju radnih sati, te na osnovu toga upozoravaju što i kada sljedeće na njima treba servisirati. Također, često sami pružaju informacije o svojoj djelotvornosti i uzrocima njenog pada.

Daljnji razvoj održavanja omogućava *Internet of Things*. To je tzv. *Prognostic* pristup koji daje objektivnu procjenu budućeg stanja tehničkih sustava za tjedan do mjesec dana (izuzetno do 1. god.), utemeljenu na velikim bazama podataka [Heggemann i von Plate, 2015].

Neke provjere stanja (istrošenosti) obavljaju se samo vizualno, najobičnijim dodirom prstiju i osluškivanjem, a za neke pokazatelje (vibracije, pritisak, viskoznost itd.) potrebna su mjerenja s odgovarajućim prijenosnim ili ugrađenim instrumentima (brojila, termometri, manometri itd.) kojima se utvrđuje stanje pojedinih komponenti strojeva bez rasklapanja. S uređajima ugrađenim u stroj dijagnostika je permanentna (*on-line*) i ne mora se zbog nje prekidati rad, a s priključnim sustavima i raznim inteligentnim alatima je povremena (*off-line*) i stroj se nekada treba isključiti iz radnog procesa. Npr. kod Caterpillarovih strojeva svakih 250 i 500 radnih sati u različitim dijelovima uzima se ulje za ispitivanje sastava (Cu, Fe, Cr, Al, Si, Pb, Mo, Na, H_2O, antifriz i dr.) i prema tome se određuju potrebni zahvati.

U nekim slučajevima propisano je da tehničku dijagnostiku moraju obavljati stručni organi vlasti i ovlaštene ustanove ili trgovačka društva (npr. kod vozila za transport po javnim prometnicama). Angažiranje specijaliziranih stručnjaka izvan poduzeća vlasnika strojeva u pravilu je skuplje nego korištenje vlastitih zaposlenika, ali vanjski suradnici u pravilu su bolje opremljeni i kompetitivniji, a i objektivniji su. Ovlaštenje za ispitivanje strojeva i uređaja s povećanim opasnostima može dobiti samo poslodavac koji ima odgovarajuću tehničku opremu i zaposlene stručnjake tehničkog smjera (minimalno jednog iz strojarstva i jednog iz elektrotehnike) s položenim stručnim ispitom iz zaštite na radu [Pravilnik, 2003].

Sam rukovatelj stroja pregledava svoj stroj svakodnevno prije početka rada. Nakon 50 (tjedno), 100, 200, 250 (mjesečno), 500, 1000, 2000 (godišnje), 3000 sati rada i u drugim od proizvođača naznačenim periodima (Tablica 2), koji donekle ovise i o uvjetima rada, ili nakon određene količine proizvodnje, obavljaju se pregledi bez rasklapanja, čišćenja i mali popravci, podmazivanja, zamjene i dopune pojedinih elemenata i podešavanja (npr. pritezanje vijaka) u kojima uz rukovatelja stroja učestvuju i mehaničar i vanjski suradnik (od strane prozvođača stroja, ako se želi zadržati garancija).

Tablica 2. Pregledi i druge održavateljske radnje prema učestalosti (analizom 7 standardnih građevin. strojeva)

Svaki dan prije rada	Svakih 50 (i 100) h	Svakih 200 - 250 h	Svakih 500 h	Svakih 1000 - 2000 h
Kontrola sigurnosnog pojasa, razine rashladne tekućine i ulja, podvozja, kočionog sustava, upravljačkog mehanizma, uređaja za dizanje i manipulaciju tereta, signal. uređaja, noževa radnog alata (**zamjena prema potrebi**) i dr. **Podmazivanje** glave cilindra, polužja kraka, strijela i radnog alata i dr. **Vanjska čišćenja i pritezanje veza**	**Kontrola** sklopa za upravljanje, parking kočnica, pritiska u gumama, začepljenja filtera, svih spojeva na konstrukciji i dr. **Ispuštanje** vode i taloga iz spremnika za gorivo **Podmazivanje** ležajeva, brze spojnice i dr. **Čišćenja** i **zamjena** filtera za zrak u kabini, zamjena filtera za ulje hidrauličkog sustava (nakon 100 h)	**Kontrola** crijeva rashladnog sustava, stepenica/penjalica i ograde, pričvršćenja čelične užadi, krajnjih isključivača visine kuke, tereta, vitla, kliznih vodova, koloture i dr. **Čišćenje** kondenzatora, odušnice osovine rashladnih lamela i dr **Zamjena** motornog ulja i filtra, te remenja po potrebi **+ sve radnje kao i nakon 50 tj. 100 h**	**Kontrola** zazora ventila motora **Čišćenje** odušnika kartera motora, poklopca spremnika za gorivo i sita **Zamjena** motor. ulja i filtera **Sevis** klima uređaja **+ sve radnje kao i nakon 200 - 250 h**	**Kontrola** zaštit. konstrukc. protiv prevrtanja (ROPS), sklopa nosača vitla i varova čelične konstrukcije **Zamjena** ulja (u transmis., diferenc. i pogon. sklopu i hidraul. sustavu) i rashlad. sredstva, odušnika kartera motora (2000 h), usis. sita, sušila rashladnog sustava, maziva u ležajevima **Čišćenje** akumalotora, magnet. filtra, mrežice filtera za zrak, sigurnos. odušnih ventila, mrežice za dovod vode u regulator na motoru **+ sve radnje kao i nakon 500 sati rada**

Srednje popravke uz čišćenja i podmazivanja obuhvaćaju zamjenu istrošenih dijelova stroja i druge radnje predviđene godišnjim planom održavanja, a period za koji se planiraju odnosi se isključivo na određeni element. Kod srednjih popravaka stroj se ne rastavlja cijeli, nego samo pojedini sklopovi, te je vrijeme koje je izvan uporabe znatno kraće nego kod generalnog održavanja [Adamović i Ilić, 2013]. Poslije njih smatra se da je stroj sposoban za rad obzirom na zamjenjeni dio u istom periodu kao i prije popravka.

Popravci velikog obima, tj. generalni remonti, trebali bi se obavljati nakon određenog vremena, bez obzira dali je došlo do kvara, a ciklusi u kojima se obavljaju ovise o vrsti i konstrukciji stroja, kvaliteti materijala, te režimu rada i često su određeni od proizvođača. Ovakvi veliki popravci podrazumjevaju potpuno rasklapanje stroja, pregled i selekciju elemenata na one koji se mogu i dalje koristiti, one koji su za reparaciju i one koji se moraju zamjeniti. Tehnički postupak remonta ovisi od karaktera utvrđenih oštećenja. Nakon čišćenja, popravki i zamjene dijelova, te sveg drugog što je potrebno, prije montaže stroja obavlja se probno ispitivanje njegovih komponenti, a nakon montaže slijedi probni rad. Za remont su potrebni dobro opremljeni pogoni, s uvjetima sličnim kao za prozvodnju novih strojeva, pa ga je najbolje obavljati kod njihovih prozvođača [Todosijević i dr., 2005]. Generalno obnovljeni strojevi trebali bi se u radu ponašati kao novi ili barem skoro kao novi, a kod većih ulaganja u obnovu i rekonstrukciju može se postići da su u nečemu i bolji nego što su bili kao novi.

3.2. Organizacija održavanja u građevinskim poduzećima

Planiranje održavanja strojeva i postrojenja temelji se na poznavanju svih bitnih podataka o njima (podaci o uporabi, funkcioniranju i upravljanju, obavljenim popravcima, načinu transporta, konzerviranja, priboru i rezervnim dijelovima, upute za podešavanje, održavanje i podmazivanje, ispitne karte strojeva, normativi za poslove održavanja i dr.) [Kalinić, 2005]. Mogući načini organizacije službe održavanja mehanizacije u građevinskom poduzeću i njihove karakteristike navedeni su u tablici 3.

Tablica 3. Organizacije održavanja građevinske mehanizacije i njihove karakteristike

Način organizacije	Karakteristike održavanja i preporučeni slučajevi za primjenu
Centralizirano	Samo jedna služba održavanja, koja djeluje vrlo kvalitetno (uigrani zaposlenici, lagano prikupljanje i obrada podataka), ali problem može biti u lošijoj povezanosti sa svim mjestima potrebe (slabo praćenje i reagiranje na iznenadne kvarove). Veća poduzeća najčešće imaju servisnu radionicu s alatnicom na svom centralnom pogonu, gdje im je smješten i strojni park.
Pojedinačno (decentralizirano)	Služba održavanja je na svakom gradilištu s mehanizacijom za koju treba osigurati odgovarajuće radionice za održavanje, prema vrsti i broju strojeva. Rijetko ima za to dovoljno stručnih djelatnika, a multiplicirana oprema vjerojatno će biti slabije iskorištena. Obično se organizira samo za neka veća, izdvojena gradilišta.
Kombinirano tj. centralizirano s dislociranim grupama za održavanje	Gradilišta imaju male službe za održavanje (dobro poznaju stanje strojeva i brzo reagiraju), a u slučaju kompliciranijih intervencija djeluju stručnjaci iz centralnog odjela. Investicijsko održavanje u pravilu se obavlja u posebnoj radionici ili servisu, a tekuće se odvija na samom gradilištu. Na strojevima je niz elemenata za koje se teško može točno predvidjeti vrijeme trajanja i u pravilu se mijenjaju kroz sitnije poravke kada se pokvare, pa treba postojati stručno osoblje koje će ih u najkraćem roku kvalitetno osposobiti za rad.
Kooperativno (outsorcing)	Održavanje je u potpunosti ili djelomično povjereno vanjskim specijaliziranim službama, često i od proizvođača. To je dobro za mala poduzeća koja nemaju potrebne stručnjake. Slična je situacija i kada se unajmi mehanizacija, pa o njenom održavanju brine vlasnik.

Obzirom da su građevinski radovi često sezonski, veće zahvate održavanja pogodno je planirati u mjesecima s manjim brojem radnih sati, što je uglavnom zimi.
Organizacija tehničkog održavanja uvijek treba biti usklađena sa strojnim parkom (sastavom tj. brojem, vrstama i rasporedom) i treba biti fleksibilna zbog čestih promjena zadataka koje mora ispuniti [Adamović i dr., 2008].

Dok je pristup održavanju s gledišta pouzdanosti u potpunosti spriječiti kvarove i njihove posljedice – bez obzira na visinu troškova, terotehnološki pristup je minimizirati ukupne troškove održavanja – no to znači i tolerirati određene kvarove. Terotehnološki pristup nalaže da se razradi vremenski plan održavanja s potrebnim rezervnim dijelovima i ostalim materijalima za održavanje, te u skladu s tim organizira odgovarajuće obučena radna snaga. Uz tablice s periodima za potrebna održavanja na određenim strojevima, po svim elementima, koje daju njihovi proizvođači, kao pomoć korisnicima služe sheme održavanja s naznačenim mjestima potrebnih održavateljskih aktivnosti. Iako bi se moglo koristiti i druge vrste vremenskih planova (npr. ciklograme i gantograme, pa i mrežne planove za velike remonte) u našoj praksi su gotovo isključivo tabelarno-brojčani [Vidaković i Bubalo, 2015].

Izbor načina organizacije održavanja u poduzeću osim o broju i vrstama strojeva i ostalim tehnološkim mogućnostima, ovisi o zahtjevima i uvjetima realizacije projekata, a u pravilu se bira prema kriterijima nižih troškova i veće pouzdanosti.

Efikasnost službe održavanja uvelike ovisi o razmjeni informacija (komunikaciji) svih sudionika održavanja (rukovatelja stroja, mehaničara vlastite službe održavanja, ugovornog vanjskog suradnika u održavanju), kao i interne nabave i dobavljača – proizvođača dijelova i novih strojeva. Uspješnost održavanja pokazuje prosječno trajanje zahvata i niz indeksa (omjer ukupnih troškova održavanja i vrijednosti izvedenih radova, ukupnih troškova održavanja i ukupnih proizvodnih troškova, ukupnih troškova održavanja i ulaganja u mehanizaciju, vremena preventivnog održavanja i sveukupnog vremena održavanja, vremena zastoja zbog kvarova i trajanja svih zastoja itd.) [Lacković, 2015].

Za poslove ispitivanja strojeva s povećanim opasnostima mora se izraditi poslovnik o postupcima, uvjetima i metodama tih ispitivanja (u skladu s ISO 10013) i o tome obvezno sastaviti zapisnik (Pravilnik, 2003). U cilju čuvanja i prenošenja informacija o strojevima vodi se odgovarajuća dokumentacija, kao što je strojna knjiga, kontrolna knjiga održavanja, matična knjiga, kolna knjiga i dr. Sve aktivnosti održavanja na strojevima i svi zastoji u radu, bez obzira na to je su li posljedica planiranog zahvata održavanja ili ih je uzrokovao kvar, pismeno se evidentiraju.

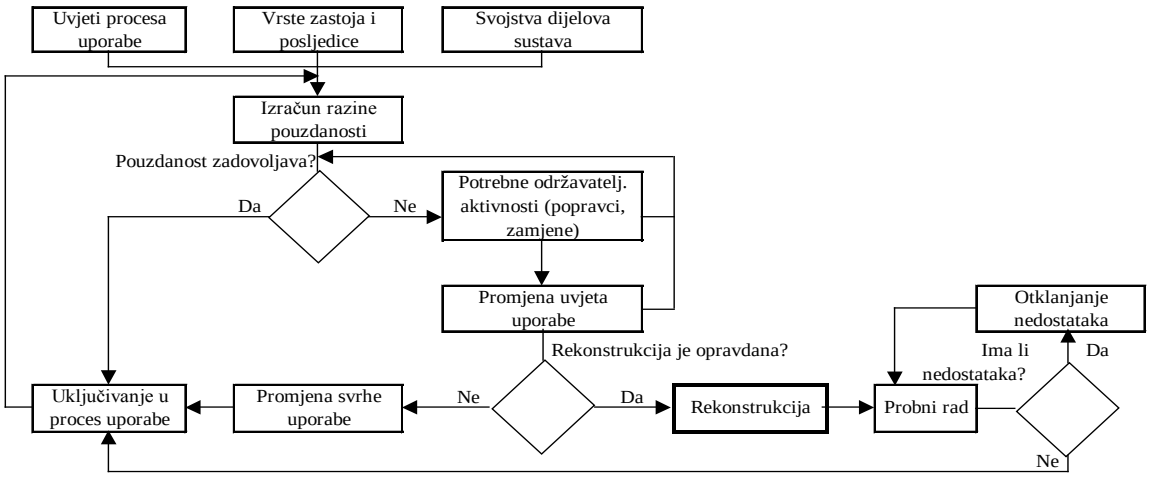
3.3. Odlučivanje o održavanju strojeva

Odlučivanje o održavanju treba biti u skladu s potrebama i tehničkim mogućnostima poduzeća i na osnovu analize troškova i pouzdanosti (Ilustracija 2), ali i ponude tržišta. Bitno je donošenje odluka kod kupnje nove mehanizacije (obzirom na svojstva u svezi održavanja), kao i kod ulaganja u preventivno održavanje i u veću obnovu i rekonstrukciju.
Zbog nedostatka novca za investicije nerijetko se koriste i 20-tak godina stari strojevi za čiji rad je izuzetno važno kako se održavaju i kada se obnavljaju. Isplativost generalnih obnova upitna je obzirom na mogućnosti stroja, napredak tehnologije i cijenu nove mehanizacije. Da bi se dokazala opravdanost takve odluke treba uzeti u obzir utjecaj na produktivnost i konkurentnost, te napraviti kalkulaciju svih troškova i višekriterijsku analizu mogućih izbora.

Za uporabu strojeva od primarne je važnosti koliko su pouzdani, odnosno kolika im je sposobnost (vjerojatnost) rada bez kvarova (učestalost kvarova je statistička veličina). Kod održavanja prema pouzdanosti odluke o zahvatima održavanja donose se na osnovu tijekom rada stalnog prognoziranja stanja, odnosno pojave kvarova koje treba izbjeći (Ilustracija 2).

Ilustracija 2. Odlučivanje o uporabi i obnovi strojeva na osnovu praćenja pouzdanosti

Najbolje je razviti strategiju održavanja koja se temelji na integralnom stanju strojeva dobivenog sveobuhvatnom procjenom. Obzirom da na stanje strojeva uz inherentno ¨zdravlje¨ (tehnička degradacija koju pokazuju senzori suvremenih strojeva) utječu i neki drugi



čimbenici (ne-tehnički), najnovije tendencije su u definiranju modela procjene stanja koji će uzimati u obzir za odlučivanje o održavanju i čimbenike kao što su starost stroja, radni uvjeti i obavljano održavanje. Takva strategija treba biti podloga za upravljanje stanjem strojeva i donošenje odluka o njihovom održavanju [Lu i dr., 2014].

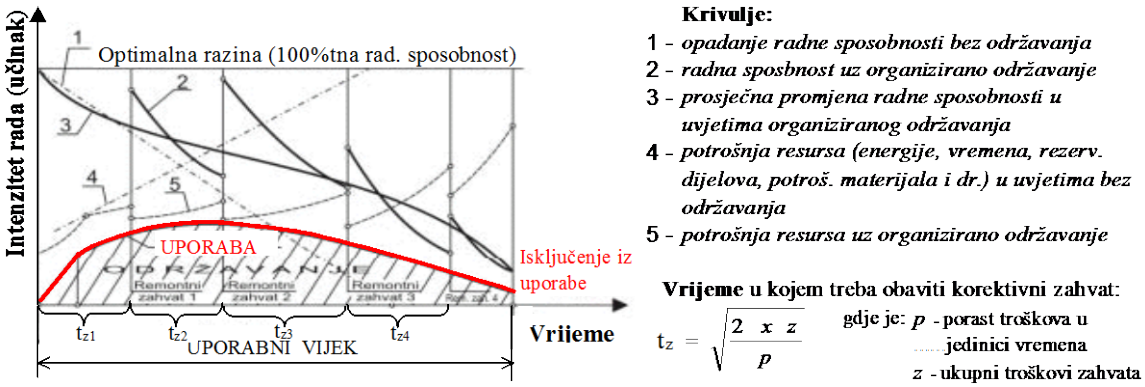
4. Povezanost održavanja i radne sposobnosti mehanizacije i posljedični troškovi

4.1. Utjecaj održavanja na učinak strojeva

Svaki tehnički sustav od prvog puštanja u pogon s vremenom ima smanjenje djelotvornosti i povećanje troškova uporabe. Ukoliko izostanu korektivni zahvati, djelotvornost tijekom uporabnog vijeka (habanjem i drugim oštećenjima) sve više opada, a rast troškova je sve veći. Krivulja radne sposobnosti na ilustraciji 3 pokazuje kada je opravdano poduzimati planske zahvate na strojevima radi povećanja njihove radne sposobnosti. Bez generalnog remonta nikada se ne može potpuno vratiti početna djelotvornost, a kada se nakon duže uporabe i većeg broja remontnih zahvata na stroju više ne može povratiti dovoljna radna sposobnost i sigurnost onda ga treba isključiti iz uporabe (otpisati).

Ilustracija 3. Krivulja radne sposobnosti strojeva (prema Kondić i dr., 2011; Vidaković i dr., 2009)

Troškovi održavateljskih zahvata proporcionalno rastu s intenzitetom održavanja (pravac), dok pri tome opadaju troškovi zastoja do kojih bi došlo zbog kvarova (po hiperboli) [Clutts, 2010.; Kalinić, 2005]. Korektivni zahvati održavanja uzrokuju skokovit porast troškova nakon



kojeg oni ponovo počinju teći kao ispočetka. Ukupni troškovi su zbroj troškova zahvata i zastoja, pa se traži intenzitet održavanja gdje krivulja ukupnih troškova ima minimum. Iz toga proizlazi da ih treba poduzeti kada kumulativni porast troškova iskorištavanja dosegne veličinu direktnih i indirektnih troškova predstojećeg zahvata (t_z na ilustraciji 3).

Održavanje, odnosno neodržavanje, građevinske mehanizacije preko kvarova i zastoja uvjetuje mogućnosti rada s njom. Obzirom na (ne)ispravnost strojeva moguća su dva stanja:

- Ispravno – uporaba, čekanje na uporabu, čuvanje, transport, preventivno održavanje;
- Neispravno – rad sa smanjenim učinkom i sigurnošću (ako može), čuvanje, transport, korektivni popravci.

Sve to utječe na dinamiku izvođenja radova, pa da bi vremensko planiranje bilo realno treba uzeti u obzir neizbježne i prosječne zastoje zbog kvarova i održavanja.

Utjecaj održavanosti na planski učinak svakog pojedinog stroja obračunava se u njegovom izračunu množenjem s koeficijentom dotrajalosti (negdje nazivan i koeficijent spremnosti ili gotovosti ili eksploatacijske pouzdanosti), koji je jedan od općih koeficijenata korekcije teorijskog učinka. Ovaj koeficijent se može izračunati iz odnosa učestalosti kvarova i učestalosti popravaka stroja. Prema nekim internim normativima uzima se da je 1,0 kada je stroj nov, odnosno ima do 2000 radnih sati, 0,91 ako je stroj očuvan, a 0,8 ako je dotrajao, odnosno ima preko 4000 radnih sati [Linarić, 2006]. No, bolje održavanje tijekom uporabe svakako će povećati njegove vrijednosti i zato ga treba odrediti za svaki konkretni stroj.

Od primjerenog održavanja mehanizacije očekuje se i da poveća motivaciju zaposlenika za rad [Adamović i dr., 2008], odnosno da spriječi njeno snižavanje zbog neispravnosti i nezgoda do kojih dolazi ako takvo održavanje izostane.

4.2. Troškovi održavanja i neodržavanja strojeva

U praksi se troškovi mehanizacije nerijetko sagledavaju nepotpuno, samo u fazi nabave i za pogonsko gorivo i mazivo, a onda se poslije događa da ostali troškovi imaju efekt ¨ledenog brijega¨, odnosno da su stvarni znatno veći od očekivanih [Blanchard, 1981]. To je zato jer se zanemaruje ostale, neizbježne troškove logističke podrške – troškove dokumentacije, transporta, obuke zaposlenika, cjelokupnog održavanja s tehničkom dijagnostikom (npr. usluge ispitivanja od vanjskih službi) i rezervnim dijelovima, te otpisa.

Troškovi održavateljskih aktivnosti uobičajeno se dijele na:

- fiksne i promjenjive troškove;
- direktne i indirektne troškove;
- troškove tekućeg i investicijskog održavanja.

Fiksni troškovi su bruto plaće vlastitih zaposlenika na održavanju, troškovi energije za osvjetljenje, zagrijavanje i ostalo potrebno za mjesta rada (radioničke prostorije).
Promjenjivi troškovi su troškovi rezervnih dijelova i potrošnog materijala, nabave novih alata i uređaja za održavanje, obučavanja zaposlenika, radioničko-tehnološke dokumentacije itd.

Direktne troškove održavanja čini sve što je izravno povezano s fizičkim izvršenjem radova održavanja – trošak ljudskog rada (bruto plaće) za sve preventivne i korektivne aktivnosti održavanja i trošak za to iskorištenih materijala (dijelovi koji se mijenjaju, materijali za čišćenje, brušenje, antikorozivna zaštita, konzerviranje itd.), te trošenje alata i nadopuna ispražnjenih medija (tehničkih tekućina).

Indirektnim troškovima održavanja smatraju su dodatni troškovi (štete) zbog neplaniranih zastoja uzrokovanih nekim kvarom, kada se gubi zbog nerada ili smanjene produktivnosti (npr. brzine) mehanizacije, zbog pada u kvaliteti izvedenih radova i povećanog opsega oštećenja na strojevima uslijed kvarova (tzv. troškovi neodržavanja). Računaju se ili kao izgubljena dobit ili kao troškovi stroja u stajanju (najčešće kao dnevna cijena zaustavljenog stroja). No, zastoj jednog stroja ili postrojenja na gradilištu, uz obično neiskorišteno radno vrijeme njegovog rukovatelja, može dovesti do prekida u radu ili rada sa smanjenim učinkom drugih proizvodnih čimbenika koji djeluju povezano tj. u tehnološkom lancu.

Neka detaljnija razmatranja troškova mehanizacije uz direktne troškove posebno izdvajaju povremene (npr. obnova) i tzv. kolateralne troškove, kao što su npr. inflacija, troškovi kapitala (s posjedovne strane), zastarjevanje, neuspjeh u radu i dr, ali njih je najteže kvantificirati i ne sadrže ih svi modeli za procjenu troškova [Zane, 1998].

Održavanje građevinskih strojeva i postrojenja po načinu financiranja, a i za neke obračune troškova, dijeli se na investicijsko i tekuće. Pod prvim se podrazumjeva redovito održavanje pomoću kojega se strojevima omogućuje da budu efikasni u cijelom predviđenom vijeku uporabe. Investicijsko održavanje u najvećoj mjeri čine veliki i srednje veliki popravci. Tekuće održavanje odvija se na gradilištu, odnosno na samom mjestu rada, ali nekada i u radionici. U njega se ubrajaju manje, rutinske popravke i dnevno servisiranje strojeva (navedeno u tablici 2), pa i kontrola pravilnosti uporabe. U pravilu ne zahtjeva puno vremena, a u njegovo obavljanje uključeni su rukovatelji strojeva i najčešće vlastiti mehaničari.

Troškovi osnovnog, srednjeg i velikog održavanja zavise od vrste stroja, a posebno je izražena razlika prema tome dali je stroj stacionaran ili transportni. Postoji velik broj metoda za prognoziranje troškova održavanja strojeva, od kojih je najveći dio empirički [Clutts, 2010; Zane, 1998]. Jedan vrlo jednostavni obrazac za orijentacijski izračun tih troškova na godišnjoj razini, u ovisnosti od obračunske cijene stroja (C), koja predstavlja tvorničku cijenu uvećanu za troškove nabave i dopreme, pokazan je u tablici 4.

Tablica 4. Orijentacijski proračun godišnjih troškova održavanja [Mirković, 2005]

Tip stroja	Osnovno održavanje (kn/god)	Srednje održavanje (kn/god)	Veliko održavanje (kn/god)
Stacionarni	0,06 x C	0,08 x C	0,10 x C
Transportni	0,09 x C	0,11 x C	0,13 x C

Troškove održavanja mora se na neki način obračunati u cijeni radova. U jediničnim analizama trošak rada stroja predstavlja direktni trošak koji je umnožak odgovarajućeg normativa vremena za strojni rad i koštanja sata rada stroja. Trošak rada za neke strojeve (npr. dizalice i drugi koji sudjeluju u obavljanju velikog broja različitih radova ili se koriste u pripremno-završnim radovima koji nisu sadržani u troškovniku) iznimno se uzima kao indirektni i onda ulazi u cijenu svih stavki kao dio veličine faktora za pokriće indirektnih troškova gradilišta (u jediničnoj analizi množi se s elementima direktnih troškova).
Koštanje sata rada stroja uz amortizaciju i ostale troškove obuhvaća i troškove održavanja koji ne ovise o radu (investicijsko održavanje) i one koji su proporcionalni količini rada i težini uvjeta rada (tekući zahvati, podmazivanja i zamjene habajućih dijelova).

Troškovi investicijskog održavanja mogu se grubo procijeniti na godišnjoj razini kao postotak od obračunske cijene stroja, a da bi se dobio udio koji treba pribrojiti u koštanje sata rada dijele se s prosječnim brojem sati rada godišnje.

Troškovi provođenja tekućeg održavanja, habajućih djelova (koji se pri radu neposredno troše: zubi, noževi, sječiva, čelična užad, remenje, čeljusti drobilica, razne unutarnje obloge bubnjeva, lopatice, udarni čekići, gume i dr.) i podmazivanja znatno se razlikuju od stroja do stroja. Postoji više načina njihovog obračuna, ali to je uvijek na bazi iskustvenih (statističkih) podataka. Troškovi obavljanja tekućeg održavanja isto se najjednostavnije mogu samo grubo pretpostaviti za cijeli uporabni vijek u odnosu na obračunsku cijenu stroja (10 - 33%), a da bi se dobio trošak po satu dijele se s planiranim brojem radnih sati za cijeli vijek uporabe. Troškovi habajućih dijelova paušalno se obračunavaju kao 10 - 15% pretpostavljenih troškova tekućeg održavanja (u odnosu na cijenu koštanja stroja oko 1 - 2,5%), dok se troškovi maziva često obračunavaju uvećavanjem troškova goriva za određeni postotak (cca. 10%) [Vidaković i dr, 2009, prema starijim izvorima]. Kod točnijeg planiranja troškova rada na određenom gradilištu u obzir bi svakako trebalo uzeti postojeće radne uvjete.
Iz dostupnih analiza cijena može se doći do granica kretanja udjela svih troškova održavanja i rezervnih dijelova u ukupnoj cijeni koštanja sata rada, pa je tako primjerice kod strojeva za izgradnju i održavanje cesta: 15 - 24% za samohodne i vučene cisterne, prskalice bitumena i razastirače sitneži, 7,5 - 10% za različite valjake, a 1,5 - 5% za manje, jednostavnije strojeve i mehanizirane alate [Vidaković i dr, 2009].

Pouzdaniji izračun troškova održavanja zahtjeva podatke od praćenja mehanizacije u uporabi. Oni mogu biti interni – unutar poduzeća (samo za svoju mehanizaciju), od nezavisnih istraživača i od proizvođača. Podaci iz vlastitog iskustva su redovito najrealniji, mada ih je svejedno poželjno usporediti još s nekim drugim izvorom, a od proizvođača najoptimističniji.

5. Zaključak

Uvijek je cilj smanjiti broj kvarova i trajanje zastoja u radu i sveukupne troškove, a povećati sigurnost i kvalitetu rada. Literatura utemeljena na praksi pokazuje kako je to moguće s odgovarajućim i pravovremenim mjerama održavanja strojeva i drugih sredstava rada. Održavanje građevinske mehanizacije tako utječe na ostvarenje glavnih ciljeva realizacije građevinskih projekata (troškovi, rokovi, rizici, kvaliteta, sigurnost ljudi) i posredno na konkurentnost poduzeća.

Obično u građevinskim poduzećima postoje brojne mogućnosti smanjenja troškova održavanja (i neodržavanja), samo ih treba znati prepoznati [Kondić i dr., 2011]. Ne treba se zadovoljavati s postojećim stanjem nego uvijek treba težiti boljem, jer uvijek postoji učinkovitiji i pouzdaniji stroj i efikasnija metoda rada i održavanja. Problem može biti što se kod nas postojeća organizacija teško mijenja i sporo prilagođava.
Unutar građevnskog poduzeća s većim strojnim parkom treba organizirati podsustav za njegovo održavanje koji će provoditi najprimjereniji način djelovanja. Iako za svaki konkretni slučaj treba analizirati kakva organizacija i održavanje mehanizacije su najbolji, danas se općenito zagovara preventivno održavanje s praćenjem stanja strojeva (prediktivno i proaktivno), jer se s njim maksimalno izbjegavaju kvarovi pri radu. To iziskuje određeno vrijeme, usvajanje novih znanja i određene početne troškove, ali potrebna oprema za dijagnostiku danas je sve dostupnija, a strojevi sve usavršeniji u svakom pogledu. S druge strane, popravci strojeva koji su otkazali tijekom rada sa svim popratnim štetama bivaju višestruko skuplji nego plansko održavanje s predviđenim preventivnim zahvatima.

Preporuča se obvezno uključivanje stručnjaka za održavanje u donošenje odluka o nabavi novih strojeva, te njihovu montažu i pripremu za puštanje u rad. Za uspješno održavanje potrebna je komunikacija i suradnja stručnjaka s više područja (strojarstvo, građevinarstvo, ekonomija, informatika).
Prije odluke o nabavi mehanizacije i organizacije održavanja i prije većih održavateljskih zahvata treba timski razmotriti raspoložive tehničke mogućnosti i financijske zahtjeve. Za odlučivanje u procesu održavanja potrebna je višekriterijska analiza (npr. AHP) gdje je u pravilu jedan od kriterija s najvećom težinom iznos troškova. Zato je troškove potrebno analizirati u cijelosti uz uzimanje u obzir i utjecaja održavanja na učinak strojeva.
Za svako građevinsko poduzeće najbolje je da samo prati mehanizaciju s kojom raspolaže i sve relevantne podatke obradi za svoju internu bazu podataka (normativi vremena i materijala

za održavanje) kako bi mogli što pouzdanije planirati troškove, ali i odrediti veličinu koeficijenta dotrajalosti, odnosno planski učinak svakog stroja.

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Metode planiranja građenja infrastrukturnih projekata

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Sažetak

Planiranje građenja infrastrukturnih projekata zahtjeva veliku pozornost zbog nepostojanja adekvatne primjene metoda planiranja pri planiranju ove vrste projekata. Važnost planiranja građenja utvrđena je još u davnim vremenima a danas planiranje predstavlja najviše pažnje od svih faza građenja kako bi sam projekt na kraju bio uspješan. Poznato je ipak da većina infrastrukturnih projekata prekorači ili vremenski rok građenja ili planirana sredstva za građenje što znači da se planiranju ovih projekata ne posvećuje dovoljna pažnja. Rad prikazuje kratak povijesni razvoj metoda planiranja, osnovne karakteristike metode te mogućnost njene primjene pri planiranju građenja infrastrukturnih projekata. Cilj rada je dobiti odgovor na pitanje može li se primjenom tradicionalnih metoda planiranja građenja infrastrukturnih projekata osigurati izvođenje projekta na vrijeme i u okviru planiranih novčanih sredstava, koliko se one danas samostalno primjenjuju te koje metode planiranja će se primjenjivati za planiranje budućih sve kompleksnijih infrastrukturnih projekata. Kvalitetno planiranje građenja jedan je od glavnih uvjeta uspješnosti cijeloga projekta, a kvalitetno planiranje moguće je ostvariti jedino pomoću adekvatne metode planiranja.

Keywords: Metode planiranja; gantogram; mrežno planiranje; planiranje građenja; infrastrukturni projekt; CPM; PERT

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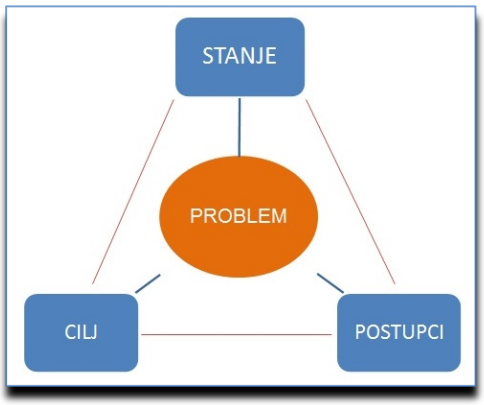
1. Uvod

Pojam planiranje podrazumjeva plan za završetak projekta na temelju logičnog rasporeda aktivnosti (Popescu i Charoenngam, 1995). Planiranje građenja predstavlja proces utvrđivanja pravilnog redoslijeda planiranih aktivnosti, određivanje realnog trajanja svake aktivnosti te određivanje početnog i krajnjeg datuma trajanja za svaku aktivnost (Oberlander, 2000). Ono podrazumjeva predviđajanje događaja koji bi se trebali u građenju odvijati na temelju postavljene organizacije, određene tehnologije raspoloživih sredstava za rad i uvjeta pod kojima se predviđa građenje (Lozančić, 1995).

Svrha rada je kroz kratak povijesni pregled prikazati primjenu tradicionalnih metoda planiranja infrastrukturnih projekata i njihovu primjenu u planiranju budućih projekata. Pitanje na koje se traži odgovor je može li se primjenom tradicionalnih metoda planiranja napraviti adekvatan plan građenja modernih infrastruktunih projekata. Zbog svoje usmjerenosti na pojedine vrste projekata tradicionalne metode planiranja građenja sve se rijeđe samostalno primjenjuju u planiranju građenja infrastrukturnih projekata zbog njihove kompleknosti. Razvoj novih metoda zasnovanih na tradicionalnim metodama planiranja građenja trebao bi omogućuti efikasnije planiranje i doprinijeti uspješnom ostvarenju građenja infrastruktunih projekata.

Planiranjem građenja vršimo postavljanje ciljeva za predvidivu budućnost. Da bi ciljevi bili što točnije predviđeni a plan što realniji, na početku postavljamo tri pitanja:

1. Gdje se nalazimo sada (stanje)
2. Kuda želimo (cilj)
3. Na koji način ćemo doći do cilja (postupci)



Ilustracija 1. Shema temeljnih pitanja pri planiranju

Početkom razvoja suvremenog planiranja smatra se razvoj dinamičkog plana - gantograma, neposredno prije početka prvog svjetskog rata. Međutim, može se reći da koncept planiranja nije nov; piramide su danas stare oko 3000 godina, Sun Tzu je pisao o planiranju i strategiji ratovanja prije 2500 godina, prije 200 godina građene su transkontinentalne željeznice, itd. Niti jedna od ovih aktivnosti ne bi mogla biti izvedena bez planiranja (Weaver, 2006).

Do razvoja prvih metoda planiranja projekata došlo je s povećanjem složenosti projekata. Zbog očite praktične važnosti, s intenzivnim istraživanjem planiranja projekata započelo se u kasnim pedesetim godinama dvadesetoga stoljeća. Njihov razvoj posebno je napredovao s početkom upotrebe računala u planiranju građenja. Danas se računala koriste za prikazivanje svih vrsta planova neovisno o kojoj metodi planiranja je riječ. Unatoč svim uloženim naporima, brojna istraživanja pokazuju da infrastrukturni projekti često prelaze planirani vremenski rok te sredstva namjenjena za građenje što pokazuje da metode planiranja građenja

u slučaju infrastrukturnih projekata još uvijek nisu pronašli pravi put do svoje praktične primjene.

Izbor metode planiranja građenja infrastrukturnog projekta varira u ovisnosti o veličini projekta, kompleksnosti, trajanju, osoblju te zahtjevima investitora. Svaka od metoda planiranja mora podržavati neke osnovne preduvjete za učinkovito korištenje. Planeri i korisnici očekuju od svake metode da:

- bude jednostavna i lako razumljiva
- omogućuje vidljivost alternative i korištenja pretpostavki u analizi scenarija
- prikazuje planirano stanje: rad-vrijeme-novac
- može prikazati stvarno stanje izvršenja: rad-vrijeme-novac
- može prikazati prognostičku sliku: rad-vrijeme-novac
- omogućuje dodavanje detalja po potrebi
- posljedice djelovanja rizika u planu čini vidljivima
- omogućuje izradu sumarnih podataka po potrebi (Radujković i suradnici, 2012)

U planiranju građenja infrastrukturnih projekata kroz povijest koristile su se sljedeće metode:

- gantogrami
- ciklogrami
- ortogonalni planovi
- mrežno planiranje

2. Karakteristike infrastrukturnih projekata

Ekonomski, na infrastrukturu se može gledati kao elemente ekonomije koja dopušta proizvodnju dobara i usluga koje same nisu dio proizvodnog procesa. Infrastruktura se tipično odnosi na tehničke strukture i sisteme koji podržavaju društvo, kao npr. ceste, vodovod, kanalizacija, elektroopskrba, itd. Širi kontekst infrastrukture obuhvaća i socijalne usluge kao što su škole i bolnice, informatičku tehnologiju, neformalne i formalne kanale komunikacije, političke i socijalne mreže ili sustav vjerovanja članova pojedine grupe. Generalno se infrastruktura može podijeliti u dvije kategorije: civilnu infrastrukturu i socijalnu infrastrukturu. Civilna infrastruktura podržava najosnovnije potrebe društva i gospodarstva (energija, telekomunikacije, transport i voda), dok je socijalna infrastruktura neophodna za razvoj kulturnih normi i promoviranje zdrave populacije (sudovi, administrativne službe, škole, bolnice i popravne ustanove). (Al-Bahar and Crandal, 1990)

U ovom radu obrađivat će se civilna infrastruktura koja obuhvaća sljedeće vrste:

- transportna infrastruktura
- energetska infrastruktura
- infrastruktura za gospodarenje vodama
- komunikacijska infrastruktura
- infrastruktura za zbrinjavanje otpada
- mreže za praćenje i mjerenje zemlje

Većina infrastrukture ima karakteristiku da se proteže duž većih udaljenosti, a njihova izgradnja između ostalog izvedbu niza građevina kojima je transport općenito osnovna namjena. Zbog određenih prvenstveno oblikovnih karakteristika navedeni objekti mogu se uvjetno nazvati linijski objekti (linijske građevine). Kod takvih se objekata na određenoj većoj dužini uglavnom ne mijenja osnovni oblik njihovog poprečnog presjeka ili ne mijenja oblik nosivog i namjenskog dijela njihove konstrukcije. Ovisno o namjeni građevine i obliku terena gdje je položen, zemljani dio linijskih objekata je najčešće promjenjiv po obliku. Zbog toga zemljani radovi čine neki općeniti objekt koji ima razvučena, izdužena i sl. svojstva (u smislu oblika) manje ili više linijskom građevinom. Tu se može izuzeti tunele, kod kojih je iskop projektno uglavnom stalan po obliku i veličini uz neka odstupanja, ovisno o vrsti podgrade i

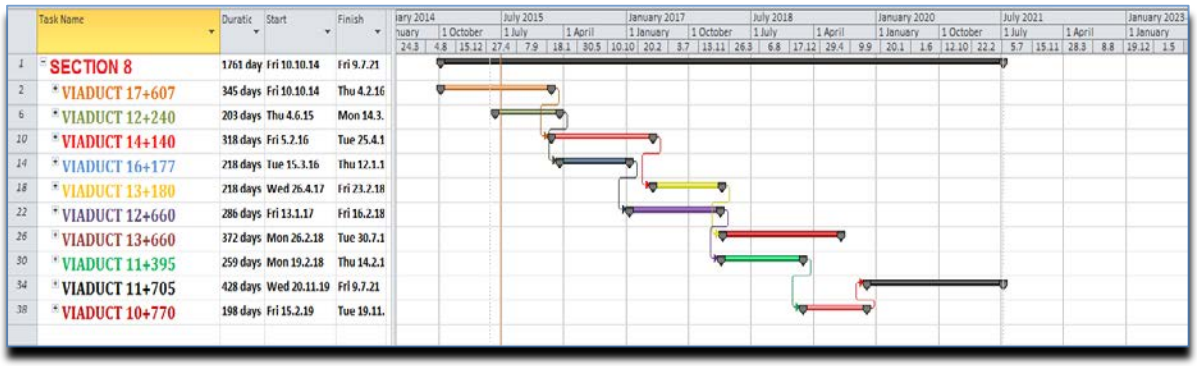
obloge tunela (isto se može reći npr. za iskop rovova i kanal u ravnici). Tamo, gdje to nije tako, nakon izvedbe po dužini promjenljivih zemljanih radova neki općeniti objekt može se sagledavati kao linijski objekt (npr. Izvedba donjeg i gornjeg ustroja prometnica nakon završetka iskopa i nasipa, te ostalih objekata u nekom brdovitom terenu).

3. Pregled metoda planiranja i način njihovog korištenja

3.1. Gantogram

Bar chart je grafički prikaz projektnih aktivnosti projekta prikazanih u vremenu bez međusobne povezanosti pojedinih aktivnosti (Popescu i Charoenngam, 1995). Bar chart je izvorno razvijen od strane Henry L. Gantta 1917. godine te je po njemu i dobio naziv Gantt chart. Točnije, prvi gantogram osmislio je Karol Adamiecki, poljski inženjer i ekonomist, i taj gantogram nosio je naziv garmonogram (garmonograf). Međutim, kako ga nije objavio do 1931. godine, ovaj plan nosi ime po Ganttu, koji je 1910. svoju verziju objavio u časopisu The Engineering Magazine (Matijević, 2012). Henry Gantt formulirao je jednostavnu grafičku metodu koja prikazuje plan proizvodnog procesa u vremenu. Jako brzo ova grafička metoda postaje popularna, osobito u građevinarstvu, zbog svoje sposobnosti da na jednostavan način grafički prikazuje projektne aktivnosti na vremenskoj skali.

Sve do 1960. godine planovi projekata prikazivani su pomoću bar charta (Lewis, 2011). Gantogram je učinkovita metoda za ukupnu planiranje projekta, ali je u prošlosti bio veoma ograničen za detaljniji prikaz građevinskih radova, jer nije prikazivao povezanost pojedinih aktivnosti što je predstavljalo važan čimbenik pri planiranju građenja složenijih projekata kao što su infrastrukturni projekti. Uvođenjem prikaza veza između pojedinih aktivnosti nastao je dijagram s brzim i točnim uvidom u međusobnu ovisnost aktivnosti.



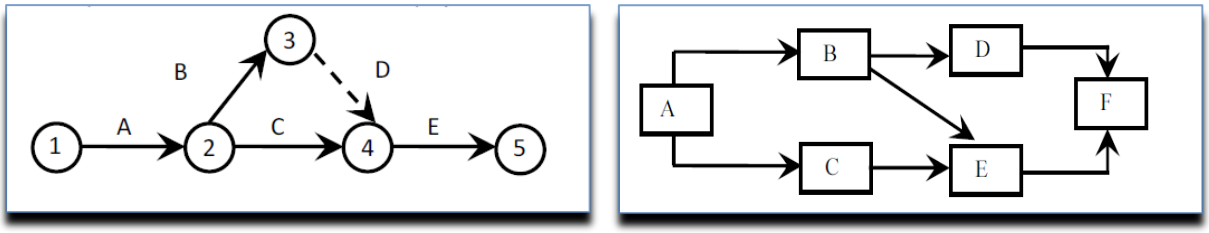
Ilustracija 2. Gantogram s prikazanim vezama između aktivnosti

3.2. Mrežno planiranje

Pojava sve složenijih projekata kod kojih planiranje postojećim metodama nije postizalo zadovoljavajuće rezultate, kao i težnja za metodom planiranja koja bi omogućila primjenu računala, doveli su do razvoja mrežnog planiranja. Prve teorije mrežnog planiranja nastale su istovremeno u Francuskoj i SAD-u. Početkom 1957. godine tvrtka DuPont Corporation izradila je prijedlog mrežnog planiranja vremena, čija je značajna točka bila razdvajanje analize vremena od analize strukture. Ovaj postupak je u prvo vrijeme bio nazvan "Production Planning and Scheduling System" a zatim "Critical Path Method" (Metoda kritičnog puta) ili skraćeno CPM. Metoda je brzo stekla široku primjenu u planiranju

svih vrsta projekata pa tako i u građevinarstvu. Godine 1958. američka mornarica razvila je novu metoda planiranja nazvanu Program Evaluation and Review Technique ili skraćeno PERT. Poznato je više stotina raznih metoda mrežnog planiranja koje su izvedene od dvije osnovne metode CPM i PERT. U stručnoj literaturi modifikacije ovih metoda imaju razne skraćenice i one se međusobno razlikuju metodološki, jer su mnoge od njih prilagođene potrebama određenih preduzeća. Navode se neke od njih: TOPS (The Operational PERT System), CPS (Critical Path Scheduling), CPPS (Critical Path Planing and Scheduling), CPA (Critical Path Analysis), RAMPS (Resource Allocatin and Multi - Project Scheduling), i dr.

Metoda mrežnog planiranja predstavlja grafički model koji prikazuje aktivnosti koje su



međusobno povezane kako bi se prikazao njihov slijed (Oberlander, 2000). Mrežni dijagrami se u osnovi dijele na dvije vrste: mreže s strijelicama te mreže sa čvorovima.

A,B…F - aktivnosti
Ilustracija 3. (a) mrežni plan sa strijelicama
(b) mrežni plan sa čvorovima

Mreže sa strijelicama veliku primjenu imale su u 1960-ih i 1970-ih a nakon toga dijagrami (napredni oblik mreže s čvorovima) postaju izbor u mrežnom planiranju (Mubarak, 2010). Razvoj mrežnog planiranja doveo je do povećanja razvijenosti cijelokupnog upravljanja projektima. Osnovnu mrežnog planiranja je eliminiranje potrebe za menadžmentom za krizne situacije zbog toga što mrežno planiranja daje slikovit prikaz cijeloga projekta (Kerzner, 2009). Sljedeće informacije za upravljanje mogu se dobiti iz mrežnog dijagrama:

- povezanost aktivnosti
- vrijeme završetka projekta
- utjecaj kasnog starta
- utjecaj preuranjenog starta
- ustupaka između resursa i vremena
- neuspjeh u planiranju/izvedbi
- procjena uspješnosti

Postupak mrežnog planiranja može se podijeliti u tri faze (Radujković i suradnici, 2012):

I. Analiza strukture:
   - Popis aktivnosti (raščlanjenje cjelokupnog tehnološkog procesa na manje organizacijske cjeline
   - Određivanje veza između aktivnost (u skladu sa usvojenom tehnologijom proizvodnje)
   - Određivanje trajanja aktivnosti (na bazi urađenih statičkih planova)
   - Određivanje potrebnih resursa (radne snage, mehanizacije, materijala i troškova)
   - Izrada strukture plana - mreže, koja prikazuje međuovisnost odvijanja aktivnosti i shematski se prikazuje krugovima.

II. Analiza vremena:
   - određivanje početka i završetka aktivnosti
   - određivanje dinamike angažiranja resursa

III. Optimizacije mrežnog plana

Pored konvencionalnog tipa veze kraj - početak (FS, finish to start) sa odgovarajućim tehnološkim zastojima gdje je to neophodno, primjenjuju se i druge veze:

- početak - početak (SS, start to start)
- kraj - kraj (FF, finish to finish)

čime se omogućava realno prikazivanje tehnologije i dinamike građenja.

3.3. Vremensko lokacijski dijagrami (V-L dijagrama)

3.3.1. Ciklogram

Metoda ciklogramskog planiranja počela se razvijati s industrijalizacijom proizvodnje poslije drugog svjetskog rata. Za projekte sa istim aktivnostima koje se ponavljaju više puta, kao što su katovi zgrada, dionice puteva ili segmenti stupova u literaturi se može pronaći veliki broj metoda planiranja koje su dostupne pod različitim imenima. Neke od njih su: Line of Balance (O'Brien, 1969; Carr i Meyer, 1974; Halpin i Woodhead, 1976; Harris i Evans, 1977.); Construction Planning Technique (Peer, 1974; Selinger, 1980); Repetitive Scheduling Model (Carr i Meyer, 1974), itd. Sve su ovo varijante dinamičkog plana, u našoj literaturi poznatog kao ciklogram.

Ciklogram je grafička metoda linijskog planiranja posebno prilagođenja dinamičkom planiranju radova koje karakterizira neprekidan lančani slijed aktivnosti (Radujković i suradnici, 2012). Pogodan je za dinamičko planiranje radova koji imaju neprekidni lančani tok aktivnosti, tj. aktivnosti se ciklično ponavljaju, ali je nepregledan ako projekt ima veći broj aktivnosti. Odvijanje radnih operacija, odnosno aktivnosti, ukoliko je to potrebno, može se podijeliti na veći broj jednakih dijelova ili etapa, a to je moguće uraditi kod objekata koji imaju izraženu dužinu (npr. saobraćajnice, potporni ziovi, kanali) ili visinu (segmenti stupova mosta). Specijalizirane radne grupe kreću se od jedne pozicije do druge gdje izvode indentičan građevinski proces (gradnja stupa mosta s jednakim segmentima). Pri tome broj etapa treba da je veći od broja operacija. Zbog ovih karakteristika ciklogram je vrlo povoljan pri planiranju građenja autocesta.

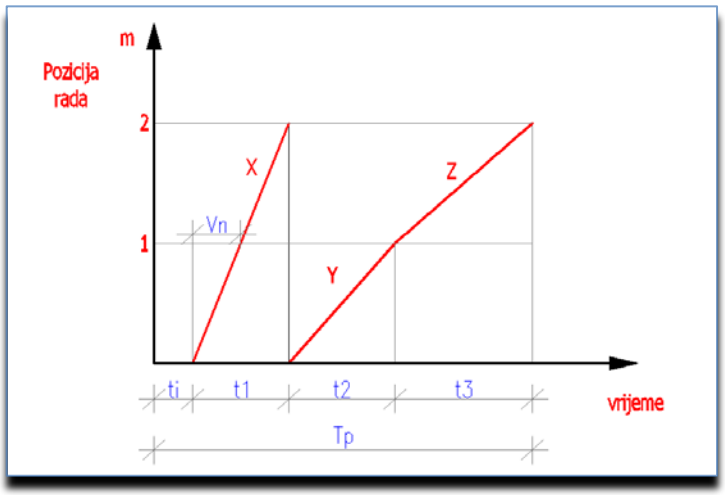
Prednosti ciklogramskog planiranja su sljedeće:

1. omogućava brz, lak i detaljan uvid u stanje radova, odnosno laku usporedbu planiranog i realiziranog stanja na projektu i sa faktora vremena i sa faktora planiranih i izvršenih radova
2. omogućava brzo i lako sagledavanje promjena u toku realizacije plana, zbog djelovanja okruženja na projekt, i brzo djelovanje na te promjene
3. omogućava lako izbjegavanje štetnih djelovanja vremenskih i prostornih zazora, što omogućava optimalnu paralelizaciju aktivnosti u okviru projekta (Kurij, 2007)

Ciklogram pripada prostornim planovima te se prikazuje u prvom kvadrantu koordinatnog sustava. Na apscisi se predočuje vrijeme, a na ordinati prostorne jedinice objekata koje se nazivaju graditeljske jedinice ili radne etape.

Trajanje građenja prikazano ciklogramom izračunava se pomoću formule:

$$Tp = t_i + \sum_{1}^{n-1} t + mxv_n$$



Ilustracija 4. Primjer konstrukcije ciklograma

t_i – vrijeme pripreme cikličkog izvođenja radova
$t_{1,2,3}$ – vrijeme trajanje aktivnosti x,y, z
m – broj pozicija građenja
v_n – vrijeme potrebno za izvođenje aktivnosti X na poziciji rada 1
n – broj aktivnosti u ciklogramu

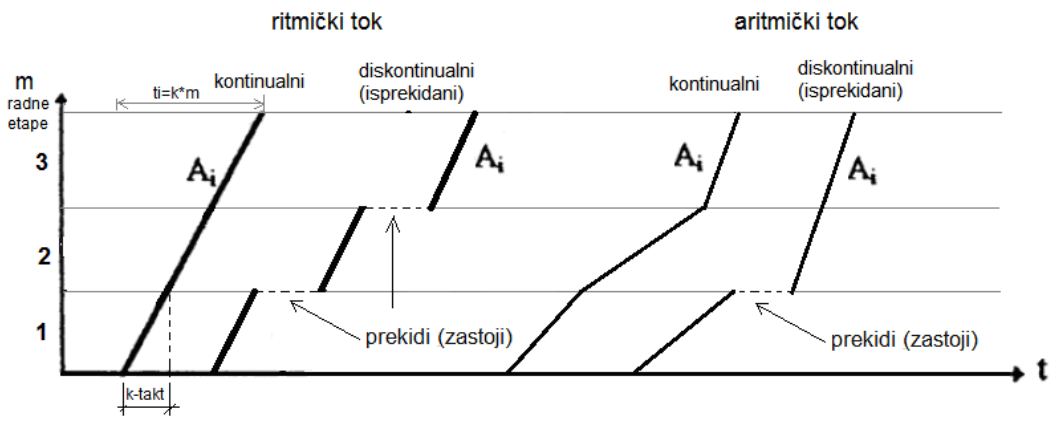
U ovisnosti od modula cikličnosti aktivnosti, procesi građenja mogu se podijeliti na:

- ritmičke – sve aktivnosti imaju isti takt
- aritmičke – aktivnosti imaju različite taktove

Ritmički i aritmički procesi građenja, zavisno od toga da li se aktivnosti realizuju sa ili bez vremenskog zastoja, mogu biti:

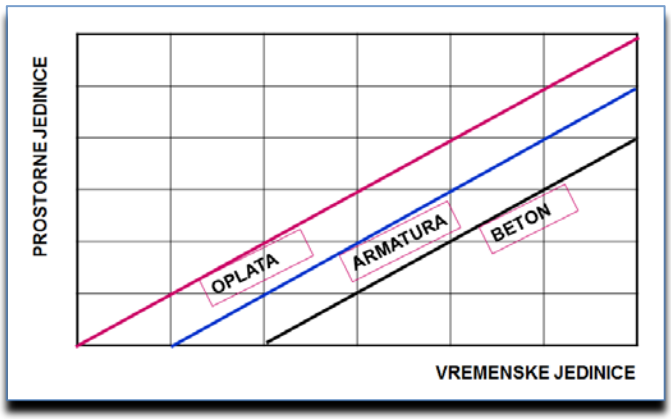
- kontinuirani – aktivnosti se realizuju bez vremenskog zastoja
- diskontinuirani (isprekidani) – aktivnosti se realiziraju sa vremenskim zastojima

Navedene vrste procesa građenja prikazane su na sljedećoj slici.



Ilustracija 5. Vrste procesa građenja

Ritmički tokovi predstavljaju pravilno odvijanje radova i u vremenu i u prostoru, dok aritmički predstavljaju nepovoljno odvijanje radova. Kod aritmičkih tokova postoje i točke kritičnog približavanja radova, koje mogu ugroziti radove na izgradnji objekta. Početni ciklogram se uglavnom prepravlja i poboljšava (tj. optimizira), čime se dolazi do konačnog rješenja.

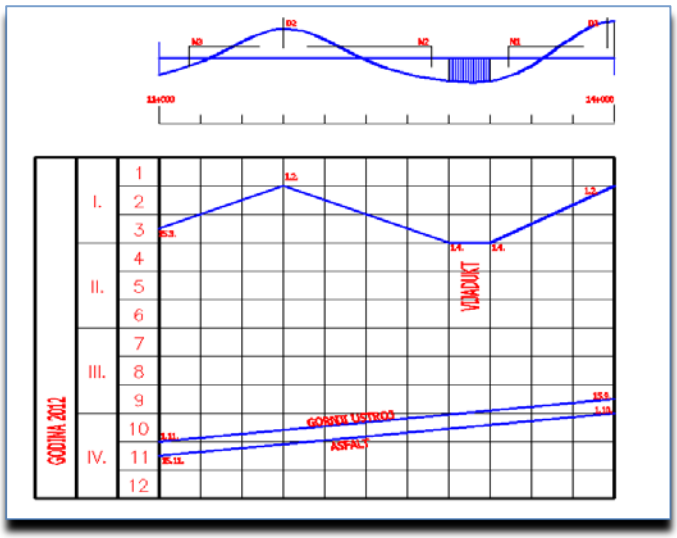


Ilustracija 6. Kontinuirani procesi građenja

3.3.2. Ortogonalni planovi

Za cjevovode, tunele, puteve, itd. gdje se napredovanje radova mjeri u smislu horizontalne dužine, kroz povijest se pojavljuju različite metode planiranja pod raznim nazivima: Time Versus Distance Diagram (Gorman 1972.); Linear Balance Chart (Barrie i Paulson, 1978.); Linear Scheduling Method (Johnston, 1981; Chrzanowski i Johnston, 1986; Russell i Casselton, 1988); i dr. Iako je svaka od ovih metoda razvijena za ispunjenje svojih pojedinačnih ciljeva, sve su one slične u tome da planiraju rad nanošenjem inteziteta aktivnosti koje se ponavljaju u vremenu. Ove metode planiranja kod nas se nazivaju ortogonalnim planom.

Ortogonalni planovi također pripadaju prostornim planovima, prikazuju napredovanje radova u odnosu na prostorne jedinice objekta i vrijeme, te se prikazuju u četvrtom kvadrantu koordinatnog sustava, pri čemu se na ordinati prikazuje vrijeme a na apscisi prostorne jedinice objekta. Aktivnosti su u planu prikazane linijama, a trajanje svake aktivnosti određuje se njenom projekcijom na vremensku os. Može se zaključiti da ortogonalni plan daje dobar pregled odnosa rada - mjesto rada - vrijeme rada, pa je metoda bila popularna kod planera linijskih građevina koji su htjeli korisnicima plana jasnije vizualno prikazati podatke (Radujković i suradnici, 2012).



Ilustracija 7. Primjer ortogonalnog plana građenja poddionice autoceste

Najveći nedostaci ortogonalnog plana su nepostojanje prioriteta izvršenja pojedinih aktivnosti, preglednost kod složenijih projekata te nepostojanje veza između pojedinih aktivnosti. Ortogonalni plan kao metoda planiranja nikada nije doživio široku primjenu a danas se gotovo i ne primjenjuje.

3.4. Korištenje metoda planiranja u praksi

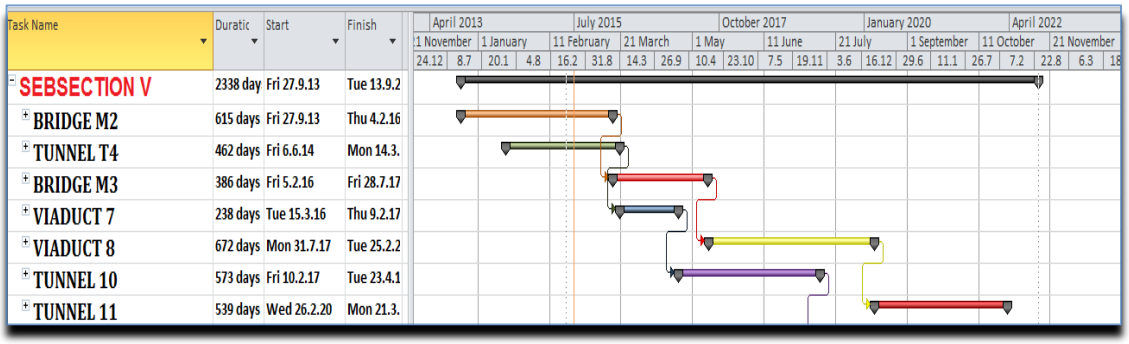
Brojni izvori tvrde da se primjenom mrežnog planiranja mogu znatno smanjiti prekoračenja početno planiranih troškova i vremena u projektu (Meredith, 1995). Međutim, mnogi projekt menadžeri te voditelji radova preferiraju gantogram za planiranje građenja zbog jednostavnosti njegove izrade i korištenja, jednostavnosti korištenja računala pri primjeni ove metode te lakom pravljenju ispravki u samom planu.

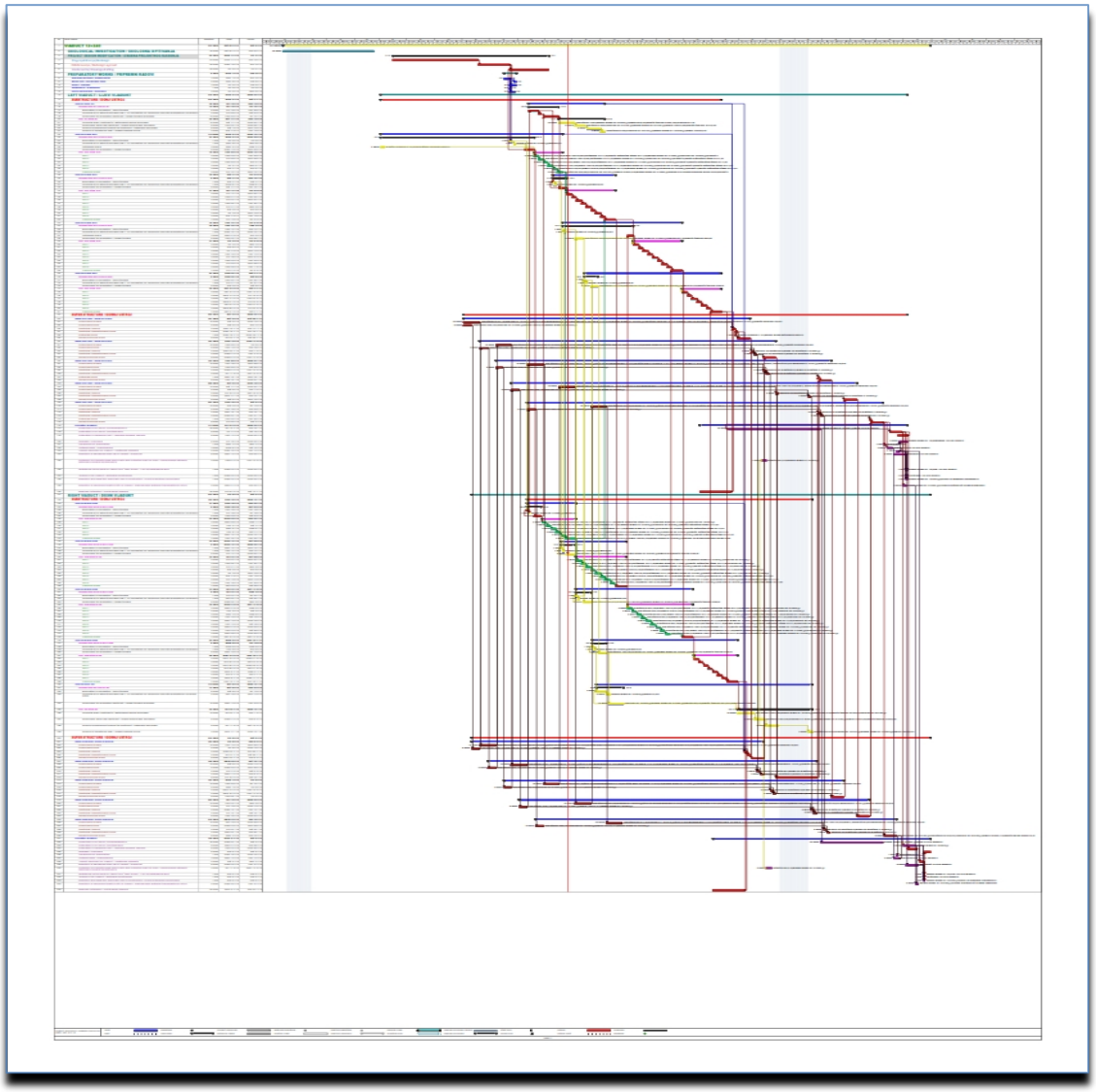
Istraživanjem tradicionalnih metoda planiranja građenja te mogućnosti njihove samostalne primjene može se utvrditi da se samostalnom primjenom pojedine metode planiranja građenja ne može osigurati adekvatno planiranje kompleksnog infrastrukturnog projekta zbog njihove usmjerenosti na specifičnosti pojedinih projekata te ograničenja u jasnim prikazima planova složenijih projekata. S obzirom na kompleksnost infrastrukturnih projekata potrebna je kombinirana primjena tradicionalnih metoda planiranja građenja kroz različite računalne pakete kako bi se stvorio efikasan plan građenja. Takav plan olakšava proces upravljanja građenjem i samo građenje te doprinosi uspješnosti projekta kao cjeline.

Iako većina današnjih programskih paketa podržavaju kombiniranu tehniku mrežnog planiranja i gantograma, korištenje mrežnog planiranja je nedovoljno zastupljeno. Pri planiranju složenih infrastrukturnih projekata mrežno planiranje omogućuje povezivanje velikog broja aktivnosti u koherentnu cjelinu, jednostavni su za unošenje izmjena u plan te intervencija u slučaju pojave kašnjenja u građenju. Međutim, aktivnosti u praksi planiraju se na razini koja ne omogućava optimizaciju resursa s obzirom na vrijeme i mjesto njihovog korištenja.

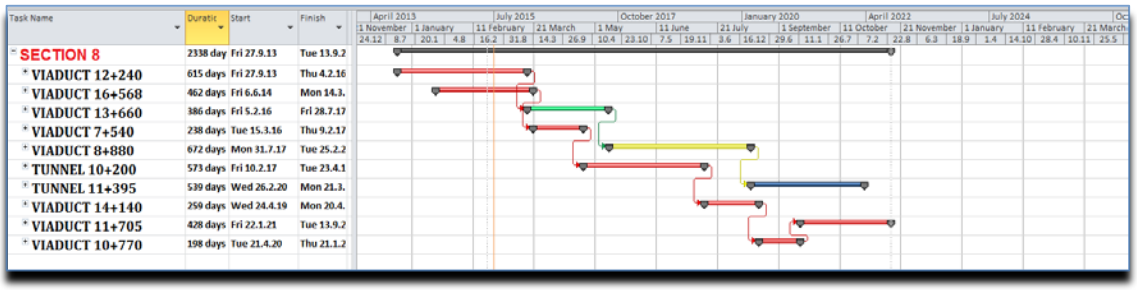
Mrežno planiranje ima veliki broj prednosti u odnosu na ostale metode planiranja:

1. mrežni plan pokazuje veze između pojedinih aktivnosti
2. mrežni plan prikladan je za matematičku obradu
3. mrežnim planom određen je kritični put aktivnosti
4. aktivnosti su podjeljene na kritične i nekritične
5. moguće je optimiziranje troškova
6. grafički prikaz mrežnog dijagrama daje dobru preglednost i tehnološki slijed radova
7. p





Ilustracija 8. (a) aktivnosti u gantogramu prikazane kao cijeli objekti
(b) Primjer prikaza plana projekta razdijeljenog do sitnih detalja izrađenog u računalnom paketu MS Project



Ilustracija 9. Prikaz kritičnog puta u gantogramu crvenom bojom

Ovakav prikaz ukazuje na dijelove projekta na koje je potrebno obratiti posebnu pozornost pri građenju kako bi se na vrijeme mogli usmjeriti potrebni resursi te kako bi se građenje izvršilo u planiranom vremenskom roku (npr. koncentracija resursa na izvođenju odvodnje pri gradnji dionice autoceste).

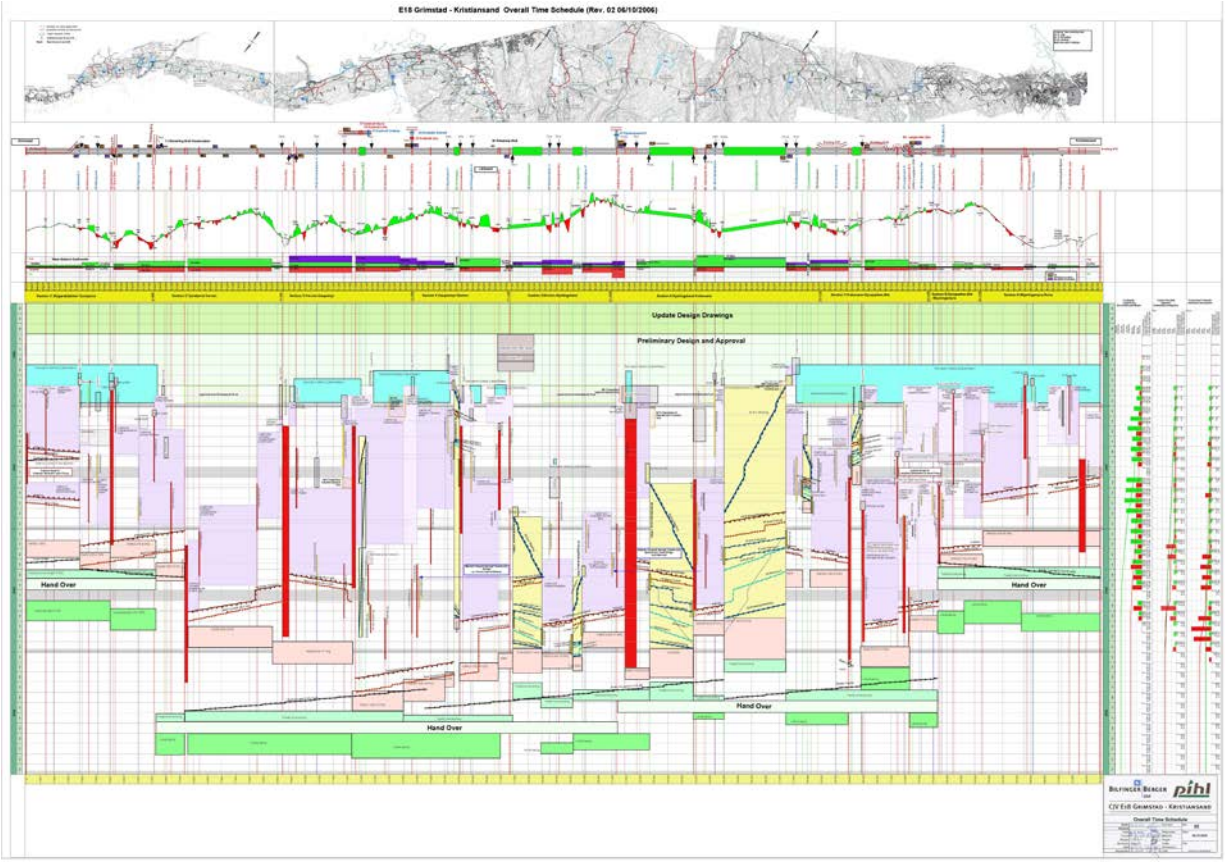
Pri građenju svih vrsta infrastrukturnih projekta ritmična gradnja je najpoželjnija zbog jednostavnosti planiranja, smanjenje troškova pripremnih radova, smanjenja troškova uređenja gradilišta te ostvarenja minimalnog ukupnog vremena građenja kroz minimalne veličine koraka pojedinačnih procesa.

Kod infrastrukturnih projekata vrlo je bitno osvariti kontinuitet korištenja građevinske mehanizacije i opreme, a Gantt chart ne može ukazati na kontinuiranost izvedbe pojedine aktivnosti pri građenju. Zato su se vremensko lokacijski dijagrami često koristili za linijske objekte prije pojave računalnih paketa koji koriste kombinaciju Gantt chart i mrežni dijagram.

Pojavom računalnih programa koji koriste vremensko lokacijski (V-L) dijagram dolazi do promjena dosadašnje prakse planiranja linijskih projekata. Ključna prednost V-L dijagrama je u vizualnom protoku podataka okupljenih u jednom planu. CPM rasporedi i mrežni dijagrami podatke prikazuju više analitički i ne omogućuju korisniku vizualni prikaz povezanosti između projektnog plana i samog projekta. Linearni projekti prestavljaju jedinstveni izazov zato što se radne skupine i oprema premještaju po gradilištu tijekom izvedbe projekta.

Korištenjem tradicionalnih dijagrama prikazivanje mjesta izvođenja radova i vremena u kojemu je taj rad izveden zahtjevala je razradu plana do detalja većih nego što praktičari smatraju da je potrebno. Prednost V-L dijagrama je u tome što omogućuje komunikaciju opsega projekta prikazivanjem detalja projekta i raspored izvedbe u isto vrijeme. Oni mogu dati više informacija zbog načina na koji se podaci uz udaljenost mogu pripisati svakom individualnom zadatku.

Veza između gradilišta i informacija o rasporedu omogućuje brže i dublje razumijevanje plana izvedbe konstrukcije. Moguće je izraditi usklađen plan bez nepotrebne detaljne razrade radi mogućnosti ukazivanja na potencijalne greške i rizike u slučaju preklapanja linija te dodatnih funkcija programskih paketa poput održavanja udaljenosti, sinkroniziranja nasljednika, sinkroniziranja brzine i računanje točke susretanja.



Ilustracija 10. Primjer vremensko lokacijskog dijagrama izrađenog računalnim paketom TILOS (www.tilos.org)

Također je moguće definirati ograničena područja u kojima se ne dopušta planiranje zadataka u danom vremenskom i prostornom prozoru zbog problema koji onemogućavaju pristup području ili predstavljaju ekološke probleme ili područja ili prostorno vremenska područja slabijeg intenziteta rada (utjecaj vremenskih prilika ili karakteristika terena).

Napredak se može bilježiti na 3 načina: bazirano na postotku izvršenja, bazirano na količini rada ili bazirano na udaljenosti. U svakom slučaju precizne informacije s lokacije gdje je rad dovršen su nužne. Ovaj napredak se može prikazati pomoću jednostavnog grafikona, koji pokazuje dovršene sektore.

4. Zaključak

Svaki infrastrukturni projekt ima različite karakteristike. Ova tvrdnja upućuje na zaključak da je za planiranje građenja svakog infrastruktunog projekta potrebno odrediti adekvatnu metodu planiranja. Zbog toga se do danas razvio veliki broj metoda planiranja koje se primjenjuju u većoj ili manjoj mjeri. Poznato je da građenje infrastruktunih projekata često prekoračuje vremenski rok i planirane troškove. Kao osnovni uzrok nastanka kašnjenja ili povećanja koštanja projekta smatra se pogrešan odabir metode planiranja.

Projekt menadžeri u praksi primjenjuju jednostavnije metode planiranja zasnovane na gantogramima za čiju pripremu izdvajaju manje vremena što za posljedicu ima loše planirane projekte. Potrebno je da projekt menadžeri u praksi više pažnje posvete planiranju kroz primjenu adekvatnijih metoda planiranja što će na početku projekta zahtjevati veći utrošak

vremena ali će na kraju projekta dati bolje rezultate i pokazati opravdanost primjene složenijih metoda planiranja.

Radi kompleksnosti i različitosti struktura infrastrukturnih projekata metoda planiranja građenja mora se odabrati vodeći računa o svim dijelovima infrastruktunog projekta kako bi plan što uspješnije bio proveden u djelo.

Međutim, vjerojatno je da niti jedna od postojećih metoda planiranja neće zadovoljiti sve dijelove građenja infrastruktunog projekta. Zbog njihove kompleksnosti infrastrukturni projekti zahtjevaju kombiniranu primjenu različitih metoda planiranja te njihovu prilagodbu uvjetima svakog pojedinog projekta.

Projekti poput mostova ili crpnih stanica mogu biti planirani u posebnih podprojektima i zatim njihovi najvažniji i za projekt potrebni podaci mogu se povezati u vremensko prostornom dijagramu.

Istraživanje primjene tradicionalnih metoda planiranja građenja te pitanja mogućnosti njihove primjene u planiranju modernih instrastrukturnih projekata ukazalo je na mogućnosti i način njihove primjene u prošlosti, neadekavtnu primjenu u sadašnjosti koja se očituje kroz česta pa gotovo i stalna kašnjenja u građenju infrastrukturnih projekata te prekoračenje planiranih troškova za građenje i mogućnost njihove primjene u planiranju budućih projekata. Rad ukazuje na potrebu konstantnog unaprijeđenja tradicionalnih metoda planiranja kroz njihovu kombiniranu primjenu te razvoj novih metoda planiranja kako bi planovi građenja bili što točniji i tako doprinijeli uspješnosti ne samo građenja nego i inftrastrukturnog projekta u cjelosti.

Vodeći računa da će u budućnosti projekti postajati još kompliciraniji i da će se od metoda planiranja građenja zahtijevati primjena na takvim projektima, vrlo će važan biti razvoj metoda planiranja te njihova prilagodba izazovima koje će donijeti karakteristike infrastrukturnih projekata u budućnosti.

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Primjena Six Sigma metodologije za optimalizaciju poslovnih procesa s ciljem povećanja konkurentnost poduzeća na tržištu

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Sažetak

U radu je istražena mogućnost korištenja 6-sigma (*engl. Six sigma*) metodologije za optimizaciju dostave sirovina (*engl. Raw Material Delivery*), sustav čiji je cilj povećanje protoka materijala kroz sustav.

Uslijed očekivanog povećanog obujma proizvodnje, pojavila se potreba za revizijom postojećeg poslovnog procesa koji se odvija svakodnevno, kako bi kapacitet sustava bio dostatan za budući povećani volumen proizvodnje.

Sve aktivnosti vezane uz optimizaciju navedenog procesa provedene su metodom 6-sigma (*engl. Six Sigma*). U prvoj fazi projekta Definiranje (*engl. Define*), su utvrđeni glavni kritični parametri procesa i određeno je mjerenje utvrđenog parametra u zadanom vremenskom periodu. U drugoj fazi Mjerenje (*engl. Measure*), su provedena detaljna mjerenja svih doprema sirovina i obradom dobivenih podataka je dobivena vrijednost sigme 3,2. U trećoj fazi Analiza (*engl. Analyse*), detaljno su analizirali svi dobiveni rezultati mjerenja pomoću kojih su locirana 4 kritična mjesta u procesu. U četvrtoj fazi Unapređenje (*engl. Improve*), su definirane i implementirane 4 modifikacije za unapređenje procesa te je ponovnim mjerenjima dokazana njihova učinkovitost na postojeći sustav. U petoj fazi Nadzor (*engl. Control*), su provedena završna mjerenja i pomoću dobivenih podataka je utvrđena uspješnost implementiranih modifikacija. Rezultati mjerenja pokazali su da je nova vrijednost sigme 3,6.

Povećanje vrijednosti sigme sa 3,2 na 3,6 rezultira povećanjem kapaciteta sustava za dopremu sirovina za 78% čime je i potvrđen odabir odgovarajuće metodologije, a što u konačnici direktno utječe na konkurentnost poduzeća na tržištu.

Ključne riječi: Six sigma; metodologija; poslovni proces; pptimalizacija; RMD; upravljanje projektima

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1. Uvod

Tema ovog rada je optimizacija poslovnog procesa dopreme sirovina. Dio sustava koji je zadužen za dopremu sirovina je PCS-MHS sustav.

Zbog očekivano povećanog obima proizvodnje, pokazala se potreba za unapređenjem postojećeg sustava dopreme sirovina. Postojeći sustav je bio prespor i nedovoljno učinkovit, a posljedica tih nedostataka bila je otežana proizvodnja.

Iz tog razloga pokrenut je projekt optimizacije procesa dopreme sirovina kako bi se povećala iskoristivost postojećeg sustava, a sve u svrhu ispunjenja proizvodnih planova.

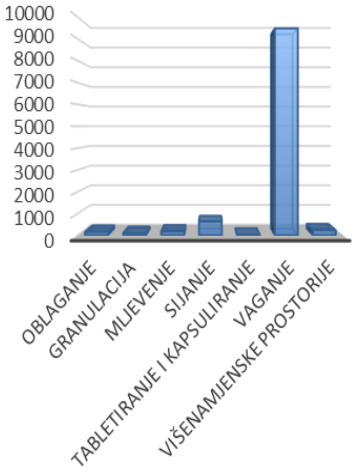
Projekt optimizacije sustava transporta sirovina u prostorije za vaganje proveden je upotrebom Six Sigma metodologije integrirane s metodologijama projektnog menadžmenta. U okviru Six Sigme formiran je projektni tim koji je kroz 5 glavnih faza (*Define, Measure, Analyse, Improve, Control*) na kraju projekta imao pozitivan ishod.

2. Svrha pokretanja projekaa i odabir metodologije

Prema proizvodnom planu i povećanju obima proizvodnje, transport i isporuka sirovina može postati usporavajući faktor u realizaciji proizvodnih procesa.

Prije pokretanja projekta, praovedena su kontrolna mjerenja (Slika 1) na cijelom sustavu transporta sirovina. Rezultati mjerenja pokazali su da se više od 87% svih aktivnosti vezanih za dopremu sirovina odnosi na prostorije za vaganje.

Proizvodne operacije	Ukupan broj dostavljenih sirovina	%	Prosječno vrijeme dostave
Oblaganje	168	1,55	0:06:47
Granulacija	107	0,99	0:07:40
Mljevenje	186	1,71	0:09:15
Sijanje	636	5,86	0:06:40
Tabletiranje i kapsuliranje	30	0,28	0:06:40
Vaganje	9485	87,37	0:05:24
Višenamjenske prostorije	244	2,25	0:06:30



Slika 1. Rezultati kontrolnih mjerenja

Kako je proces vaganja sirovina od vitalnog značaja za sveukupni proces proizvodnje, bilo je evidentno da treba provesti detaljnu analizu postojećeg sustava.

Zadatak je bio da se optimizacijom sustava transporta poveća kapacitet dopreme sirovina u prostorije za vaganje.

2.1. Odabir metodologije – Six Sigma

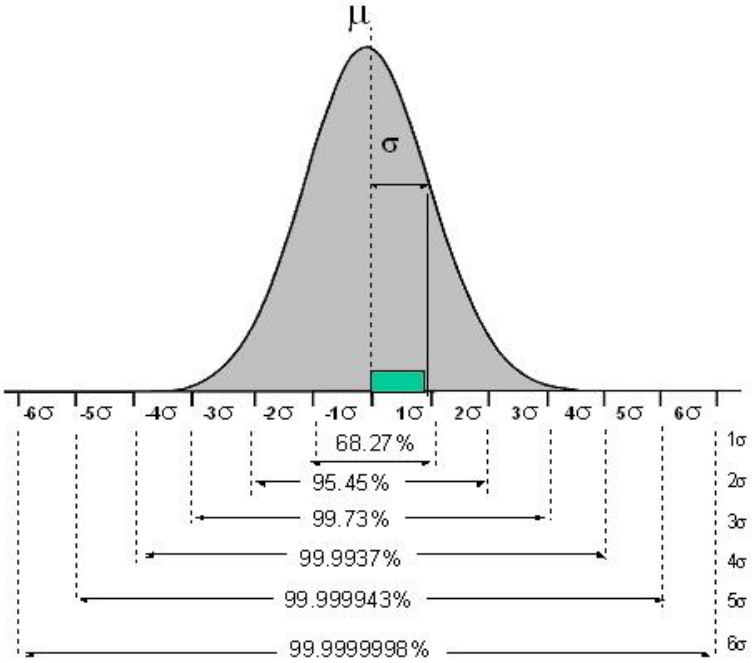
Six Sigma je metodologija usmjerena optimiranju poslovnih procesa i unapređenju operativnih rezultata (Pyzdek, T., Keller, P., 2009.).

Podizanje poslovnih performansi vodi smanjenju nepotrebnih i beskorisnih koraka u procesu, podizanju profita, morala zaposlenika i na kraju, kvalitete proizvoda uslijed uravnoteženog poslovnog procesa.

Six Sigmu kao metodologiju karakterizira sistematičnost jer je bazirana na prikupljenim informacijama obrađenim statističkim metodama, kako bi se mogla nedvosmisleno izvršiti usporedba sadašnjeg i budućeg stanja. Usko je povezana s inicijativom izbjegavanja defekata u dizajnu i procesu, uzevši u obzir potrebe korisnika te zahtjeve svih izravno i neizravno uključenih u proces. Cilj je postići najviši stupanj kvalitete označen sa „6σ“ (šest sigma).

6	3,4	99,99966	<10% prodaje	Svjetska klasa
5	233	99,997	10-15% prodaje	
4	6210	99,38	15-20% prodaje	Industrijski prosjek
3	66807	99,32	20-30% prodaje	
2	308537	69,15	30-40% prodaje	Nekonkurentno
1	690000	30,85	>40% prodaje	

Tablica 1. Six Sigma razine



Slika 2. Six Sigma raspon

3. Model optimizacije PCS-MHS sustava dopreme sirovina

U sljedećim poglavljima biti će opisan projekt optimizacije PCS-MHS sustava dopreme sirovina u prostorije za vaganje. Prema odabranoj Six Sigma metodologiji, definirane su pojedine faze projekta.

3.1. Prva faza – Definiranje (Define)

U prvoj fazi (*Define*) projektni tim provodi nekoliko aktivnosti: kreira Projektnu povelju, analizira sve osobe uključene u proces koji se optimizira (stakeholdere[†]) i ispituje sve

[†] http://www.stakeholdermap.com/stakeholder-definition.html

korisnike tog procesa primjenom VOC (engl. *Voice of Customer*) alata (Pyzdek, T., Keller, P., 2009.).

Rezultat tog ispitivanja (provedenog upitnicima ili fokusnim grupama) je tablica naziva "Kritično kupcu" CTC (engl. *Critical to Customer*).

Kritične parametre koje je korisnik naveo potrebno je povezati s kritičnim parametrima našeg procesa. Taj odnos prikazuje relacija CTC-CTQ (kritično korisniku-kritično za kvalitetu).

Zadatak projektnog tima je da prikazom SIPOC (engl. *Supplier-Input-Process-Output-Customer*) prikaže nekoliko vodećih aktivnosti koje povezuju korisnika i dobavljača svake aktivnosti, potrebne ulazne parametre i rezultate (Pyzdek, T., Keller, P., 2009.).

Time je završena prva faza projekta nakon koje nam je poznat popis kritičnih parametara procesa, a time su nam ujedno poznate i potrebne promjene koje su od najvećeg interesa za korisnika.

3.2. Druga faza – Mjerenje (Measure)

Sljedeća faza je faza mjerenja (*Measure*) u kojoj projektni tim izrađuje detaljan plan prikupljanja podataka.

3.2.1. Plan prikupljanja podataka

Plan prikupljanja podataka DCP (engl. *Data Collection Plan*), određuje koji podaci će biti prikupljeni tijekom Six Sigma projekta (Pyzdek, T., Keller, P., 2009.). Ovakav plan pruža okvir za dokumentiranje podataka koji su potrebni te što, gdje, kada i kako oni trebaju biti prikupljeni.

U prvoj fazi projekta postavljen je korisnički zahtjev kojim je definirano vrijeme dostave sirovina u prostorije za vaganje. To znači da sirovine moraju biti dostavljene u maksimalnom roku od 15 minuta. Prema tom zahtjevu kreiran je plan prikupljanja podataka prikazan u tablici (Tablica 2.).

Postupak mjerenja	
Što se mjeri?	Vremenski ciklus / dostavljena paleta
Kako se provodi mjerenje? (Operativna definicija mjerenja)	Sva kretanja kroz sustav MHS-a prate se i pohranjuju u proizvodnu bazu podataka (2 mjeseca) i dodatna 4 mjeseca u arhivsku bazu. Korištenjem softverskog alata potrebno je prikupiti podatke iz Oracle baze podataka - sva kretanja vezana uz dopremu sirovina.
Tko mjeri?	Six Sigma tim
Otkada mjerimo?	01.01.
Do kada mjerimo?	30.04.
Koliko često mjerimo u određeno vrijeme?	Sve dostave tijekom faze mjerenja
Status mjerenja	Zatvoren
Podaci o uzorku	
Vrsta podataka	Neprekidna
Minimalna veličina uzorka	Sve dostavljene palete unutar mjerenog vremena

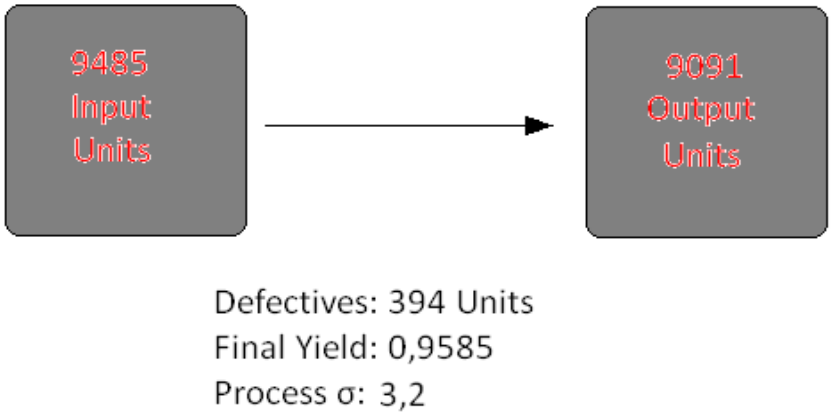
Izvor uzorka	Oracle – proizvodna baza podataka i arhivska baza
Faktori segmentacije	
Faktori segmentacije 1	Prostorija za vaganje
Faktori segmentacije 2	Broj istovremeno zauzetih prostorija za vaganje
Faktori segmentacije 3	Tip smjenskog rada (jutarnja, popodnevna, noćna)

Tablica 2. Plan prikupljanja podataka

3.2.2. Defekti i standardna devijacija

Izvor	Destinacija	Broj misija	Prosječno trajanje	Omjer misija	Ukupno vrijeme	Preko 15 min	Preko 15 min	Standardna devijacija
Skladište	Sve vagaone	3811	0:07:39	40,18%	485:50:54	**268**	**7,03%**	**0:07:52**
Priručno skladište (Buffer)	Sve vagaone	5674	0:03:54	59,82%	368:05:32	**126**	**2,22%**	**0:05:31**
	Sve vagaone	9485	0:05:24		853:56:26	**394**	**4,15%**	**0:06:49**

Tablica 3. Odnos defekata i standardne devijacije



Slika 3. Final Yield – broj jedinica koje prođu kroz proces bez greške

3.3. Treća faza – Analiza (Analyze)

Faza analize (*Analyze*) je zapravo postupak traženja uzroka grešaka.

Detaljno se mapira sam proces, na njemu se označavaju točke defekata i traži se uzrok. To se provodi korištenjem raznih tehnika analize uzroka, primjerice dijagramom "Riblja kost"[‡] (engl. *Fishbone – Ishikawa diagram*), FMEA (engl. *Failure Mode and Effect Analysis*), "5 zašto", itd... Kada smo pronašli uzrok problema i kada je on potvrđen provjerom, možemo krenuti u traženje rješenja (Pyzdek, T., Keller, P., 2009.).

[‡] http://en.wikipedia.org/wiki/Ishikawa_diagram

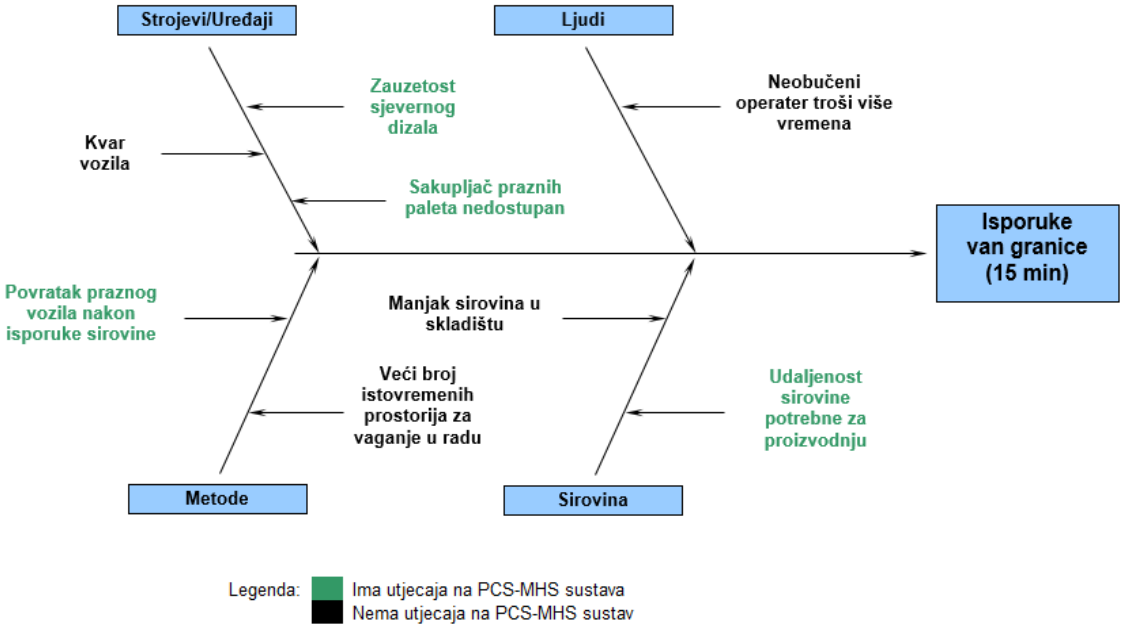
Rješenje problema generirano je u fazi analize, a primjenjuje se u fazi unapređenja (*Improve*).

3.3.1. Analiza podataka

U fazi mjerenja, praćena je isporuka sirovina kroz sveukupno kretanje od skladišta do prostorija za vaganje sirovina. Kretanje vozila unutar PCS-MHS sustava podijeljeno je u segmente.

U fazi analize, kretanja su promatrana kroz segmente (trajanje uzimanja sirovina iz skladišta, trajanje horizontalnog i vertikalnog transporta, trajanje dostave sirovina na odredište, itd...).

Uz pomoć *Ishikawa* dijagrama (Slika 4.) pokušavamo pronaći moguće uzroke grešaka.

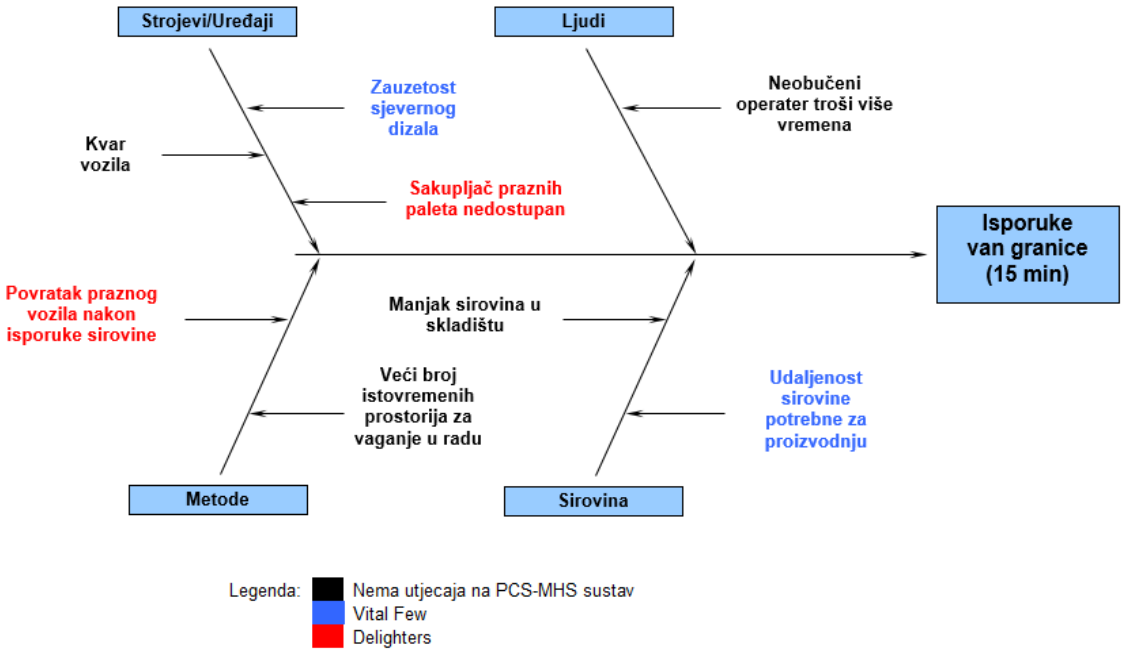


Slika 4. Ishikawa dijagram

Radi se podjela na one na koje imamo utjecaja i one na koje nemamo (na njih u okviru ovoga projekta ne možemo utjecati i nalaze se izvan obuhvata).

Daljnjom analizom izdvaja se nekoliko vitalnih (engl. *Vital Few*) dijelova sustava koji su nam interesantni i mogu voditi do unapređenja procesa (Brue, G., 2009).

Kratkim opisom sustava potvrđuju se identificirana mjesta za unapređenje procesa.



Slika 5. Ishikawa dijagram – kraj treće faze

3.4. *Četvrta faza – Unapređenje (Improve)*

U fazi unapređenja (*Improve*), projektni tim provodi korektivne mjere u procesu, izdaje novu dokumentaciju, vrši promjene u informatičkim sustavima, provodi edukaciju, izdaje nove proizvodne propise, itd.

Ta faza je kritična jer u njoj se počinje nazirati konačni oblik novog promijenjenog procesa. Kraj djelovanja na samom procesu ujedno je i kraj ove faze po Six Sigma metodologiji.

3.4.1. *Definiranje rješenja*

U prethodnoj fazi analize identificirana su dva mjesta unapređenja procesa dopreme sirovina u prostorije za vaganje.

1. Problem zauzetosti sjevernog dizala
2. Velika udaljenost sirovina potrebnih za proizvodnju

Sve promjene bazirane su na softverskoj promjeni algoritma (kôda), a obuhvaćaju promjenu puta kretanja vozila koja dopremaju sirovine u prostorije za vaganje.

Rješenje problema definirano je kroz četiri modifikacije koje će obuhvatiti glavne promjene navedene u nastavku:

- nema više kružnog kretanja vozila, odnosno odlazaka vozila s 11. razine preko sjevernog dizala i povratak vozila preko južnog dizala
- da bi vozilo otišlo s 11. razine na neku od razina 2-17 ili u hladne prostorije smještene na sjevernoj strani 1. razine, za to koristi južno dizalo, a isto južno dizalo koristi za povratak vozila na 11. razinu
- vozilo koje treba pristup sjevernom prostoru na 1. razini gdje su smještene tekuće sirovine, koristi sjeverno dizalo za odlazak i povratak
- vozila se više neće vraćati prazna (bez palete i sirovina na njoj) na 11. razinu, već kada je to moguće, vozilo koje vraća određenu sirovinu na paleti u skladište (razine 1-17)

prilikom svojeg povrataka uzima sljedeću potrebnu paletu te je dovozi na 11. razinu i isporučuje u prostoriju za vaganje

U tablici (Tablica 4.) navedene su četiri modifikacije s napomenom da se modifikacije 1 i 3 odnose na "*vital few*", dok 2 i 4 spadaju u "*delighters*" modifikacije.

	Opis
Modifikacija br.1	Izbjegavanje čekanja na sjeverno dizalo – za sva kretanja prema ostalim razinama (1-17) vozila koriste južno dizalo
Modifikacija br.2	Eliminiranje praznih kretanja deklariranih vozila prema prostorijama za vaganje
Modifikacija br.3	Promjena prioriteta za izvršavanje isporuke sirovina – vozila za dopremu sirovina u prostorije za vaganje imaju najviši prioritet
Modifikacija br.4	Promjena prioriteta procesa vaganja prilikom startanja rada više od jedne prostorije za vaganje

Tablica 4. Modifikacijske faze – "Vital Few" & "Delighters"

3.4.2. Utjecaj promjena na postojeći sustav i direktna korist

Analizirani podaci temelje se na proizvodnji u prva četiri mjeseca tekuće godine. Prikazana je direktna korist i učinak na rad prostorija za vaganje. Očekuje se i onaj indirektni učinak uslijed rasterećenja čitavog MHS sustava (rasterećenje sjevernog dizala i zbog toga smanjen broj kretanja vozila). Povećanjem obima proizvodnje i očekivana korist se linearno povećava.

- Korist uslijed kraćeg trajanja dopreme sirovina iz skladišta u prostore za vaganje:

Ovu korist dobivamo promjenom algoritma (*software*) na način da sva kretanja od prostorija za vaganje prema skladištu i natrag idu preko južnog dizala koje prevozi isključivo vozila s paletama. Uslijed toga, južno dizalo ima znatno kraće trajanje kretanja u odnosu na sjeverno dizalo koje uz vozila s paletama prevozi i drugi tip vozila.

U tablici (Tablica 5.) prikazan je vremenski omjer dopreme sirovina prije i poslije provedene modifikacije u periodu od siječnja do svibnja.

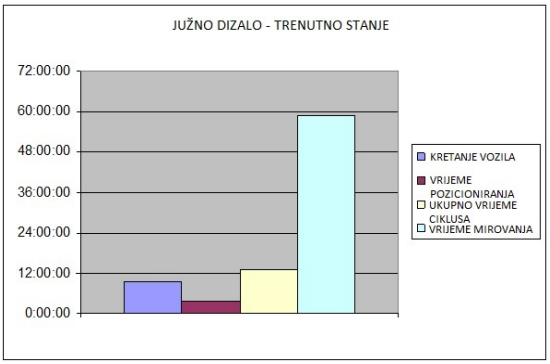
01/Siječanj – 01/Svibanj	Iz	U	Broj isporučenih paleta	Prosječno trajanje	Ukupno vrijeme
Prije modifikacije	Skladište	Sve vagaone	3811	0:07:39	485:54:09
Nakon modifikacije	Skladište	Sve vagaone	3811	0:06:52	436:08:52

Tablica 5. Usporedba prije i poslije modifikacije

Direktno na modifikaciju dopreme sirovina korištenjem južnog dizala, postavlja se pitanje njegova opterećenja. Iz tog razloga napravljena je priložena analiza opterećenja južnog dizala i projekcija nakon implementirane modifikacije algoritma (*software*).

U tablici (Tablica 6.) i priloženom grafikonu prikazano je trenutno opterećenje južnog dizala. Vidljivo je da južno dizalo posjeduje veliko vrijeme mirovanja što nam daje prostora za implementaciju potrebne modifikacije.

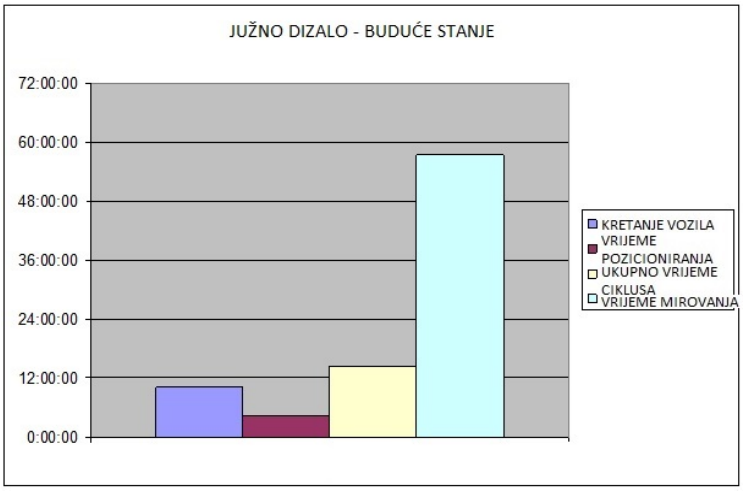
Vrijeme kretanja vozila	9:08:40	12,70%
Vrijeme pozicioniranja	3:50:38	5,34%
Ukupno vrijeme ciklusa dopreme	12:59:18	18,04%
Vrijeme mirovanja	59:00:42	81,96%
Broj kretanja vozila	890	
Broj pozicioniranja	629	
Broj ukupnih kretanja	1519	



Tablica 6. Trenutno stanje – južno dizalo

Kroz projekciju budućeg stanja (Tablica 7.), potvrđena su predviđanja da južno dizalo nije i neće biti mjesto zagušenja procesa dostave sirovina. Izračun se temelji na podacima proizvodnje prikupljenim od 01. siječnja do 01. svibnja kada je proizvedeno „xyz“ ljekovitih pripravaka.

Trenutna proizvodnja	Trenutna kretanja	Dodatna kretanja	Ukupna kretanja
Broj kretanja vozila	890	96	986
Broj dodatnih kretanja	629	69	698
Ukupan broj kretanja	1519	165	1684
	Vrijeme kretanja vozila	10:08:02	14,07%
	Vrijeme pozicioniranja	4:15:56	5,92%
	Ukupno vrijeme ciklusa kretanja	14:23:58	20%
	Vrijeme mirovanja	57:36:02	80%



Tablica 7. Buduće stanje – južno dizalo

Prikazanim primjerom dokazala se svrhovitost navedene modifikacije. Rasterećenjem sjevernog dizala i promjenom algoritma za kretanje vozila sa i prema 11. razini smanjilo se

vrijeme potrebno za dopremu sirovima u prostorije za vaganje. Povećanjem kapaciteta i bržim vremenom dopreme sirovina odgovorilo se na zahtjeve proizvodnje.

Modifikacije koje su označene kao „*Delighters*“ opisat ću samo u kratkim crtama jer su vezane uzročno posljedičnom vezom s „*Vital Few*“ modifikacijama.

3.4.3. Povezanost „Delighters“-a i vitalnih dijelova sustava

Modifikacija 2: Eliminiranje praznih kretanja deklariranih vozila prema prostorijama za vaganje

- Dosadašnji način rada – vozilo preuzima nalog za dopremom sirovine na paleti u prostoriju za vaganje, odlazi po potrebnu sirovinu, dostavlja sirovinu u prostoriju za vaganje, odlazi na definiranu poziciju i čeka sljedeći nalog.
- Novi način rada – nakon obavljenog naloga za dopremom sirovine, vozilo ne odlazi na poziciju za čekanje, već provjerava postoji li sljedeći nalog i kreće u izvršavanje, a ako ne postoji, tada odlazi na definiranu poziciju za čekanje

Modifikacija 4: Promjena prioriteta procesa vaganja prilikom startanja rada više od jedne prostorije za vaganje

Prilikom preuzimanja naloga za dopremu sirovina, sustav nudi nekoliko prioriteta, a raspon može biti od 1 do 10. Vozila za dopremu sirovina ravnaju se po dobivenom prioritetu, tj. što je prioritet niži prije se pokreće njegovo izvršavanje.

- Dosadašnji način rada: ako istovremeno startaju dvije prostorije za vaganje i prva svoje naloge postavi s prioritetom 1, a druga s prioritetom 5, tada će se dogoditi situacija da druga prostorija svoje sirovine potrebne za fazu vaganja dobije tek kada prva odradi svoje naloge.
- Novi način rada – startanjem dviju prostorija za vaganje postavljeni prioriteti su isti, pošto se radi o sekvencama kreiranim u dijelovima sekunde. Osim postavljenog prioriteta provjerava se i vrijeme kreiranja naloga za dostavu sirovine koje je zapisano u milisekundama. Na ovaj način mogu raditi dvije i više prostorija za vaganje u isto vrijeme, a da jedna drugu ne čeka na isporuku sirovina.

3.5. Peta faza – Nadzor (Control)

Posljednja faza je faza nadzora (*Control*). Cilj svakog projekta je da se trajno izmjeni stanje i unaprijedi poslovanje. Nakon što se izmijenilo stanje, bitno je da ono postaje novi standard i da se osigura kontinuirano upravljanje po novom sustavu. To omogućuje sustav korektivnih i preventivnih mjera u slučajevima ponovljenih defekata.

Obzirom da su poznate indikacije i način kojim su one jednom uklonjene, važno je da to postane službeni postupak u takvim situacijama. Vlasnici procesa se mogu mijenjati, ali postupci ostaju.

Konačni izvještaj znači i kraj rada na projektu u kojem se računaju uštede, odnosno sve promjene koje su napravljene na procesu.

3.5.1. Plan nadzora modificiranog sustava

Nakon implementacije svake definirane faze provedeno je testiranje kako bi se potvrdio utjecaj na ukupne performanse sustava.

U slučaju smanjenja performansi sustava nakon softverske modifikacije, vraća se posljednja valjana verzija softvera na kojoj je sustav ispravno funkcionirao, a nova se dorađuje dok ne bude ponovo spremna za implementaciju na sustav.

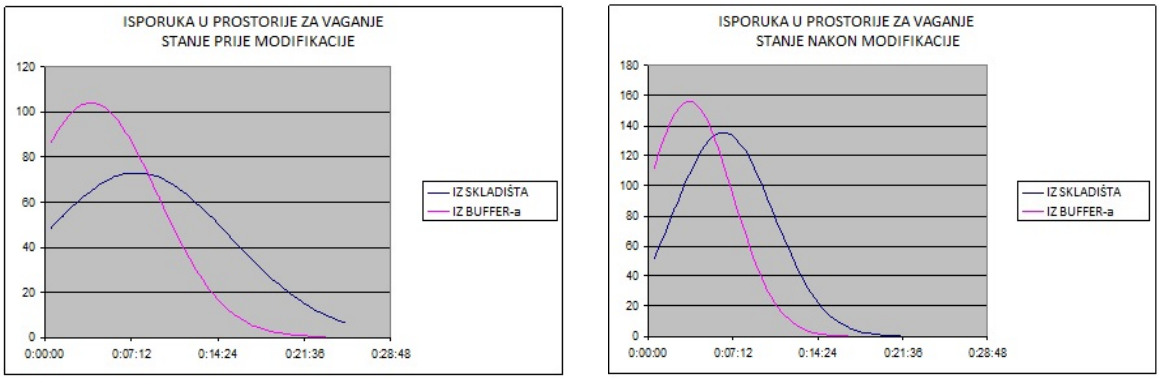
3.5.2. Stanje prije i nakon implementiranih modifikacija

Faza kontrole obuhvaća stalni nadzor i kontrolu implementiranih modifikacija na sustavu. Mjerenja performansi i ponovna analiza prikupljenih podataka pokazuju nam funkcionira li sustav onako kako je definirano.

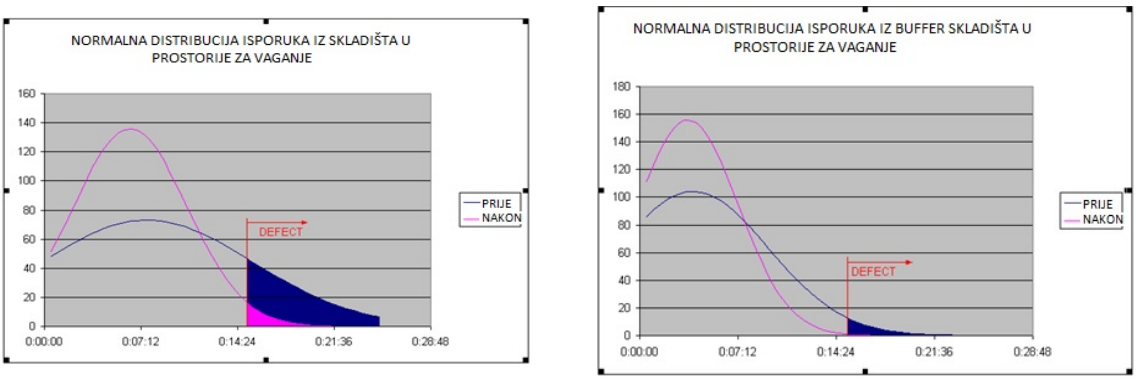
U nastavku slijedi niz tablica i grafikona koji prikazuju odnose performansi sustava prije i nakon provedenih modifikacija.

PRIJE MODIFIKACIJE	Broj misija	Prosječno trajanje	Standardna devijacija	Defekti (>15 min)
Jedna prostorija za vaganje	77,31%	0:04:31	0:05:16	2,02%
Dvije prostorije za vaganje	20,90%	0:07:00	0:08:45	8,13%
Tri prostorije za vaganje	1,79%	0:12:41	0:10:25	23,07%
Ukupno	2177 (100%)			
NAKON MODIFIKACIJE	Broj misija	Prosječno trajanje	Standardna devijacija	Defekti (>15 min)
Jedna prostorija za vaganje	28,74%	0:04:25	0:04:38	1,81%
Dvije prostorije za vaganje	48,69%	0:05:05	0:06:08	3,43%
Tri prostorije za vaganje	22,57%	0:05:46	0:06:58	4,63%
Ukupno	957 (100%)			

Tablica 8. Stanje prije i nakon modifikacije



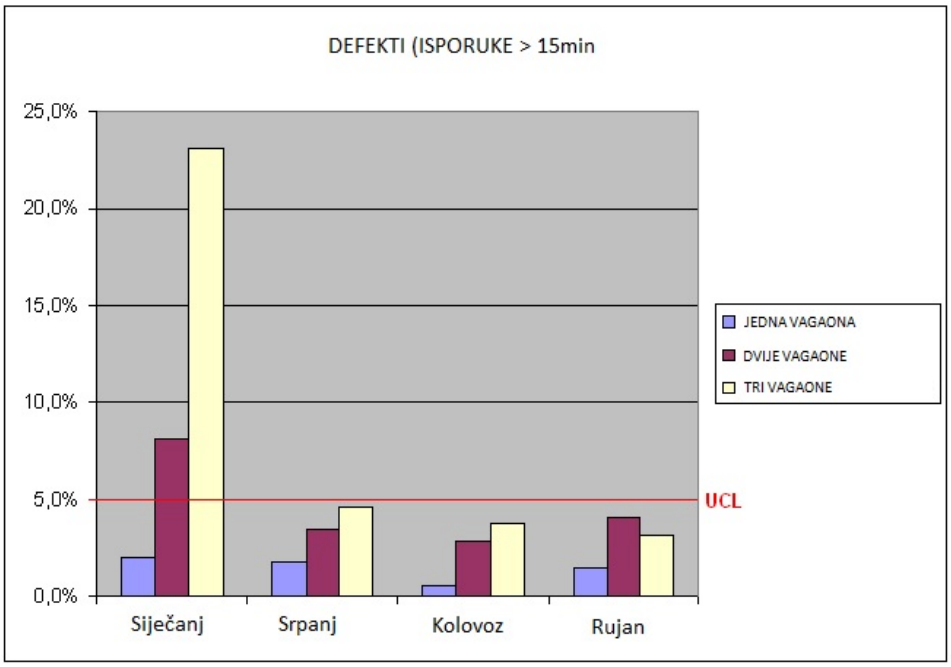
Slika 6. Broj defekata – prije i nakon modifikacije



Slika 7. Normalna distribucija skladišta i buffer skladišta

Završetkom kontrolnih mjerenja postavljena je gornja granica kontrole UCL (engl. *Upper Control Limit*) i iznosi 5% svih defekata bez obzira koliko prostorija za vaganje istovremeno radi (Pyzdek, T., Keller, P., 2009.). Zadatak projektnog tima je da kvartalno provodi kontrolna mjerenja. Ukoliko se dogode značajnija odstupanja, provest će se detaljna analiza kako bi se pronašla odstupanja i ponovo uspostavila kontrola sustava.

Na slici (Slika 8.) je vidljiv omjer defekata prije i nakon modifikacije pri čemu je UCL postavljen na 5% onih defekata koji prelaze vremensku granicu isporuke veću od 15 minuta.



Slika 8. UCL granica 5% svih defekata iznad 15min

3.5.3. Završni prinos – Final Yield

Tijekom cijele prošle godine, prije optimizacije, sustav je bio u mogućnosti isporučiti maksimalno 18.768 paleta sa sirovinama. Nakon izvršene optimizacije i implementiranim modifikacijama sustav je u mogućnosti isporučiti 33.496 paleta sa sirovinama.

Odnos između početnog i završnog prinosa vidljiv je iz slike (Slika 7.).

Slika 9. Završni prinos – Final Yield

4. Zaključak

Upotrebom Six Sigma metodologije i tehnika vođenja projekata, postigli smo glavni cilj projekta, a to je optimizacija poslovnog procesa dopreme sirovina.

U prvoj fazi projekta Definiranje (*Define*), ustanovili smo da je glavni kritični parametar procesa spora doprema sirovina i odredili mjerenje utvrđenog parametra unutar 15 minuta. U drugoj fazi Mjerenje (*Measure*), proveli smo detaljna mjerenja svih doprema sirovina te obradom dobivenih podataka dobili vrijednost sigme 3,2. U trećoj fazi Analiza (*Analyse*), detaljno smo analizirali sve dobivene rezultate mjerenja pomoću kojih smo locirali 4 kritična mjesta u procesu. U četvrtoj fazi Unapređenje (*Improve*), definirane su i implementirane 4 modifikacije za unapređenje procesa te je ponovnim mjerenjima dokazana njihova učinkovitost na postojeći sustav. U petoj fazi Nadzor (Control), proveli smo završna mjerenja i pomoću dobivenih podataka ustvrdili uspješnost implementiranih modifikacija. Rezultati mjerenja pokazali su da je nova vrijednost sigme 3,6.

Povećanje vrijednosti sigme sa 3,2 na 3,6 rezultirala je osjetnim povećanjem kapaciteta sustava za dopremu sirovina za 78 %. To konkretno znači da je prije pokretanja projekta sustav godišnje mogao isporučiti 18768 paleta sa sirovinama, a nakon izvršene optimizacije taj broj povećao se na 33496 paleta.

Iz ovih rezultata možemo zaključiti da je projekt bio uspješan jer je direktno utjecao na povećanje proizvodnje.

Odabir prave metodologije svakako jest bitan faktor za uspješnost nekog projekta, ali tu treba istaknuti i veliki doprinos timski uigranog i stručno osposobljenog kadra.

Općenito, optimizacije poslovnih procesa bitan su čimbenik koji u konačnici direktno utječe na konkurentnost poduzeća na tržištu.

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Sustav za Upravljanje incidentima i promjenama temeljen na ITIL standardu

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Sažetak

Odlučeno je da će se razviti skup metodologija i pratećih alata za upravljanjem kompleksnim integriranim poslovno-informacijskim sustavom. Odabran je ITIL kao dobro poznati skup standarda i preporuka za upravljanjem informacijskim sustavom. Prepoznate su dvije kategorije ITIL-a, Upravljanje incidentima i Upravljanje promjenama poslovno informacijskog sustava kao kategorije koje su se u praksi upravljanja konkretnim sustavom već koriste, ali metodološki i tehnološki nisu dovoljno razvijene (za prijavu incidenata koristi se elektronička pošta, a za evidenciju excel tablice; slično je i kod zahtjeva za promjenom, koriste se excel tablice).

Od implementacije rješenja za upravljanje incidentima očekuju se sljedeće koristi: minimiziran utjecaj incidenta na kontinuitet poslovnih procesa i omogućeno mjerenje performansi s ciljem optimiziranja rada svih komponenti sustava.

Od implementacije rješenja za upravljanje promjenama očekuje se efikasno i sustavno vođenje iniciranih promjena, bolja kontrola kvalitete implementacije promjene, i poboljšana razina dokumentiranosti sustava. GAP analiza je pokazala stanje prije provedbe projekta, projekciju željenog stanja na koji način doći do rješenja. U članku su opisani poslovni procesi i softverska arhitektura sustava. Implementirani sustav je trenutno u funkciji te se može potvrditi da je ispunio ciljeve povećanja efikasnosti, ekonomičnosti i pouzdanosti sustava uz smanjenje mogućih rizika na rad sustava.

Ključne riječi: upravljanje promjenama; upravljanje incidentima; ITIL metodologija; upravljanje projektima; informacijski sustav

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1. Uvod

Integrirani sustav Državne riznice je složen sustav koji se sastoji od sljedećih komponenti: SAP transakcijskog sustava i BI sustava s modulom za planiranje proračuna, EDEG sustava (Electroni Document Exchange Gateway), koji služi kao sučelje za izmjenu podataka sa financijskim sustavima proračunskih korisnika s jedne strane i SAP transakcisjkim sustavom Državne riznice s druge strane, MDM (Master Data Management) sustav za središnje održavanje računa dobavljača i banaka, sustava za podršku deviznom poslovanju, informacijskog sustava za proračunske klasifikacije, sustava za izradu proračunskih obrazloženja, sustavu za procjenu financijskog učinka i aplikacije za upravljanje korisničkim računima. Trenutno integrirani sustav ima više od 400 imenovanih korisnika, više od 500.000 transakcija godišnje, i 15 integriranih financijskih sustava korisnika proračuna, uz još tri u pripremi.

Svi ovi sustavi su međusobno povezani i međusobno izmjenjuju informacije. Dodatno, preko EDEGa su povezani i financijski sustavi proračunskih korisnika. MDM sustav je povezan s JRR-om, registrom svih računa koji mogu sudjelovati u platnom prometu u Hrvatskoj. Sustav za podršku deviznom platnom prometu je povezan s Hrvatskom narodnom bankom preko koje se vrše devizna plaćanja. UKR sustav služi za upravljanje korisničkim računima u LDAP servisu (Lightweight Directory Access Protocol), u kojem se nalaze korisnički računi kojima se korisnici spajaju na sve ove sustave.

Upravljanje takvim složenim sustavom bez odgovarajuće metodološke i softverske podrške alata je postalo otežano. Zbog toga je pokrenut projekt izrade rješenja za upravljanje takvim integriranim poslovno-informacijskim sustavom, temeljenim na ITIL metodologiji.

2. Problemi u postojećem sustavu upravljanja

Pokrenut je projekt s ciljem odabira metodologije i implementacije informatičkog alata pod nazivom Sustav za upravljanje incidentima i promjenama (SUIP). **Opći cilj** tog projekta je podići razinu pouzdanosti, efikasnosti i ekonomičnosti cijelog sustava. **Posebni ciljevi** koji se žele ostvariti: neprekinut rad sustava uz najkraće moguće vrijeme rješavanja prekida rada sustava uzrokovanih incidentima i kontrolom nad procesom implementacije promjena bilo koje komponente sustava. Time će povećati vrijeme dostupnosti sustava uz manje trajanje prekida rada što utječe na efikasnost, bolja raspodjela resursa i timova koji rade na implementaciji promjena – što utječe na ekonomičnost, te bolja dokumentiranost sustava i kontrola kvalitete, koji utječu na pouzdanost cijelog sustava. Dodatno su kod pokretanja projekata definirani konkretni sljedeći načini na koji se želi ostvariti te ciljeve: kod modula za upravljanje incidentima želi se postići promptnost u rješavanju incidenta tako da cijela povijest incidenta ostane zapisana. To je pogotovo važno na incidentima koji se događaju na periodičkim poslovima (npr. priprema proračuna koja se radi jednom godišnje). Dodatno, kad dođe do incidenta, općenito je prioritet što brže rješavanje incidenta. Zato je potrebno imati metodologiju i alat koji će osigurati da cijeli tijek ostane zapisan za kasnije analize. Sustav treba omogućiti analize po raznim kategorijama, npr. dobavljačima, korisnicima, sustavima, prosječnom vremenu rješavanja incidenta i slično. Te analize moraju omogućiti pokretanje daljnjih akcija, npr. kod učestalih incidenata redizajn korisničkog sučelja, ili poslovnog procesa. Kod korisnika kod kojih su incidenti učestaliji nego kod ostalih, možda postoji potreba za kvalitetnijom edukacijom. Potrebno je još i omogućiti izradu baze znanja u kojoj će uz mogućnost pretraživanja biti opisani svi incidenti.

Kod upravljanja promjenama, želi se postići da svi sudionici imaju informaciju kad se mijenja određena komponenta sustava, čak i kad nisu izravni korisnici te komponente, jer korisnici koji nisu upoznati s promjenom mogu koristiti sustav na pogrešan način, ili pogrešno

interpretirati informacije iz sustava i slično. To je posebno važno u integriranom sustavu, s velikim brojem sustava povezanih sa središnjim sustavom. Potrebno je analizom ustanoviti da li neka promjena ima utjecaja na povezane sustave, i osigurati da svi imaju informaciju o tome. Nadalje treba osigurati da svi povezani sustavi pravilno implementiraju promjenu, obave testiranje i slično. Najmanja promjena može imati neželjene posljedice na drugom dijelu sustava koji naizgled ne mora imati veze s tom promjenom. Zahtjevi za promjenom moraju proći korake registriranja, analize, procjenu složenosti, dodjelu prioriteta i odobravanje. Želi se postići da izvođači, odnosno tehnički timovi dobiju jasan radni nalog registriran u bazi sustava, umjesto telefonskih poziva iza kojih ne ostaje analiza i tragovi. Izvođači tako mogu bolje planirati svoj posao. S druge strane to omogućuje kvalitetnije praćenje rada izvođača i njihovih ugovora, što na kraju utječe na ekonomičnost sustava. Na pouzdanost sustava utječe i povećanje razine kontrole kvalitete koje se očekuje od ovog projekta. Kontrola kvalitete treba garantirati da je u toku implementacije neke promjene provedeno i dokumentirano testiranje promjene, da je izmijenjena i prilagođena dokumentacija sustava, i da je prema potrebi održana dodatna obuka korisnika sustava. Kasnije analize bi trebale pružiti podatke kao što su tko podnosi najviše zahtjeva, čiji se zahtjevi prihvaćaju odnosno odbijaju, koliko traje izvršavanje zahtjeva, koliko su točne procjene izvođača, kod kojih sustava dolazi do najviše problema na testiranju i slično.

2.1 Postojeći način upravljanja integriranim sustavom i prisutni problemi

Prva faza projekta bila je izrada GAP analize koja je detektirala razlike između postojećeg i željenog stanja na razini procesa i alata. Neki od nedostataka navedenih postojećem stanju u GAP analizi za Upravljanje incidentima su sljedeći: procedure koje se koriste su neformalne i nekonzistentne i ne provode se dosljedno, incidenti se prijavljuju telefonom i elektroničkom poštom i prosljeđuju se na rješavanje elektroničkom poštom ili telefonom, pristup podacima o incidentima je moguć samo operaterima koji imaju pristup tom računu elektroničke pošte, zbog nepostojanja središnje baze podataka o incidentima nije moguće detektirati incidente koji se ponavljaju i riješiti ih na odgovarajući način, podaci o incidentima se nalaze na više mjesta i nije moguća kvalitetna analiza.

U procesu Upravljanja promjenama, procedure su definirane i postoje, ali se zbog nepostojanja informatičkog alata provode ručno pomoću elektroničke pošte i proračunskih tablica. Djelatnici službe za razvoj i podršku sustavu odgovorni su za analizu i evaluaciju zahtjeva, što je u nekim slučajevima pogrešno.

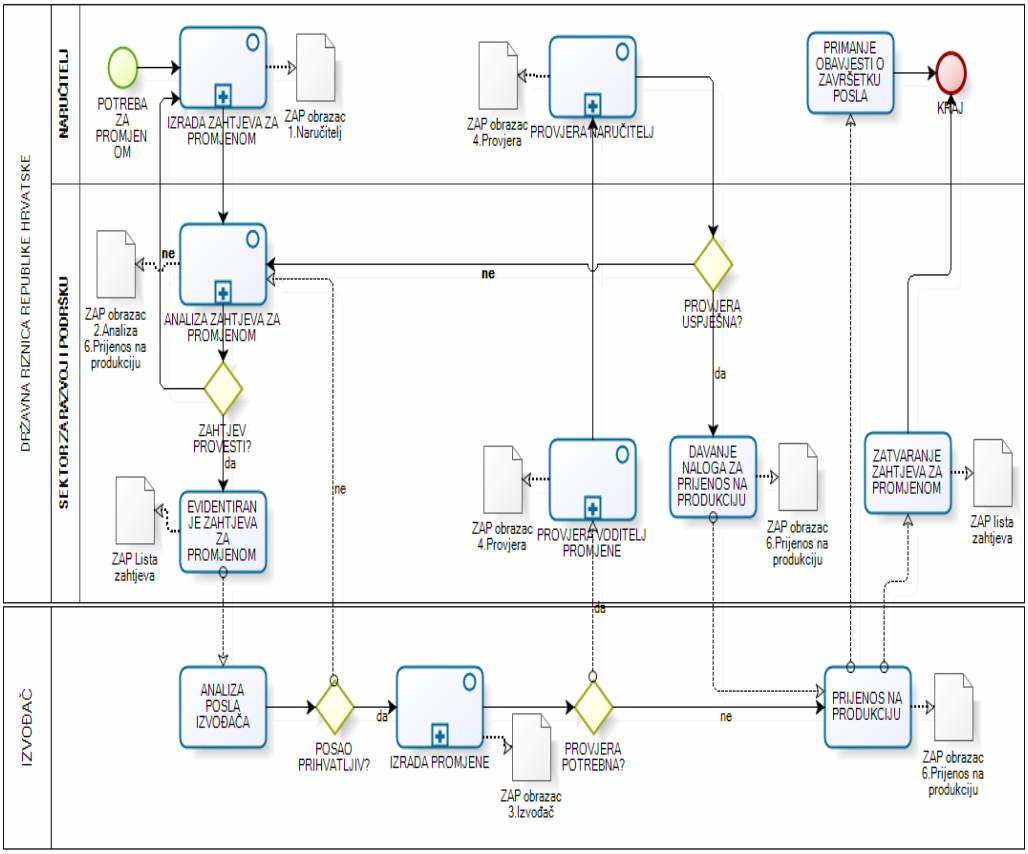
2.2 Postojeći alati

Postojeći alati ne dozvoljavaju primjenu razvijenije metodologije kakva je npr. ITIL. Za upravljanje incidentima se koristi elektronička pošta. Korisnici prijavljuju incidente u slobodnom formatu na generičku adresu elektroničke pošte koja je otvorena samo za tu namjenu. Operater na service desku analizira incidente i rješava one koje je moguće odmah. Incidente koji zahtijevaju daljnju analizu prosljeđuje na drugu razinu gdje je zaprimaju djelatnici koji pružaju podršku za određena područja ili određene sustave, ili odgovarajućim tehničkom timovima. Iz samog alata je očito da nije moguće dobiti statističke podatke niti izvještaje o incidentima. Dodatno, jedan tehnički tim je osigurao svoj vlastiti alat za prijavu incidenata, pa se incidenti prepisuju u njihov alat. Komunikacija sa svim drugim timovima odvija se putem elektroničke pošte ili telefona.

Proces upravljanja promjenama je podržan predefiniranim excel obrascima u kojima sudionici u procesu mogu opisati svoje zahtjeve za izmjenom. Obrazac se kroz prilično kompliciranu proceduru kopira u drugi excel obrazac koji ima ulogu središnje baze podataka svih zahtjeva. Taj alat podržava zamišljeni poslovni proces prilično dobro, međutim zbog

neadekvatnog alata njegova upotreba nije nikad zaživjela. Stoga može poslužiti prilikom definiranja i izgradnje novog sustava.

Na slici 1. se vide tri osnovne grupe sudionika. Naručitelj koji podnosi zahtjev, Sektor za razvoj i podršku je organizacijska jedinica koja upravlja cijelim postupkom, i izvođač u koje spadaju tehnički timovi za pojedine sustave. GAP analiza je procijenila da je ovako opisani proces dobra osnova koju treba samo detaljnije razraditi i podržati odgovarajući informatičkim alatima.



Slika 1.: Dijagram toka za postojeći proces Upravljanja promjenama.

3. ITIL metodologija

ITIL pokriva sljedeće glavne module (Bon J., 2009.): Strategija servisa, Dizajn servisa, Tranzicija servisa, Redovni rad servisa, Trajno unapređenje servisa.

3.1. Strategija servisa

Ovdje je važno napomenuti da se ITIL okrenuo sa središnjeg fokusa na razvoj aplikacija još '90-tih godina, prema pružanju informatičkih servisa. Definicija servisa kako je navodi ITIL je sljedeća: *„Usluga je način isporuke vrijednosti kupcu koja će mu olakšati postizanje ciljeva koje kupac želi postići bez da posjeduje sva potrebna sredstva i snosi sve rizike.“*

Strategija servisa se bavi temama kao što su definicija tržišta, tipovima vanjskih i unutarnjih pružatelja usluga, imovinom potrebnom za rad servisa, portfeljem servisa i implementacijom strategije kroz životni vijek servisa. Dodatno se još strategija servisa bavi upravljanjem financija, zahtjeva na servis, razvojem organizacije i strateškim rizicima.

3.2. Dizajn servisa

U životnom ciklusu servisa, dizajn je faza u kojoj se strategija pretvara u nacrte za postizanje poslovnih ciljeva. Dizajn servisa pokriva principe i metode za pretvaranje strateških ciljeva u portfeljem servisa. Poglavlje o dizajnu servisa osim izradom novih servisa, bavi se i izmjenama i poboljšanjima postojećih servisa, dostupnošću servisa, postizanju određenih razina te pridržavanja standarda i pravila.

3.3. Tranziciju servisa

Poglavlje o tranziciji servisa bavi se prijelazom novih i unaprijeđenih servisa iz faze razvoja u živu produkcijsku fazu. Tu su opisane metodologije promjene i konfiguracije servisa, verzije, puštanje u rad, upravljanja rizicima.

3.3.1. Upravljanje promjenama

Upravljanje promjenama je komponenta ITIL-ovog modula Tranzicije servisa. Upravljanje promjenama je korak u procesu tranzicije servisa, koji se sastoji od sljedećih koraka:

- Planiranje i podrška tranziciji
- *Upravljanje promjenama*
- Upravljanje konfiguracijom i imovinom
- Upravljanje verzijama i isporukama
- Validacija i provjera servisa
- Evaluacija
- Upravljanje znanjem

Promjena servisa je dodatak, modifikacija ili uklanjanje odobrenog, planiranog i održavanog servisa i njegove dokumentacije (Klosterboer L., 2009.).

Uzroci promjena IT sustava mogu biti proaktivni, u svrhu smanjenu troškova, lakšeg korištenja IT servisa i učinkovitije podrške, ili reaktivni, zbog rješavanja grešaka, prilagodbe izmijenjenim okolnostima, promjeni zakonskih propisa i slično.

Upravljanje promjenama je važno zbog: smanjenja izloženosti rizicima implementacije, smanjivanju utjecaja uvođenja promjene na posao i prekid rada sustava te da bi se promjena implementirala u prvom pokušaju.

3.3.1.1. Poslovna korist od implementacije procesa Upravljanja promjenama

Sam taj proces možda se može činiti pretjeranim birokratiziranjem, pogotovo jer koristi nisu izravno vidljive. S druge strane, nepridržavanje procesa može imati neizravne posljedice na kvalitetu rada sustava. Koristi su sljedeće: određivanje prioriteta u sustavima s većim brojem promjena, implementacija promjena uz optimizirane troškove, manji broj neuspješno implementiranih promjena, implementiranje promjena u zahtijevanim rokovima, procjena rizika implementacije, procedura testiranja i odobravanja promjene, pravovremeno otkrivanje utjecaja na druge sustave, prepoznavanje i komunikacija sa svim korisnicima sustava. *Npr.*sustav Državne riznice je integriran s drugim sustavima proračunskih korisnika. Bilo kakva izmjena u nekom dijelu sustava koja bi imala utjecaja na strukturu ili rad komunikacijskog sustava na neplanirani način onemogućila bi komunikaciju sa svim povezanim sustavima korisnika proračuna, trenutno njih 15. Po proceduri upravljanja promjenama, svi oni bi bili na vrijeme obaviješteni o izmjeni, dobili novu specifikaciju servisa, vrijeme za prilagodbu, testiranje i slično.

Dodatno, procedura upravljanja promjenama omogućuje praćenje indikatora uspješnosti izmjena servisa. Neki indikatori uspješnosti mogu biti: broj implementiranih servisa unutar

očekivane kvalitete/troškova/vremena implementacije, smanjenje broja prekida servisa uzrokovanog promjenama, smanjenje broja neodobrenih promjena, smanjenje broja neplaniranih i hitnih intervencija na sustavu, smanjenje broja neuspjelih promjena, broj incidenata koji su posljedica promjena, točnost procjena vremena implementacije promjena i slično.

3.4. Redovni rad servisa

To poglavlje se bavi svakodnevnim poslovima vezanim za osiguravanje redovnog i ispravnog rada servisa. Navode se preporuke za postizanje efikasnosti i efektivnosti. Tu se nalaze upute kako postići stabilnost u radu servisa, uz istovremeno omogućavanje izmjena, veličine, kapaciteta, razine i slično. Obuhvaćeni su upravljanje događajima, incidentima, problemima, zahtjevima, aplikacijama.

Upravljanje incidentima je dio ITIL-ovog modula koji se bavi Redovnim radom servisa. Procesi u modulu za redovni rad servisa su sljedeći:

- Upravljanje događajima
- *Upravljanje incidentima*
- Upravljanje problemima
- Upravljanje pravom pristupa

3.4.1. Upravljanje incidentima

Ove kategorije su prilično povezane. Neki događaj na sustavu ne mora imati neželjene ili negativne posljedice. Međutim kad događaj smanjuje i onemogućuje korisnika u korištenju servisa, onda takav događaj zovemo incident. Kada se neki incident ponavlja više puta, onda se takav incident zove problem. Rješavanje problema se pokreće gore spomenutom procedurom za Upravljanje promjenama, jer je očito potrebno napraviti prilagodbu sustava s kojom će se spriječiti pojavljivanje tog incidenta.

Po ITIL-u, incident je prekid u radu IT servisa, ili smanjena kvaliteta rada servisa (Moeller R.R., 2013.). Otkazivanje nekog elementa konfiguracije koje još uvijek nije izazvalo prekid u radu servisa također se smatra incidentom, na primjer otkazivanje jednog od diskova koji se međusobno zrcale.

Upravljanje incidentima je proces koji se bavi svim vrstama incidenata, koje uključuju zakazivanje pojedinih elemenata, pitanja koja korisnici upućuju na primjer telefonom na service desk, pitanja tehničkog osoblja, ili incidenti koje su automatski detektirali alati za nadgledanje sustava. Te sve vrste incidenata su predmet ovog rješenja. Primarni cilj koji se želi postići ovim rješenjem je uspostava normalnog rada servisa u najkraćem moguće roku i minimiziranje utjecaja na posao. Normalni rad servisa je onaj koji je definiran SLA sporazumom (Service Level Agrement) između pružatelja servisa i korisnika. Važno je primijetiti da otklanjanje uzroka incidenta ne spada u primarni cilj, pogotovo ako bi ono produžilo vrijeme uspostave normalnog rada servisa.

U sklopu projekta je potrebno izraditi procedure za upravljanje incidentima, prilagođene za organizaciju i sustav Državne riznice. Procedure moraju opisivati sve korake koje treba slijediti prilikom rješavanja incidenta i zahtjeva za promjenama. To je u projektu postignuto izradom pravilnika, koji mora biti prihvaćen od organizacije, jer propisuje korake kojih se moraju pridržavati i krajnji korisnici i partnerske tvrtke koje održavaju sustav. Zato se na taj pravilnik treba pozvati i kod ugovaranja narednih poslova održavanja sustava s partnerskim tvrtkama.

Informatičko rješenje koje će se izraditi treba omogućiti svim korisnicima sustava prijavu incidenata i zahtjeva za promjenom kroz web sučelje, u koje će biti ugrađena standardna pravila, šifarski sustav i slično. Pristup podacima će biti omogućen svim relevantnim stakeholderima na principu dodijeljenih uloga. Tako će tehnički timovi koji održavaju pojedini sustav imati pristup svim incidentima vezanim uz taj sustav. Treba definirati parametre po kojima će sustav automatski prepoznati incidente koji se ponavljaju. Takvi incidenti koji se ponavljaju po ITIL metodologiji nazivaju se problemi (Moeller R.R., 2013.). Takvi problemi se rješavaju tako da problem koji sustav za incidente detektira može automatski pokrenuti izradu zahtjeva za promjenom sustava, koji će tehnički timovi odgovorni za održavanje tog sustava formulirati i tako predložiti način rješavanja problema. Treba razviti procedure koje će ravnopravno definirati korake i akcije bez obzira da li je incident tehnički ili ne-tehnički i bez obzira na izvor incidenta.

Procedure moraju pokriti sve korake, od prijave incidenta pa do zatvaranja, npr. bilježenje svih informacija o incidentu za naknadnu analizu, opis incidenta u bazu znanja i slično. Procedure također moraju definirati način i kriterije izrade baze znanja o incidentima.

Kad je riječ o upravljanju promjenama, cilj je dokumentirati sve korake u procesu s obzirom na sudionika/ulogu. Sustav treba pružiti odgovarajućim timovima informacije potrebne za analizu zahtjeva, i na kraju prihvaćanje zahtjeva. Iz prihvaćenog naloga sustav treba kreirati radni nalog. Zahtjeve prihvaća 'Tim za upravljanje promjenama' temeljem podatka o prioritetu zahtjeva, složenosti, rizicima, utrošku konzultant dana, zahtijevanim rokovima, troškovima i slično. Zahtjevi se mogu prihvatiti ili odbiti. Izgradnja baze znanja o promjenama treba biti sastavni dio ovog procesa.

Koraci u procesu rješavanja incidenata:

- Identifikacija incidenta
- Bilježenje incidenta
- Kategorizacija incidenta
- Određivanje
- Početna dijagnoza
- Eskalacija
- Dijagnoza
- Rješavanje
- Zatvaranje incidenta

3.5. Trajno unapređenje servisa

U ovom poglavlju se navode preporuke za trajno poboljšanje dizajna, tranzicije i svakodnevnog rada servisa. U njemu se kombiniraju principi i metode upravljanja kvalitetom, upravljanja promjenama i poboljšanja mogućnosti servisa. Navode se mogućnosti inkrementalnih poboljšanja i poboljšanja velikih razmjera u kvaliteti servisa i efikasnosti rada i dostupnostima.

4. Opis sustava

Spomenuti procesi trebaju biti podržani jedinstvenim informatičkim sustavom. Korisnici Državne riznice i tehnički timovi koji održavaju sustave su dislocirani. Zato sustav mora izložiti web-korisničko sučelje bez potrebe za instalacijom na korisničkom računalima. Sustav mora podržavati najbolju svjetsku praksu i industrijske standarde koji su prepoznati u ITIL metodologiji. Sustav mora omogućiti jednu ulaznu točku za sve korisničke akcije, i za prijavu incidenata i za povratne informacije i komunikaciju sa service deskom. Za prijavu incidenata treba postojati web forma za unos podataka. Svi parametri koji se mogu unaprijed prepoznati

trebaju biti grupirani u sustav šifarnika. U tekstualna polja bez kontrole se upisuju samo opisni podaci o incidentu. Npr. moraju postojati šifarnici sustava, organizacija iz kojih dolazi korisnik koji prijavljuje incident, vrste incidenta, prioriteta i slično. To je važno jer omogućuje korisniku precizan opis incidenta, a operateru na service desku brže postupanje s incidentom. Osoblje koje održava sustav mora biti u mogućnosti nadopunjavati i mijenjati tablice sa šifarnicima kako se komponente svih sustava podržanim ovim projektom budu mijenjale.

Sustav mora omogućiti pretraživanje po bazi podataka o incidentima i promjenama. Isto tako sustav treba omogućiti korisnicima postavljanje upita u bazu podataka i izradu izvještaja. Upiti moraju omogućiti podatke kao što su broj incidenata po korisnicima, vrstama incidenta, prosječnom vremenu rješavanja i slično. U procesu upravljanja promjenama, sustav mora omogućiti dokumentiranje svih faza u procesu, a to su: analiza, prihvaćanje, stvaranje radnog naloga, implementacija, testiranje, dokumentiranje, izrada korisničkih uputa, korisnička dokumentacija i prijenos na produkciju.

Sustav se sastoji od sljedećih glavnih modula: Modul za upravljačke komponente (registri IT imovine i poslovnih procesa, upravljanje incidentima i upravljanje promjenama), Modul za upravljanje dokumentima (upravljanje dokumentima za SUIP, interni sustav za upravljanje dokumentima), Modul za komponente poslovne inteligencije (baza znanja, analiza i izvještavanje) i Modul s komponentama podrške i sigurnosti sustava (sigurnost i administracija, kolaboracija i komunikacija.)

Postoje dva registra resursa koja dijele druge dvije komponente: registar IT imovine i registar poslovnih procesa. Tu su još dodatni šifarnici: fizičkih lokacija, ustrojstvenih jedinica, partnera i ugovora.

Registar IT imovine sadrži svu imovinu kojom upravlja 'Služba za podršku sustavu'. U registru se vodi ona imovina koja može biti predmet bilo incidenta bilo zahtijeva za promjenom. U imovinu spadaju softverske komponente i licence. Vode se osnovni podaci kao što su naziv, lokacija, vlasnik i opis.

U registru poslovnih procesa se vode svi poslovni procesi koji se na bilo koji način provode pomoću informatičkih komponenti. Svi procesi u tom registru mogu biti predmet incidenta ili zahtjeva za promjenom. Vode se osnovni podaci kao što su naziv, opis, vlasnik i slično.

Namjena ta dva procesa je omogućiti korisniku što preciznije opisati bilo incident bilo zahtjev za promjenom, izborom neke ponuđene vrijednosti iz padajućih izbornika. Kvaliteta opisa incidenta ili zahtjeva za promjenom može utjecati na vrijeme rješavanja i analize incidenta.

Komponenta za upravljanje incidentima upravlja incidentima svih servisa koje pruža sustav, a uklopljena je u cjelokupno web rješenje i integrirana sa svim drugim komponentama. Komponenta podržava sljedeće procese: zaprimanje incidenta, kategorizacija, klasifikacija i opis incidenta, praćenje rješavanja incidenta, izvještavanje.

Funkcija zaprimanja incidenata svim korisnicima omogućuje da koriste jedinstveni web obrazac za unos prijave svih incidenata bilo koje vrste bez obzira na sustav. Takav pristup omogućuje konzistentan opis problema. Korisnik popunjava niz podataka o incidentu kao što su naziv, opis, identifikacija korisnika, vrijeme nastanka, vrijeme prijave, organizacijsku jedinicu i slično.

Funkcija kategorizacije incidenta korisniku omogućuje biranje podatke iz postojećih registara i šifrarnika poslovnih procesa, imovine i lokacije.

Funkcija praćenja rješavanja incidenta korisniku omogućuje rješavanje incidenata propisanim procedurama za prepoznavanje uzroka ponavljajućeg incidenta, procedurom povezivanja incidenta s postojećim člankom s opisom problema u 'Bazi znanja' i procedurom za obavještavanja sudionika u procesu prilikom promjene statusa incidenta.

Funkcija izvještavanja daje preglede kao što su pregled aktivnih incidenata, pregled incidenata prema odgovornom tehničkom timu, pregled incidenata prema korisniku i pregled incidenata prema sustavu. Po potrebi je moguće definirati dodatne preglede i izvještaja iz podataka pohranjenih u bazi.

Komponenta za upravljanje promjenama pruža dio svojih funkcionalnosti kroz objavljenu web aplikaciju koja će služiti za pristup korisnicima koji nemaju pristup centralnom sustavu. Upravljanje promjenama se sastoji od sljedećih funkcionalnosti koje moraju biti podržane sustavom: podnošenje zahtjeva za promjenom, analiza zahtjeva, odobravanje zahtjeva, stvaranje radnog naloga, praćenje izvođenja zahtjeva, provjeru ispravnosti napravljenih izmjena, ovjeru kvalitete i prijenos gotovih promjena na produkciju.

Zahtjev za promjenom podnosi naručitelj, koji može biti ključni korisnik sustava, djelatnik 'Službe za podršku sustavu' ili tehničko osoblje koji uočava potrebu za poboljšanjem sustava. Zahtjeve ne mogu podnositi krajnji korisnici sustava. Zahtjev se podnosi ispunjavanjem web forme koja je dio SUIP sustava.

Analizu zahtjeva provodi projektni tim, i pri tom utvrđuje i unosi sljedeće podatke: voditelja posla, datum analize, troškove implementacije, procjenu trajanja, vrstu promjene, druga moguća rješenja tog zahtjeva, rizike utjecaja na sustav, prioritet i potrebne resurse. Ove podatke određuje projektni tim čiji članovi mogu biti iz pojedinog tehničkog tima, ključnih korisnika i 'Službe za podršku'. U toj fazi se zahtjev odobrava. Odobravanjem zahtjeva treba nastati radni nalog za izvođača. Za popunjavanje izdanog radnoga sustav omogućuje ulozi izvođač davanje komentare i preporuke za testiranje i evidenciju utrošeni broj dana.

Funkcionalnost provjere je dostupna imenovanom voditelju provjere, koji vrši provjeru na testnom sustavu i evidentira da li su promjene ispravno izvršene i datum provjere.

Funkcionalnost ovjere kvalitete vrši djelatnik 'Službe za podršku' zadužen za ovjeru kvalitete u toj promjeni. Bilježi da li je ispunjena eventualna potreba za izmjenom dokumentacije sustava i dodatnom izobrazbom korisnika.

Sustav omogućuje evidentiranje prijenosa na produkciju ako su svi prethodni koraci uspješno odrađeni. Sustav omogućuje izdavanje naloga za prijenos na produkciju s listom transportiranih elemenata, datumom prijenosa i tko ga je izvršio.

Funkcionalnost izvještavanja omogućuje uvid u pregled aktivnih zahtjeva, zahtjeva prema aplikacijama, ustrojstvenim jedinicama, voditeljima posla i slično. Moguće je definirati nove preglede i upite.

Modul za upravljanje dokumentima se koristi za dvije namjene: Podršku procesima upravljanja promjenama i incidentima, i podršku poslovanju 'Službe za podršku' sustavu (interni DMS).

Funkcionalnost tog modula omogućuje 'Službi za razvoj i podršku' *upload* i organiziranje korisničke dokumentacije. *Uploadana* dokumentacija je dostupna krajnjim korisnicima kroz web sučelje SUIP sustava. Korisnik kojem se dogodio incident lako doći do korisničke dokumentacije i provjeriti ispravnost svog načina rada sa sustavom prije nego što prijavi incident. Djelatnici službe mogu u internom DMS sustavu organizirati kompletnu tehničku i drugu dokumentaciju sustava.

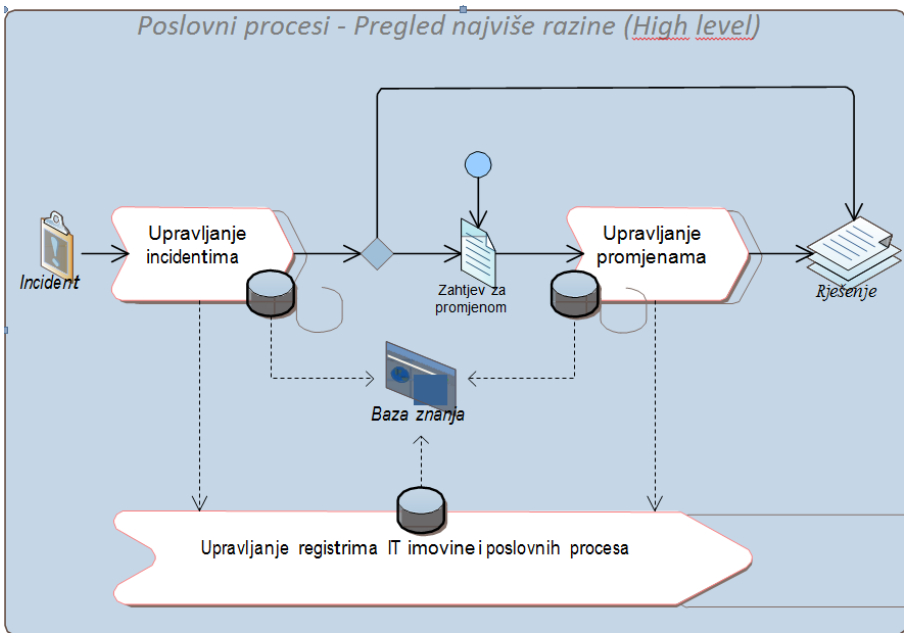
Modul komponente poslovne inteligencije pruža funkcionalnosti izrade i korištenja baze znanja, i analiza i izvještavanje. Baza znanja služi za izgradnju kvalitetne baze informacija o incidentima, problemima i njihovom rješavanju. Bazom znanja se koriste djelatnici koji pružaju korisnicima podršku, a podatke uređuju djelatnici 'Službe'. Informacije se zapisuju u strukturiranom obliku kako bi se olakšalo njihovo korištenje. Postoje sljedeće forme za upis u Bazu znanja: procedura – forma za opis procedure, pitanja i odgovori – forma za često postavljana pitanja i odgovore, rješenje problema-forma za opis problema koji se ponavljaju, standardni članak u bazi znanja – forma za unos članka. Članci koji se objave biti će vidljivi svim korisnicima aplikacije.

Modul s komponentama sigurnosti sustava pruža funkcionalnost sigurnosti i administriranja sustava. Postoji sustav sigurnosnih uloga u koje su ugrađena poslovna pravila, i prava pojedinim grupama korisnika. Samo korisnici koji su za to ovlašteni imaju pristup pojedinim podskupovima podataka i pojedinim komponentama sustava.

Modul za kolaboraciju i komunikaciju omogućava praćenje komunikacije na pojedinim slučajevima. Moguće je pratiti aktivnosti kao što su zadaci, telefonski pozivi, poruke elektroničke pošte, sastanci i slično.

5. Implementacija ITIL metodologije

Service desk je organizacijski podijeljen u 2 razine: 1. razina je prva kontaktna točka prema korisnicima. Prva razina zaprima incident i kategorizirati ga. Ako je moguće odmah ga rješava, a ako ne proslijedit će ga na drugu razinu. Drugu razinu čine tehnički stručni timovi, uglavnom osoblja i partnera koji održavaju pojedine sustave i aplikacije, računski centri u kojima je udomljena oprema i slično (Holtsnider B., Jaffe B.D., 2012.).

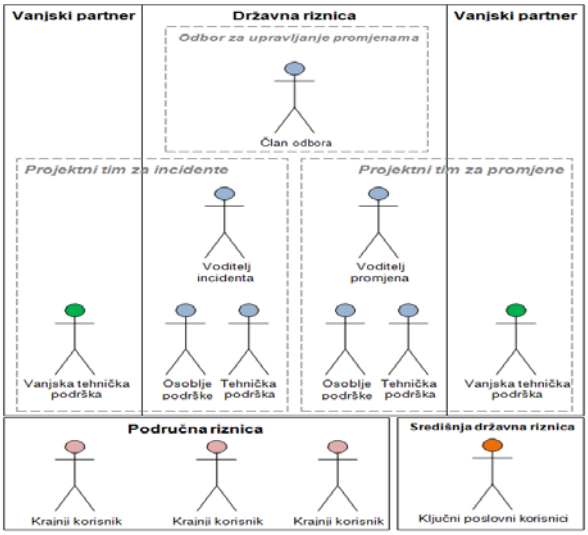


Slika 2.: Razine poslovnih procesa pokrivenih projektom

Na slici 2. je prikaz najviše razine poslovnih procesa pokrivenih projektom. Proces upravljanja incidentom počinje nastankom incidenta, koji se prema ITIL-u definira kao događaj koji nije standardan operacija sustava, a može prouzročiti prekid ili smanjenje kvalitete rada IT sustava (Moeller R.R., 2013.). Teži incidenti, ili incidenti koji se ponavljaju mogu zahtijevati promjenu na sustavu. Takvi incidenti se nazivaju problemi i iz njih zastaje Zahtjev za promjenom koji okida proceduru 'Upravljanja promjenama'.

Za opis poslovnih procesa neophodno je razumijevanje uloga. Na sljedećoj slici su prikazane sljedeće uloge: odbor za upravljanje promjenama, voditelj incidenta, voditelj promjene, osoblje podrške, tehnička podrška. Glavna funkcije Odbora za upravljanje promjenama su slijedeće: odobravanje zahtjeva za promjenama, određivanje prioriteta zahtjeva, komunikacija s ostalim sudionicima u procesu – svi sudionici i korisnici sustava moraju biti obaviješteni o promjenama na sustavu.

Voditelj incidenta brine o koordinaciji aktivnosti između različitih razina podrške, praćenje incidenata upućenih prema drugim razinama podrške, komunikacija i koordinacija s projektnim timom za upravljanje promjenama, analiza i revizija cjelokupnog sustava radi uočavanja učestalih incidenata koji zahtjevaju dodatne akcije.



Slika 3.: Organizacija dionika service desk-a

Voditelj promjena je zadužen za koordinaciju aktivnosti vezanih uz analizu i implementaciju odobrrenih zahtjeva za promjenu između internih članova projektnog tima i vanjskih partnera.

Osoblje podrške osigurava krajnjim i ključnim korisnicima prvu točku kontakta i adekvatnu potporu u rješavanju problema. Ako osoblje podrške ne može samo riješiti incident, prosljeđuje ga dalje stručnijm i tehničkim timovima.

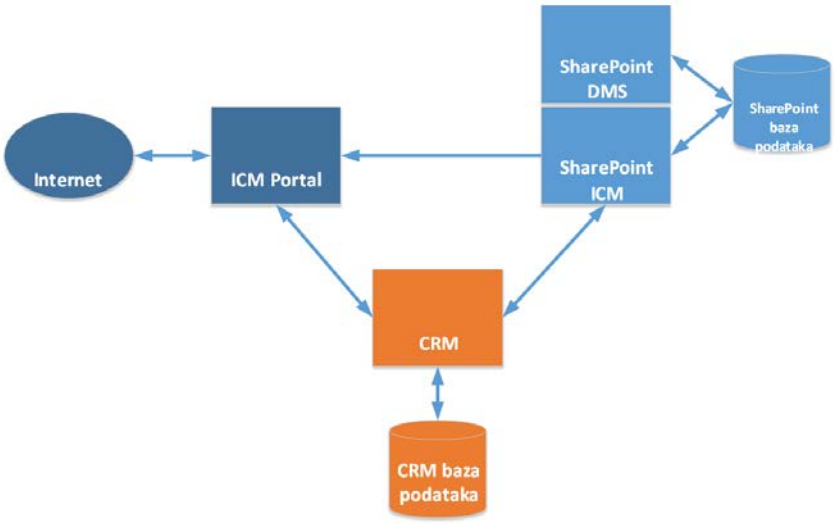
Tehničkio timovi sudjeluju u rješavanju incidenata koje nije bilo moguće riješiti na prvoj razini podrške, i provode zathjeve za promjenom na sustavu koji održavaju.

Nastanak incidenta mogu otkriti krajnji ili ključni korisnici, tehničko osoblje ili osoblje koje pruža podršku sustavu (Slika 3.). Po otkrivanju incidenta, podaci o incidentu se prijavljuju u sustav putem web forme. U sljedećem koraku se incident analizira, identificira i određuje mu se kategorija pomoću zadanog šifrarnika kategorija. U tom koraku se može ustanoviti da događaj ne spada u incidente, i incident se zatvara. Prilikom analize incidenta utvrđuju se sljedeći podaci: točan razlog pojave greške, kronološki redoslijed događaja, potpuni utjecaj incidenta uključujući broj i raspon korisnika koji su zahvaćeni incidentom. Ukoliko se ipak radi o incidentu, utvrđuje se prioritet njegovog rješavanja. Postavlja se inicijalna dijagnoza i konzultira se baza znanja u kojoj se traže slični incidenti u prošlosti. Dalje se radi analiza i dijagnoza incidenta koja rezultira rješenjem incidenta, ili se incident prosljeđuje na drugu razinu podrške tehničkim stručnim timovima koji održavaju pojedine sustave, koji onda rade analizu i dijagnozu i rješavaju incident. Po rješenju podaci o incidentu se zapisuju u bazu znanja. Incident se zatvara, a korisnik koji je prijavio incident se obavještava o zatvaranju.

Elementi koji mogu biti objekt zahtjeva za promjenom su sljedeći: aplikativna programska rješenja, sistemski programski proizvodi, računalni resursi i programska oprema, cjelokupna dokumentacija i procedure koje opisuju aktivnosti na sustavu. Proces upravljanja promjenama počinje nastankom potrebe za promjenom sustava, što rezultira prijavom zahtjeva za promjenom. Zahtjev može podnijeti ključni korisnik, podrška sustavu, tehnička podrška sustavu. Podneseni zahtjev se analizira, u analizi sudjeluju ključni korisnici i podrška sustavu. Analiza uključuje identifikaciju razloga za promjenom, utjecaj promjene na sustav, potrebne resurse, zahtijevani prioritet i rokove. Sljedeći korak u analizi vrši tehnički tim odgovoran za održavanje spomenutog sustava. U toj analizi utvrđuju se podaci kao što su izvedivost promjene, potrebni resursi, troškovi, angažman ljudi i slično. Nakon pozitivne analize zahtjev se odobrava, i generira se radni nalog za tim koji će ga implementirati. U fazi implementacije su ključni tehnički timovi koji provode implementaciju i komunikaciju sa svim ostalim sudionicima procesa. Nakon implementacije zahtjeva rezultat se prosljeđuje krajnjem korisniku na testiranje. Ako se testiranje pokaže uspješno, slijedi provjera kvalitete u kojoj se pregledava dokumentacija sustava i obučenost korisnika. Kad su sve faze uspješno završene,

izdaje se nalog za prijenos na produkciju. Nakon prijenosa na produkciju vrši se analiza cijelog posla i zatvaranje zahtjeva.

5.1. Korištenje softvera u implementaciji ITIL metodologije



Na slici 4. su prikazane softverske komponente sustava. CRM je osnovna komponenta sustava u kojoj su definirani svi entiteti vezani za poslovne procese upravljanja incidentima i promjenama. Sve informacije su dostupne kroz CRM aplikaciju, a pohranjuju se u CRM bazu podataka. Pristup CRM-u je potreban i omogućen samo zaposlenicima Službe za razvoj i podršku sustavu.

Slika 4.: Softverske komponente ICM sustava

Svi vanjski korisnici i konzultanti pristupaju sustavu preko web aplikacije koja je razvijena s namjerom pružanja dijela funkcionalnosti CRM-a širem spektru korisnika. Ovisno o ulogama u sustavu, korisnici web aplikacije će biti u mogućnosti sudjelovati u dijelovima poslovnih procesa koji se odnose na njih.

SharePoint kao treći povezani sustav služi za pohranu i upravljanje dokumentima i dokumentacijom sustava. Postoje dvije aplikacije unutar SharePoint komponente: *SharePoint ICM* koji služi za pohranu dokumenata vezanih uz poslovne procese upravljanja incidentima i promjenama, te *SharePoint DMS* koji služi za ostale procese naručitelja koji nisu direktno vezani uz osnovnu namjenu sustava. SharePoint ICM je povezan s obje dosad navedene komponente (CRM-om i web aplikacijom) te omogućava pregled i upravljanje korisničkom dokumentacijom.

Postoje tri komunikacijska kanala koja sustav korisit. Veza između ICM portala i CRM-a je najbitnija jer se tu korsiti najveći broj funckionalnosit. Podaci putuju u oba smjera. ICM portal uvijek inicira komunikacija, i to putem poziva servisa kojima dohvaća podatek i šalje ih u CRM sustav. Drugi kanal je dvosmjerni kanal između CRM-a i Sharepoint sustava. Preko tog kanala se pozivaju biblioteke s dokumentima iz Sharepointa i vrši se prijenos dokumenta direknto kroz sučelje CRM-a. Taj kanal služi za uređivanje bilblioteka korisničkih uputa koji će kasnije biti dostpuni korisnicima.

Treći kanal je između ICM-a i Sharepointa, i on služi samo za čitanje dokumenata. Kroz taj kanal korisnici mogu dohvaćati korisničku dokumentaciju kroz web portal.

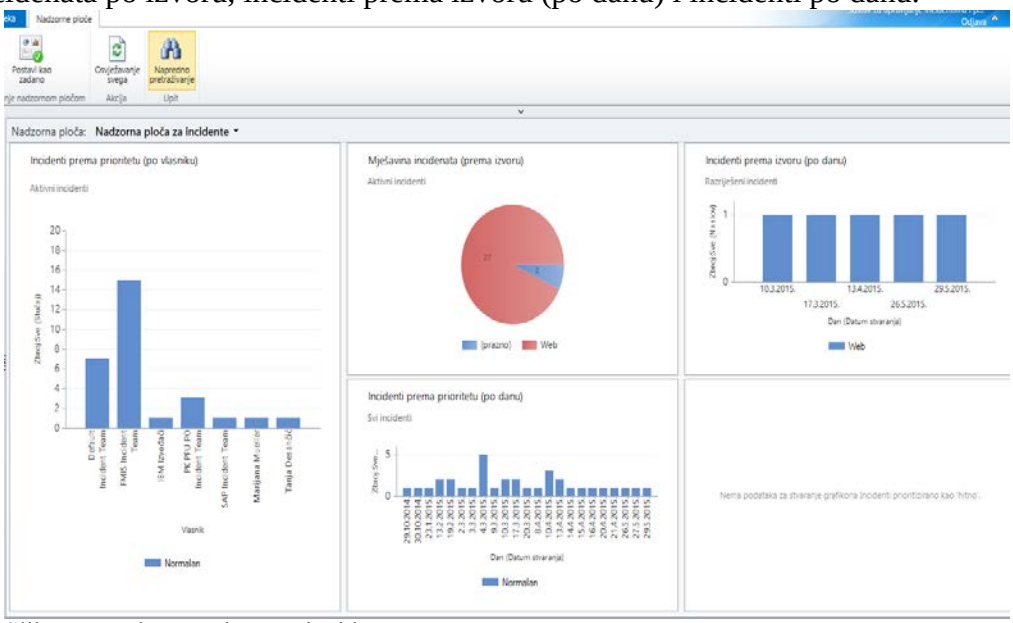
Korisnička sučelja koja se koriste su sučelje CRM-a, sučelje web-aplikacije i Sharepoint sučelje. Kroz sučelje CRM-a dosputpna je većina funckionalnosti sustava i koriste ga djealtnici Službe za podršku sustavu. Dodatno su kroz njega dostupne sve informacije i izvještaji.

Web sučelje je aplikacija kroz koju sustavu pristupaju svi krajnji i ključni kornsnici sustava, tehnički i projektni timovi.

Sharepoint sučelju se pristupa kroz CRM. Dodatno, Sharepoint sučelju se može pristupiti izravno za potrebe organizacije cijelokupne dokumentacije integiranog sustava.

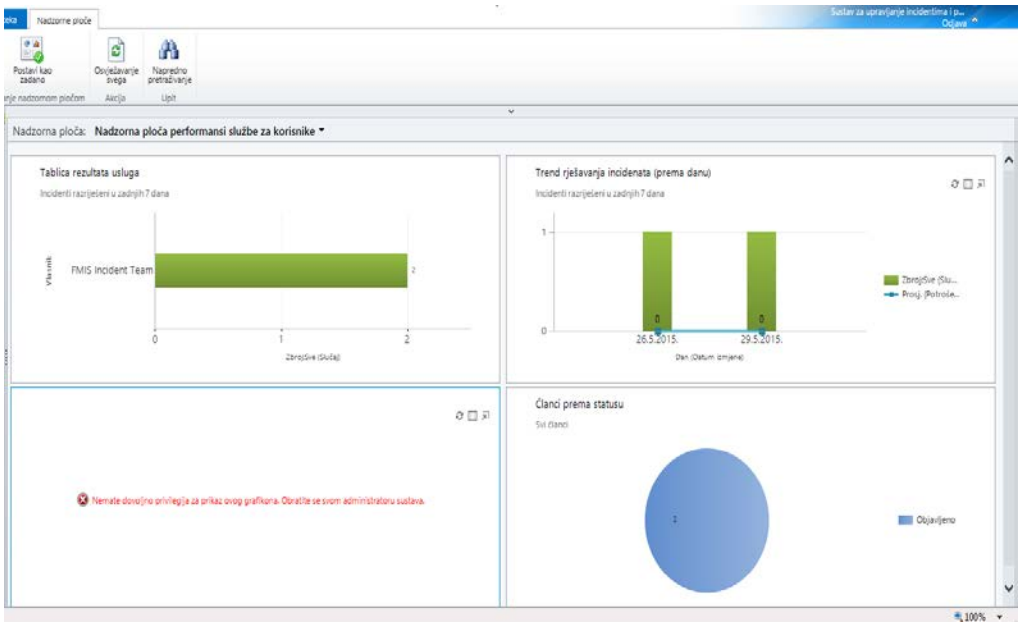
5.2. Izvještavanje i mjerenje performansi

Za kvalitetno upravljanje informacijskim sustavom potrebno je imati uvid u njegove performanse. Performanse mjerimo pomoću praćenjem pokazatelja uspješnosti, kojima se prate performanse sustava definirane metrikom (Steinberg R.A., 2013.). Neke mogućnosti izvještajnog sustava bit će prikazana na sljedeće tri slike. Moguće je definirati i izrađivati nove prikaze po potrebi, ovdje je prikazano samo nekoliko primjera. Na slici 5. se vidi nadzorna ploča za incidente s nekoliko grafova: incidenti po prioritetu (po vlasniku), prikaz incidenata po izvoru, incidenti prema izvoru (po danu) i incidenti po danu.



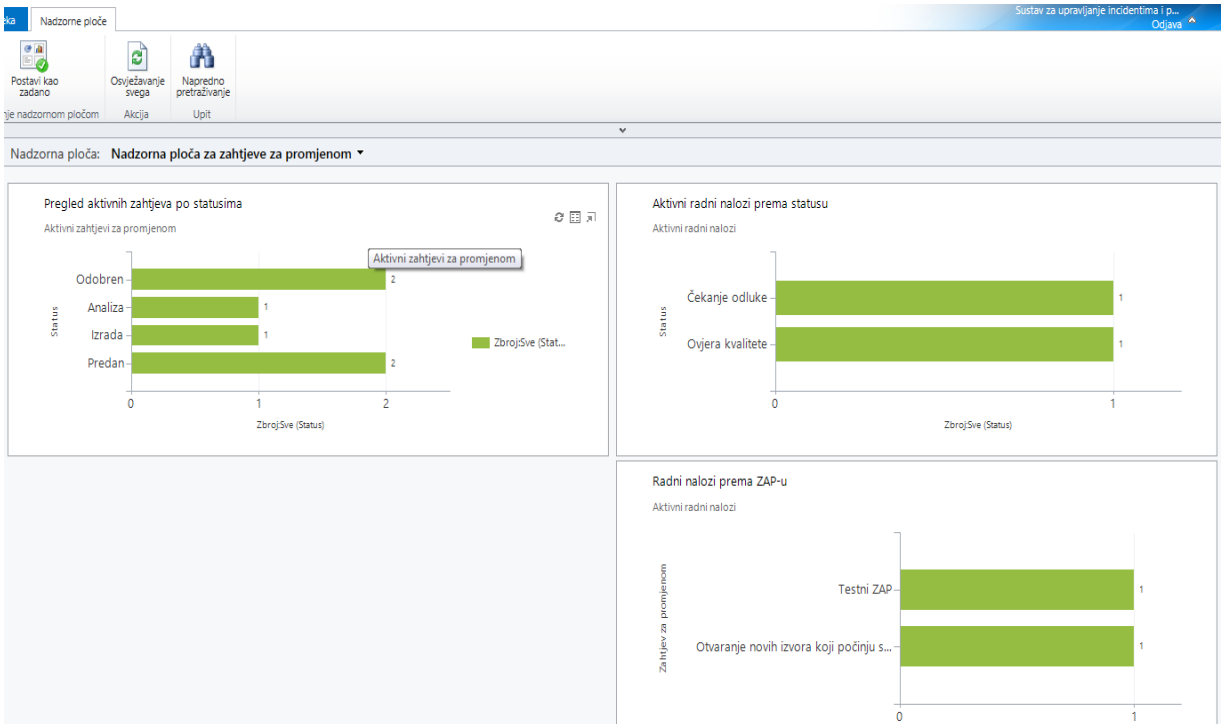
Slika 5.: Nadzorna ploča za incidente

Na slici 6. ispod vidi se kako sustav prikazuje performanse osoblja Službe za podršku. Prvi dijagram prikazuje broj riješenih incidenata po jednom tehničkom timu (tim koji se bavi integriranim sustavima), zatim trend rješavanja incidenta po danu za zadnjih 7 dana, i broj članaka prema statusu, koji prikazuje postotak objavljenih članaka. Svi prikazani grafovi su sa testnog sustava za obuku i ne prikazuju stvarno poslovno stanje.



Slika 6.: Performanse osoblja Službe za podršku

Slika 7. prikazuje nadzornu ploču modula za Upravljanje promjenama. Na prvom grafu je vidljiv pregled zahtjeva za promjenom po statusima (a). Na drugom grafu se vide aktivni radni nalozi po statusu (b). Na trećem grafu je prikaz radnih naloga prema Zahtjevu za promjenom (c). Naime, iz jednog zahtjeva za promjenom teoretski može izaći više od jednog radnog naloga za više timova.



Slika 7.: (a) Zahtjev za promjenom po statusima; (b) Aktivni radni nalozi po statusu; (c) Radni nalozi prema Zahtjevu za promjenom

6. Zaključak

Postojeće stanje nije omogućavalo kvalitetno upravljanje i nadgledanje cijelog integrirano sustava Državne riznice. Nadgledanje rješavanja incidenta kroz sustav elektroničke pošte je

nezadovoljavajuće. Podaci o broju incidenata, prosječnom rješavanju incidenta i slično su teško dostupni. Tako je na primjer korisnik prigovorio da je čekao rješavanje svog incidenta tjedan dana. Bez adekvatnog sustava nije bilo moguće odmah odgovoriti na tu primjedbu. Naknadno su zbog tog prigovora vađeni podaci iz arhive elektroničke pošte, što je postupak koji zahtjeva određeno vrijeme. Analizom podataka iz konkretnog navedenog primjera je ustanovljeno da je korisnik prijavio incident s nedovoljno informacija, da mu je sa Service deska odmah po prijavi upućen zahtjev za dodatnim informacijama, i da je on na taj zahtjev odgovorio tek nekoliko dana kasnije. Nakon njegovog odgovora je incident bio riješen. Uz implementiran sustav za upravljanje incidentima bilo bi moguće odmah korisniku pružiti informacije o tijeku rješavanja incidenta.

Dodatno, izuzetno je važno imati podatke o pojavi incidenata, na kojim modulima se pojavljuju, koliko često i slično, jer takvo podaci mogu ukazati na neke probleme koji mogu predstavljati rizik na funkcioniranje sustava.

Kod upravljanja promjenama, postojala je i razvijena je metodologija, međutim nedostatak adekvatnih alata je onemogućio kvalitetnu primjenu takve metodologije. Korisnici su komunicirali direktno i bez pisanog traga s tehničkim timovima koji su izvodili promjene na sustavu. Promjene nisu bile dobro dokumentirane. Dokumentiranost cijelog sustava nije bila odgovarajuća, što opet za posljedicu predstavlja rizik za funkcioniranje sustava. Zbog nedostatka tih podataka teže je pratiti ugovore s vanjskim partnerskim kućama i utrošak njihovih resursa. Novi sustav omogućuje proceduralno praćenje promjena na sustavu, dokumentirano testiranje, bolji nadzor nad vanjskim partnerima, i općenito bolju dokumentiranost sustava. Dodatno, novi sustav osigurava bolju analizu utjecaja promjene na ostale dijelove sustava, i obaviještenost svih sudionika o promjenama koje se događaju na sustavu. Cijeli SUPI sustav omogućuje smanjenje rizika na funkcioniranje integriranog sustava Državne riznice u cjelini.

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Utjecaj smrzavanja na kolničke konstrukcije i organizacija zimske službe u Ličko-senjskoj županiji

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Sažetak

Problem smrzavanja kolničke konstrukcije i tla ispod nje (posteljice) predmet je intenzivnih proučavanja i znanstvenih radova u svijetu. Taj problem je vrlo izražen u Ličko-senjskoj županiji i to posebice na županijskim cestama koje su obično poddimenzionirane i ne zadovoljavaju u smislu otpornosti na smrzavanje. U ovome radu prikazati će se različiti utjecaji na kolničke konstrukcije kao što su temperatura, vlaga, smrzavica, dubina smrzavanja, hidrološke okolnosti i indeks smrzavanja.

U područjima s većom nadmorskom visinom nakon zimskog perioda nastaju velika oštećenja kolničkih konstrukcija, koja ako se ne saniraju, dovode do rapidnog propadanja kolničkih konstrukcija i takve ceste više nisu sigurne za vožnju i sudionike u prometu.

Konkretno će biti obrađena provedba zimske službe na županijskim cestama u Ličko-senjskoj županiji, te analiza posljedica smrzavanja i moguća rješenja za poboljšanje kolničkih konstrukcija na području županije.

Ključne riječi: županijske ceste; kolnička konstrukcija; smrzavica; dubina smrzavanja; posteljica; zimska služba

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1. Uvod

Kolnička konstrukcija uslijed djelovanja niskih temperatura ispod 0°C i prirodnih sila, izložena je pojavi smrzavanja.

Prirodne sile nikad ne miruju i zato kolnička konstrukcija mora biti sastavljena tako da „preživi“ u takvim uvjetima i da odoli utjecajima koje na nju ima okolina. Mehanizmi kojima kolnička konstrukcija smanjuje utjecaje djelovanja okoline ovise o:

- mehaničkim svojstvima materijala od kojih je izrađena,
- trajnosti i rezistentnosti tih materijala i
- volumenskim promjenama u materijalima, odnosno rezultirajućoj ravnoteži unutarnjih naprezanja u konstrukciji.

Strukturu kolničke konstrukcije koja je dimenzionirana na prometno opterećenje, potrebno je provjeriti i na smrzavanje ako je tlo u posteljici kolničke konstrukcije osjetljivo na smrzavanje i ako su hidrološki uvjeti nepovoljni. Ako kolnička konstrukcija nije sigurna od smrzavanja, potrebno je predvidjeti određene tehničke mjere u samoj konstrukciji, ili ispod nje, kako bi se opasnost od smrzavanja uklonila ili smanjio njezin rizik.

Štetni učinci djelovanja smrzavanja na kolničku konstrukciju odnose se na dva zasebna, ali međusobno povezana procesa, a to su:

- bubrenje i izdizanje tla uzrokovano skupljanjem vode i stvaranjem ledenih leća u tlu tijekom razdoblja smrzavanja (zimi),
- smanjenje nosivosti tla, a time i nastajanje kolotraga i/ili pukotina u pojedinim slojevima kolnika zbog velike vlažnosti tijekom razdoblja otapanja (u proljeće).

Zimsko održavanje županijskih cesta značajan je dio ukupnog godišnjeg održavanja cesta koji utječe na okoliš i kolničku konstrukciju te se tek nakon prestanka zimske službe sa preostalim financijskim sredstvima osiguranim za održavanje planiraju radovi ljetnog održavanja cesta.

Zbog toga je važno razvijati djelotvorne strategije i metode planiranja aktivnosti zimske službe te dokumentirati i usvajati različite standarde, uvjetovane važnošću ceste i gustoćom prometa. Primjena znanja i stalno učenje omogućuje postizanje optimalnih rezultata, uz snižene troškove i smanjeni utjecaj na okoliš.

Nakon svake zimske službe u Ličko-senjskoj županiji na određenim dionicama županijskih cesta ostaju vidljive posljedice i oštećenja na površinskom sloju kolnika te u kolničkoj konstrukciji u obliku mrežastih pukotina i bubrenja kolnika. Posljedica ovoga su ceste s nezadovoljavajućom kvalitetom vožnje, većim oštećenjima kolnika, opsežnim potrebama za održavanjem, neprihvatljivim troškovima za korisnika ceste, nedovoljnom nosivošću, stoga je potrebno poduzeti određene tehničke mjere, ili rješenja za poboljšanje kolničkih konstrukcija.

2. Utjecaji na kolničke konstrukcije

Kolnička konstrukcija je izložena brojnim utjecajima i djelovanjima okoline. Ti su utjecaji i djelovanja ponekad takvi da bi u nekim slučajevima mogli prouzročiti oštećenja, pa i uništenje kolničke konstrukcije čak i bez prometnog opterećenja.

Glavni utjecaji okoline na kolničku konstrukciju svakako su temperatura i vlaga pojedinačno, kao i kombinirani utjecaj niske temperature i vlage pri smrzavanju (Babić, 1997: 30).

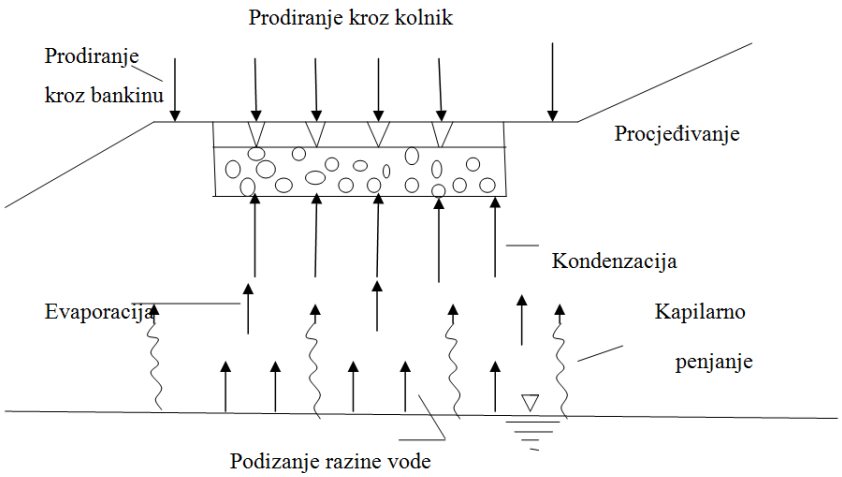
2.1. Utjecaj temperature

Temperatura slojeva ovisi o nekim vanjskim faktorima koji proistječu iz vremenskih prilika, to su primjerice temperatura zraka, sunčana radijacija i vjetar, te o unutrašnjim faktorima emitiranjem dugovalne radijacije iz tla i termička svojstva materijala u kolničkoj konstrukciji i posteljici.

Od vanjskih čimbenika najveći utjecaj imaju temperatura zraka, ali i sunčana radijacija u nekim slučajevima uvelike utječe na temperaturu kolničke konstrukcije.

2.2. Utjecaj vlage

Vlaga je drugi utjecaj okoline koji ima veliko značenje za kolničku konstrukciju, osobito ako je izgrađena u materijalima koji su osjetljivi na vodu. Vlaga je općeniti problem za stabilnost tla, a na kolničke konstrukcije ima posebno jak utjecaj, jer se one grade u zoni u kojoj obično postoje jake varijacije količine vlage.



Ilustracija 1. Mogućnost dolaska vode u zonu kolničke konstrukcije (Babić, 1997:34).

2.3. Problem smrzavanja

Za kolničku konstrukciju je vrlo važna dubina smrzavanja tla, koja pak ovisi najviše o klimatskim okolnostima. O dubini smrzavanja, naime, ovisi potrebna debljina kolničke konstrukcije, odnosno dubina do koje treba zamijeniti tlo osjetljivo prema smrzavanju sigurnim materijalom, kako ne bi došlo do štetnih posljedica od smrzavanja.

2.4. Dubina smrzavanja

Dubina smrzavanja definira se kao najveća dubina ispod površine kolničke konstrukcije na kojoj se voda u porama tla smrzava (Sršen, Kovačić, Kaučić, 2004). Ona nije posve jednaka dubini na kojoj temperatura iznosi 0°C, ali se u praksi s obzirom na male razlike i jednostavnost, usvaja da je to tako. Prema tome, dubinom smrzavanja smatra se dubina od površine do crte iste temperature (izoterme) od 0°C u tlu (odnosno kolničkoj konstrukciji).

2.5. Indeks smrzavanja zraka

Indeks smrzavanja zraka može se odrediti na dva načina:

- Prema švicarskim normama, razlika između najviše i najniže točke na krivulji srednjih dnevnih temperatura zraka tijekom jedne godine naziva se indeksom smrzavanja za tu godinu. Indeks smrzavanja u odnosu je s dubinom smrzavanja i primjenjuje se kao relativan čimbenik za projektiranje/dimenzioniranje i ocjenjivanje kolničkih konstrukcija.
- Po AASHTO metodi, dubina smrzavanja i otapanja dijelom ovisi o veličini i trajanju temperaturne razlike ispod ili iznad smrzavanja (32 °F) na površini tla. Indeks smrzavanja se stoga daje kao zbroj stupanj – dana u određenom vremenskom razdoblju tijekom godine kada dolazi do smrzavanja ili otapanja.

3. Provedba zimske službe na županijskim cestama u Ličko-senjskoj županiji

Zimska služba je pojam i uobičajeni izraz za cijeli niz radnji, mjera, postupaka i aktivnosti u zimskom razdoblju, koje imaju zadaću osigurati mogućnost odvijanja prometa cestama uz najveću moguću sigurnost sudionika u prometu i prihvatljive troškove (Narodne novine, 2011).

Na području Ličko-senjske županije sukladno Odluci o razvrstavanju javnih cesta razvrstano je ukupno 1.161,07 km županijskih i lokalnih cesta od kojih je 500,57 km ili 43,11% županijskih cesta i 660,50 km ili 56,89% lokalnih cesta, kojima upravlja i gospodari Županijska uprava za ceste Ličko-senjske županije (Županijska uprava za ceste, 2015).

Na osnovu višegodišnjeg ugovora poslove redovnog održavanja, pa tako i zimske službe, izvodi tvrtka „LIKA CESTE“ d.o.o..

Zimska služba u pravilu traje od 15. studenoga tekuće do 15. travnja slijedeće godine, te se ceste u tom razdoblju održavaju u skladu s izvedbenim programom zimske službe (Narodne novine, 2014).

Izvedbeni program zimske službe izrađuje se prije početka same zimske službe i njime se utvrđuju sve potrebne radnje i aktivnosti za uspješnu provedbu zimske službe (LIKA CESTE d.o.o., 2014).

Zimsko održavanje značajan je dio ukupnog godišnjeg održavanja cesta, te znatno utječe na okoliš (Jurjević, 2006).

3.1. Stupnjevi pripravnosti

Ovisno o prognozi meteoroloških uvjeta i vremenskih prilika, izvođač radova zimske službe svojim znanjem, odgovornošću i profesionalnošću dužan je pratiti i utvrđivati stupnjeve pripravnosti u zimskom održavanju cesta. Postoje ukupno četiri stupnja pripravnosti u provedbi zimske službe, koji se uvode početkom rada zimske službe.

Ilustracija 2. Prikaz jedne županijske ceste tijekom zimske službe (Županijska uprava za ceste, 2015)

Na ilustraciji 2 prikazana je jedna županijska cesta tijekom trajanja zimske službe u drugom stupnju pripravnosti, gdje se jasno vidi da je kolnik očišćen od snijega, ali je istovremeno i sužen zbog velikih količina napadanog snijega kojeg su ralice zgurale na bankinu.

3.2. Pripremni radovi

Pripremni radovi obuhvaćaju prvenstveno radove i aktivnosti na:

- pripremi mehanizacije, prometne signalizacije i opreme, posipnog materijala,
- pripremi javnih cesta i njenog neposrednog okoliša (postavljanje dopunske prometne signalizacije na opasnim mjestima, postavljanje snježnih kolaca, postavljanje naprava i provođenje mjera za zaštitu od snježnih zapuha i sl.),
- osposobljavanju i stručnom usavršavanju svih radnika koji sudjeluju u obavljanju zimske službe.

Snijeg, a naročito snježni nanosi (zapusi) izazivaju povremene ili dugotrajne poremećaje u prometu, ugrožavaju sigurnost vožnje uslijed smanjene vidljivosti, jakih udara vjetra i klizavog kolnika. Istovremeno je održavanje cesta prohodnima u takvim uvjetima vrlo složen zadatak zimske službe kao što se može vidjeti na ilustraciji 3, te zahtijeva znatna materijalna i financijska sredstva.

Ilustracija 3. Probijanje snježnih nanosa na županijskoj cesti

Snijeg, a naročito snježni nanosi (zapusi) izazivaju povremene ili dugotrajnije poremećaje u prometu, ugrožavaju sigurnost vožnje uslijed smanjene vidljivosti, jakih udara vjetra i klizavog kolnika (Mašala-Buhin, 2006).

3.3. Mjesta pripravnosti

Na temelju iskustvenih podataka, konfiguracije terena, mikroklimatskih uvjeta i drugih pogodnosti koje utječu na rad zimske službe, po ustaljenoj višegodišnjoj organizaciji tvrtke „LIKA CESTE“ d.o.o., zimska služba obavlja se iz četiri glavna i deset pomoćnih mjesta pripravnosti (zimskih baza) kako je prikazano u Tablici 1. (Izvor: LIKA CESTE d.o.o., 2014.)

Tablica 1. Raspored mjesta pripravnosti zimske službe

Redni broj	Mjesto pripravnosti	Nadcestarija	Županijske ceste (km)	Lokalne ceste (km)
1.	Gospić – glavno	Gospić	116,20	134,60
2.	Karlobag – pomoćno			
3.	Kosinj – pomoćno			
4.	Perušić – pomoćno			
5.	Sv. Rok – pomoćno			
6.	Otočac – glavno	Otočac	137,00	156,00
7.	Jezerane – pomoćno			
8.	Korenica – glavno	Korenica	138,80	225,00
9.	Prijeboj – pomoćno			
10.	Udbina – pomoćno			
11.	Donji Lapac – pomoćno			

12.	Senj – glavno	Senj	81,57	132,10
13.	Krasno Polje – pomoćno			
14.	Novalja		27,00	12,80
		Ukupno	**500,57**	**660,50**

3.4. Kriteriji osiguranja prohodnosti i posipanje ceste protiv poledice

Pod osiguranjem prohodnosti, izvođač je dužan intervenirati prema kriterijima iz Tablice 2. (Izvor: LIKA CESTE d.o.o., 2014.)

Tablica 2. Kriteriji osiguranja prohodnosti

Razina prednosti	Održavanje prohodnosti	Posipanje	Uklanjanje snijega
I.	24 sata	Preventivno i kurativno	Više od 10 cm snijega na kolniku - kontinuirano
II.	Od 5:00 do 22:00 sata	Preventivno i kurativno	Više od 10 cm snijega na kolniku – kontinuirano
III.	Od 5:00 do 20:00 sata	Preventivno i kurativno	Više od 15 cm snijega na kolniku – kontinuirano
IV.	Od 7:00 do 20:00 sata, uskladiti s lokalnim potrebama	Kurativno	Više od 15 cm snijega na kolniku – kontinuirano
V.	Uskladiti s lokalnim potrebama	Kurativno	Više od 15 cm snijega na kolniku - kontinuirano

U praksi održavanja cesta zimi postoje dvije metode posipanja kolnika u svrhu sprječavanja nastanka i uklanjanja poledice, a to su *Preventivno* posipanje i *Kurativno* posipanje.

Preventivno posipanje je ono posipanje koje se vrši prije nastanka očekivane poledice, ovisno o vremenskoj prognozi, a izvodi se u slijedećim slučajevima:

- pri vlažnom kolniku kada temperatura naglo pada prema 0°C,
- neposredno prije početka padanja snijega,
- kod suhog ili vlažnog kolnika kada se očekuje ili je u prognozi pojava „Ledene kiše“.

Kurativno posipanje izvodi se kada je na kolniku smanjena hvatljivost, a može se koristiti suha ili vlažna sol što ovisi o stanju na kolniku. Kod debljeg sloja snijega ili leda potrebno je izvršiti posipanje kolnika te nakon jednog sata djelovanja soli, ukloniti sa kolnika raskvašen snijeg ili led.

Prema specifičnim stanjima na kolniku (klizavost), a zbog sprječavanja nastanka poledice primjenjuju se:

- abrazivna sredstva,
- sredstva za otapanje leda.

Skladištenje soli – materijale za posipanje potrebno je pravodobno planirati prema duljini i površini prometnica i objekata za posipanje, prosječnoj potrošnji, kapacitetima strojeva za posipanje i uskladištiti sukladno mogućnostima nabave, popune i dopreme zimi.

Osim skladišnih hala ili nadstrešnica potrebite količine soli, koje su uobičajen način skladištenja soli u Ličko-senjskoj županiji, novija mogućnost skladištenja soli su silosi za sol izgrađeni od drveta zapremine od 50 do 250 m^3 pojedinačno.

Silosi imaju prednost u načinu skladištenja soli za zimsku službu, a to su korištenje, upotreba soli bolje granulacije (1-2 mm), dakle bolje pokrivenosti površine kolnika i bržeg procesa otapanja. (Mikulčić, Tomašić, 2001).

Ilustracija 4. Silos za skladištenje soli

3.5. Raspored mehanizacije, opreme, materijala za posipanje te radne snage

U tablici 3 (Izvor: LIKA CESTE d.o.o., 2014.) je iskazan pregled sve potrebne mehanizacije i radne snage po glavnim mjestima pripravnosti, a ovisno da li se radi o dežurstvu – pripravnosti kapaciteta ili planiranih kapaciteta za potrebe održavanja prohodnosti i rada na osiguranju prohodnosti, posebno za županijske i lokalne ceste.

Tablica 3. Raspored mehanizacije, opreme i radne snage po glavnim mjestima pripravnosti

Stupanj pripravnosti	**Glavna mjesta pripravnosti**				**Ukupno**
	Gospić	Otočac	Korenica	Senj	
I. Stupanj					
Cestar	2	2	4	3	**11**
Stroj za utovar posipala	1	1	2	1	**5**
Mali silosni posipač	1	1	2	2	**6**
II. Stupanj					
Cestar	5	7	12	8	**32**
Kamion s priključcima	1	1	3	1	**6**
Unimog s priključcima	2	4	5	4	**15**
Stroj za utovar posipala	1	1	2	1	**5**
Mali silosni posipač	1	1	2	2	**6**
III. Stupanj					
Cestar	3	5	8	5	**21**
Kamion s priključcima	1	1	3	1	**6**
Unimog s priključcima	2	4	5	4	**15**
Utovarivač s priključcima	3	2	3	2	**10**
Stroj za utovar posipala	1	1	2	1	**5**
Snježna freza				1	**1**

Ilustracija 5. Prikaz rada utovarivača sa priključenom snježnom frezom (Županijska uprava za ceste, 2015)

3.6. Uvjeti za ograničenje i zabranu prometa

Ako javna cesta ili pojedine dionice javnih cesta zbog vremenskih nepogoda ne budu sposobne za promet svih ili pojedinih vrsta vozila, Stožer zimske službe u dogovoru sa odgovornom tehničkom osobom u mjestu pripravnosti i područnom policijskom upravom može donijeti odluku o obustavi prometa za sva ili za pojedine vrste vozila.

Ilustracija 6. Zatvorena cesta zbog vremenskih nepogoda (Županijska uprava za ceste, 2013)

Ilustracija 6 prikazuje jednu županijsku cestu koja je zatvorena zbog vremenskih nepogoda, pojave „ledene kiše“ i slomljeno stablo koje onemogućava prometovanje vozila.

Izvoditelj odmah poduzima mjere da se u skladu sa utvrđenim prioritetima održavanja cesta u što kraćem vremenu uklone smetnje i prometnica osposobi za siguran promet.

3.7. Praćenje rada vozila i strojeva u zimskoj službi

U zimskoj službi se koristi informacijsko-telekomunikacijski sustav ARMS (Advanced Road Management System) tvrtke RASCO d.o.o., kojim stožer zimske službe iz svih mjesta pripravnosti daljinski prati stanje i navodi kretanje radnih timova, vozila i strojeva.

Vozila i strojevi na radu u zimskoj službi su opremljeni GPS satelitskim prijamnicima koji zemljopisne odrednice o svom trenutnom položaju šalju putem web aplikacije do računala na stolovima izvođača radova te investitora, koji imaju stalni uvid u trenutni prostorni razmještaj i povijest putovanja svih vozila i strojeva sa opremljenim GPS uređajem.

3.8. Meteo-informacijski sustav u službi zimskog održavanja cesta

Za pravodobno postupanje u zimskoj službi i bolje korištenje resursa zimske službe, te za povećanje sigurnosti prometa u zimskim uvjetima, tijekom 2012. godine Županijska uprava za ceste je uspostavila Meteo postaju koja u realnom vremenu prikuplja meteo podatke s jedne kritične točke na županijskoj cesti kod naselja Krivi Put. Ova Meteo postaja je uspostavljena zbog toga što je zimska baza, odnosno mjesto pripravnosti u zimskoj službi smješteno u Senju, dakle u priobalju, a pokriva široko područje od Senja pa sve do naselja Krivi Put i okolnih sela na cca 800 mnm. Dakle rukovodstvo u Senju ne može pravodobno reagirati na pojavu snježnih padalina ili poledice, te stvaranje snježnih zapuha zbog jakih udara vjetra (bure) oko Krivog Puta bez očitanja meteo podataka prikupljenih od strane Meteo postaje.

4. Analiza posljedica smrzavanja kolničkih konstrukcija

U Ličko-senjskoj županiji glavnina županijskih cesta nije niti projektirana niti dimenzionirana obzirom na dubinu smrzavanja i prometno opterećenje, već su te ceste građene na nekim postojećim putovima uz minimalna proširenja kolnika i minimalne debljine kolničke konstrukcije, stoga se na županijskim cestama učestalo pojavljuju oštećenja takve poddimenzionirane kolničke konstrukcije prilikom prolaska teretnih motornih i priključnih vozila, osobito u proljetnom periodu nakon prestanka zimske službe i pojave odmrzavanja kolničke konstrukcije, kako prikazuje ilustracija 7.

Ilustracija 7. Uništena kolnička konstrukcija jedne županijske ceste (Županijska uprava za ceste, 2013)

Ako je tlo u posteljici kolničke konstrukcije osjetljivo na smrzavanje i ako su hidrološki uvjeti nepovoljni, dimenzioniranje na prometno opterećenje neće biti dovoljno.

Kolničke konstrukcije projektirane za teško prometno opterećenje imaju takve dimenzije i sastav da u većini slučajeva mogu spriječiti prodor niskih temperatura u posteljicu. Slabije konstrukcije (za srednji i laki promet) za to neće biti uvijek sposobne (Babić, 1997:102).

Na ovim brdsko-planinskim teritorijima postoji opasnost od smrzavanja, stoga treba provjeriti je li kolnička konstrukcija dimenzionirana na prometno opterećenje sigurna i od smrzavanja te ako nije, predvidjeti neke mjere u samoj konstrukciji ili u posteljici kako bi se opasnost od smrzavanja otklonila ili svela na prihvatljivu mjeru.

Utvrđeno je da smrzavanje slobodne vode u tlu počinje pri temperaturi tla od -0,1°C. Što je vlažnost tla manja, temperatura smrzavanja tla je niža, odnosno porastom vlažnosti tla raste i temperatura smrzavanja tla.

Tlo bubri poradi kristalizacije leda u većim šupljinama i širenja u ledene leće, slojeve, kanale ili druge ledene mase. Ledena leća raste sve dok se ne iscrpe zalihe vode ili kad uvjeti smrzavanja u ravnini smrzavanja (dodirna površina smrznutog i nesmrznutog tla) više nisu pogodni za daljnju kristalizaciju (Sršen, Kovačić, Kaučić, 2004).

Segregacija leda prvenstveno se javlja u tlima koja sadrže sitne (fine) čestice tla osjetljiva na smrzavanje. Čisti pijesak i šljunak su tla neosjetljiva na smrzavanje.

Osjetljivost na smrzavanje uglavnom je ovisna o postotku sadržaja sitnih čestica.

Dva su glavna učinka koja mogu prouzročiti smrzavanje kolničke konstrukcije i tla, a to su:

- izdizanje kolnika i
- smanjenje nosivosti kolnika prilikom odmrzavanja.

Izdizanje kolnika ne uzrokuje velika oštećenja ako je homogeno, odnosno jednoliko. To je uglavnom rjeđi slučaj. Zbog nehomogenosti tla i lokalnih većih nakupljanja vode, izdizanje je nepravilno i može doći do pucanja kolničke konstrukcije. Isto tako, zbog čišćenja snijega koji se odlaže s krajeva i izolira rubove, srednji dio kolnika može jače smrznuti i više uzdignuti, što također doprinosi oštećenju konstrukcije.

5. Moguća rješenja za poboljšanje kolničkih konstrukcija

Veći dio županijskih cesta Ličko-senjske županije, osim onih koje se protežu primorskim i otočnim dijelom županije, nalazi se u području gdje dolazi do smrzavanja a kolnička konstrukcija, i ona koja je dimenzionirana na prometno opterećenje i ona koja nije, na posteljici od materijala osjetljiva na smrzavanje nema takvu debljinu i sastav da može sama spriječiti smrzavanje posteljice, odnosno sama se oduprijeti štetnom djelovanju smrzavice, te je u tim slučajevima potrebno poduzeti određene tehničke mjere, ili rješenja za poboljšanje kolničkih konstrukcija.

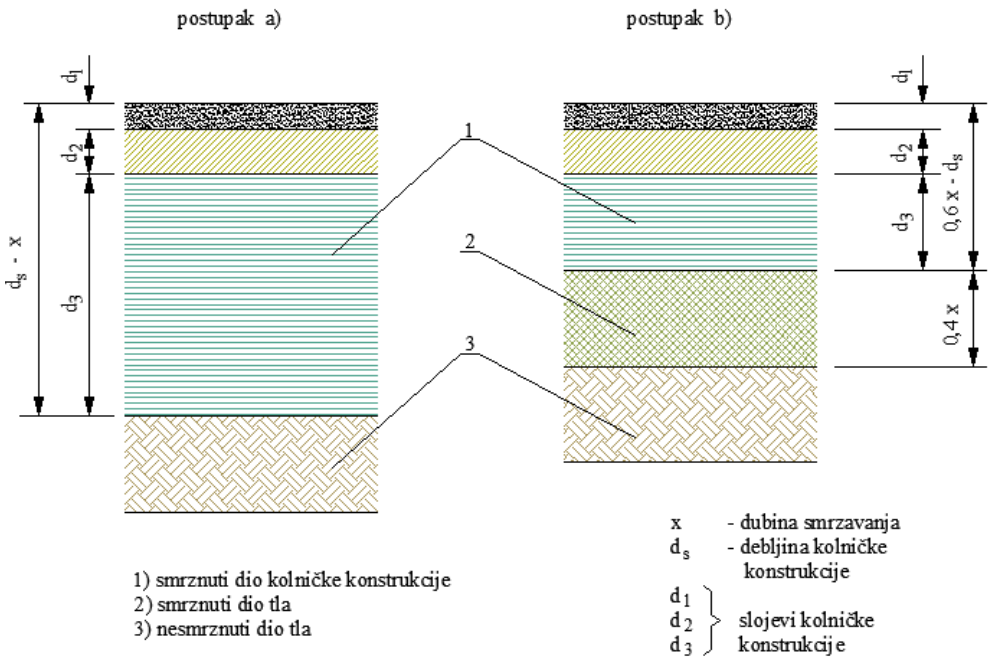
Načelno se ove mjere mogu podijeliti na one što se poduzimaju:

- ispod kolničke konstrukcije,
- u kolničkoj konstrukciji.

5.1. Mjere za poboljšanje kolničke konstrukcije od štetnog djelovanja smrzavanja ispod kolničke konstrukcije

Ove mjere uključuju potpunu zamjenu materijala osjetljivog na smrzavanje, te djelomičnu zamjenu materijala osjetljivog na smrzavanje.

Postupak potpune zamjene materijala osjetljivog na smrzavanje uključuje zamjenu tla ispod kolničke konstrukcije sve do dubine smrzavanja, tako da ni u najhladnijim zimama ne dođe do smrzavanja ispod kolničke konstrukcije (Ilustracija 8, postupak a).



Ilustracija 8. Odnos debljine kolničke konstrukcije i dubine smrzavanja kod potpune zamjene tla (postupak a) i djelomične zamjene tla (postupak b) (Babić, 1997:108)

Postupkom djelomične zamjene materijala osjetljivog na smrzavanje ne zamjenjuje se tlo ispod kolničke konstrukcije do dubine smrzavanja, nego samo dio toga tla. Prema tome, ispod kolničke konstrukcije ostat će dio tla koji će se za hladnijih zima smrznuti (Ilustracija 8, postupak b).

Postoje iskustva o minimalnim debljinama kolničke konstrukcije kad pri smrzavanju ne dolazi do štetnih pojava, iako nije u potpunosti spriječeno smrzavanje tla ispod njih. U Hrvatskoj je, na temelju švicarskih iskustava, usvojeno da minimalna debljina kolničke konstrukcije bude 60% od dubine smrzavanja.

5.2. Mjere za poboljšanje kolničke konstrukcije od štetnog djelovanja smrzavanja u kolničkoj konstrukciji

Ove mjere uključuju izradu stabiliziranog sloja u kolničkoj konstrukciji, te ugradnju termoizolacijskog sloja u kolničku konstrukciju.

Ispitivanja su pokazala da stabilizirani slojevi, zbog svoje krutosti, djeluju tako da je kolnička konstrukcija znatno manje osjetljiva na sezonske promjene nosivosti tla u posteljici nego što je to slučaj za kolničke konstrukcije bez takvoga sloja.

Zato je kod takvih tipova kolničkih konstrukcija potrebna i manja debljina materijala ispod nje za osiguranje od smrzavanja, premda još nisu razrađeni kriteriji koliko bi to smanjenje moglo biti.

Da bi se spriječilo prodiranje hladnoće kroz kolničku konstrukciju, mogu se u tu konstrukciju ili ispod nje ugrađivati materijali s posebno dobrim izolacijskim svojstvima. To može biti npr. sloj stiropor-betona, koji je nosiv (otprilike kao neke vrste stabilizacije), ili stiroporne ploče koje ne pridonose nosivosti, a polažu se na posteljicu.

5.3. Metoda poboljšanja kolničke konstrukcije primjenom postupka recikliranja asfaltnih kolnika

Jedna od metoda poboljšanja postojeće kolničke konstrukcije uz prihvatljive troškove izvedbe svakako je metoda recikliranja postojećih asfaltnih kolnika. Dakle, postalo je jasno da se kod planiranja i projektiranja moraju odabrati najučinkovitiji i najisplativiji postupci i

materijali, osobito u područjima gdje zaliha kvalitetnog agregata za asfaltne zastore više nema, a dovoženje novog materijala s neke druge lokacije nije više isplativo zbog porasta troškova transporta kao posljedica porasta cijene energije.

Recikliranje asfaltnih kolnika znači ponovno korištenje materijala iz postojeće kolničke konstrukcije, tj. podrazumijeva izvedbu nosivog sloja od bitumenom i cementom stabilizirane smjese materijala glodane iz postojeće kolničke konstrukcije i po potrebi dodanog drobljenog kamenog materijala.

Ovisno o primjeni, recikliranjem kolničke konstrukcije povećava se strukturalna čvrstoća kolnika, sprječava pojava reflektivnih pukotina, povećava otpornost na djelovanje smrzavice (Schwabe, Halle, 2008).

Metode recikliranja asfaltnih kolnika mogu se podijeliti u dvije glavne kategorije:

- one koje koriste fiksne pogone („in plant“),
- one na licu mjesta („in place“).

Svaka od ovih metoda može se podijeliti u dvije nove kategorije, a vezano za temperaturu kod građenja – vruće ili hladno recikliranje.

6. Zaključak

Svaka kolnička konstrukcija kroz svoj vijek trajanja podložna je brojnim utjecajima svoje okoline kao što su temperatura, vlaga i smrzavanje, bilo da se radi o kolničkoj konstrukciji koja je dimenzionirana prema određenim pravilima i propisima te o onoj koja nije. U Ličko-senjskoj županiji postoje određene županijske ceste koje uopće nisu dimenzionirane niti na prometno opterećenje niti na smrzavanje, a prolaze brdsko-planinskim i šumskim područjima koja su u zimskom periodu bogata vlagom, snijegom i niskim temperaturama, što za posljedicu ima smrzavanje i bubrenje kolničke konstrukcije. U proljeće prilikom pojave odmrzavanja, a uz izrazito veliko prometno opterećenje od eksploatacije šume dolazi do pojave pukotina na asfaltnim kolnicima te potpunog uništenja kolničke konstrukcije.

Redovno održavanje cesta tijekom zime prvenstveno obuhvaća osiguranje prohodnosti i uvjeta za sigurno odvijanje prometa na cestama. Primarna zadaća zimske službe je održavanje kolnika prohodnim, kao najvažnijeg dijela ceste, u prometno prihvatljivom stanju. Planiranje, koordinacija i praćenje izvršenja aktivnosti zimske službe važan su segment gospodarenja cestama. Sigurno i nesmetano odvijanje prometa, uz jasno definirane prioritete i optimizaciju troškova, osnovni je cilj zimske službe. Realizaciju navedenih ciljeva teško je ostvariti bez korištenja informacijskih tehnologija i alata.

Pravovremena i točna informacija, kao i pristup podacima relativnim za izradbu i provedbu izvedbenog programa rada zimske službe, temelj je praćenja zimske službe i odlučivanja na svim razinama gospodarenja cestama.

Prije nastupanja zimskih uvjeta na cestama treba započeti s pripremnim radovima, tj. ne treba čekati izradu izvedbenog programa rada zimske službe, već tim radovima treba pristupiti sukcesivno, tako da budu sigurno završeni prije uvođenja „zimske službe“.

Za izgradnju novih i obnovu postojećih kolničkih konstrukcija potrebno je odabrati tehnički prihvatljive i ekonomične metode izgradnje i sanacije te koristiti materijale koji nisu osjetljivi na smrzavanje kao što su čisti šljunak i pijesak bez sitnih glinovitih čestica, a izbjegavati tla osjetljiva na smrzavanje odnosno glinovita i prašinasta tla, kako bi ove kolničke konstrukcije bile otporne na smrzavanje i prometno opterećenje dugi niz godina.

Zimski period u Gorskoj Hrvatskoj pa tako i u Ličko-senjskoj županiji može stvarati izrazito velike probleme prilikom održavanja prohodnosti županijskih cesta kao i održavanja kolničkih konstrukcija, što naravno ovisi o količinama snježnih oborina i trajanju temperatura zraka ispod 0°C. Količine snježnih oborina i niske temperature utječu na financijske troškove, stoga je potrebno racionalno i ekonomično ponašanje svih sudionika u zimskoj službi prilikom održavanja prohodnosti cesta, kako bi što više sredstava ostalo za ljetno održavanje i obnovu loših kolničkih konstrukcija županijskih cesta koje se uništavaju uslijed smrzavanja zimi i odmrzavanja u proljeće.

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