REPLACEMENT POINT SYSTEM – Pipeline Replacement Assessment

LO, Anthony W S[a*], CHAN, Alpha K W[a]

[a]The Hong Kong and China Gas Company Limited, Hong Kong, China

Abstract: The Replacement Point System is an in-house developed automation system of Towngas to provide a risk based approach to evaluate the integrity of gas pipes so as to justify and prioritize their replacement needs. It is based on the evaluation factors such as material, protection, proximity distance, age, ground condition, cover, leakage history and frequency etc. to evaluate pipe integrity. Each factor will be given a score and recommendation will be made on the total score. Required data of the evaluation factors can be obtained from the Geographical Information System (GIS) which was built in the early 90s to manage the underground facilities and replace the paper-based pipeline records. The Replacement Point System is then developed on top of the GIS and determined the point score of individual pipe leg in accordance with the pre-defined evaluation factors. Point score of individual pipe leg can be distributed to different score range. The System will present the point score result of individual pipe leg with different score range in different colors in a topographic map view. The System enables Towngas engineers to have an efficient and effective means to prepare the replacement plan of the pipeline based on the point score result as well as the geographic location.

1. INTRODUCTION

Hong Kong is characterized by its terrain so that nearly 70% of its land is mountainous. The lack of flat land supply implies that residential and commercial developments have to be confined to small portions of land and causes high density of high-rise buildings. The underground utilities are required to be installed closer together. In Hong Kong, there are many excavation works every day to cater for the rapid development, sometimes these works are located around underground utilities. And underground utilities may shift from footpaths to carriageways because of environment change due to road or building works at above. These changes affect the pipelines design environment. Apart from this, some underground utilities would be located closer to buildings. In case of incident, it could have uncertain impact on the occupant. The Hong Kong and China Gas Company Limited (Towngas) operates a complex gas distribution network supplying some 1.8 million customers. The pipeline networks like a spider web spanning over the whole territory and reaching household. Towngas focuses on distribution pipeline integrity to ensure public safety, instantiates a pioneer Replacement Point System (RPS) to effectively evaluate potential threats and calculate risk level on each underground pipe segment automatically. It is an intuitive design on-line system. Operators can easily

Email Address : anthony.lo@towngas.com

identify and locate those high risk segments on map and carry out mitigation measures so that the integrity of pipeline systems could be maintained.

2. GEOGRAPHICAL INFORMATION SYSTEM (GIS)

Before 90's, Towngas used paper records to keep its pipeline networks information. Since there are several hundreds of paper records, it was not easy to search and update individual pipe segment information on paper. As the digital electronic maps were available from the Hong Kong Government, Towngas started a pioneer project of construct a Geographical Information System (GIS) in gas industry early 90's. After the system was established, Towngas formed a data conversion team to spend several years to digitize all pipeline paper records into GIS. During the past twenty years, via continuous development of the GIS and updating of pipeline data, the system now becomes a popular and reliable means inside company to provide a strong support for the network day-to-day operation needs.

3. REPLACEMENT POINT SYSTEM (RPS)

Nowadays, in Hong Kong, there are many pipe segments in the gas networks, it is impossible to evaluate risk on each segment without GIS. In the Towngas' GIS system, each pipe segment has own attribute data e.g. facility ID, location, pressure class, materials, diameter, buried depth, age etc… Apart from GIS, there is another Emergency Log System which stores pipe leak records. These two systems can be integrated to construct an automated RPS to frequently carry out the pipeline risk assessment. The structure of it is shown in figure 1. There is a common key facility ID (FID) which represent a segment comes from GIS system.
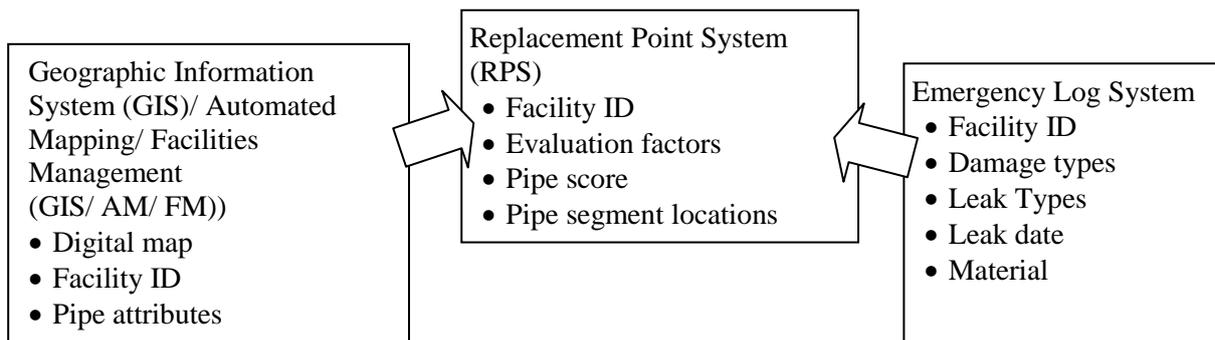
Geographic Information System (GIS)/ Automated Mapping/ Facilities Management (GIS/ AM/ FM))
- Digital map
- Facility ID
- Pipe attributes

Replacement Point System (RPS)
- Facility ID
- Evaluation factors
- Pipe score
- Pipe segment locations

Emergency Log System
- Facility ID
- Damage types
- Leak Types
- Leak date
- Material

Fig. 1 The structure of Towngas' Replacement Point System (RPS)

4. APPROACH TO RISK EVALUATION

The RPS is a risked based approach for better replacement planning of ageing resources. It gives a comprehensive overview with all risk factors related to underground pipework taken into consideration. The number of points allocated to individual criterion and the weighting factors were originally based

on similar systems adopted by other advanced gas corporations which were forerunners on RPS, and gradually refined in the past two decades to reflect the genuine needs and conditions in the unique environment of Hong Kong. The application of the RPS in its present form has proved to provide an objective and effective means in Towngas' replacement prioritization. The system is based on the material, protection, proximity distance, age, ground condition, cover and leakage history and frequency. Each factor will be given a point value and weighting to determine the score and recommendation will be made on the total score. But in the past, the points were worked out manually thus the procedure was extremely tedious. Some of the criteria like proximity to buildings, road conditions are difficult to check on manual maps. The limited leakage history in the data library (since the GIS was only established in the mid 90s) also affected the accuracy of such as risk based analysis. We are now making use of data in GIS to evaluate each pipe segment under these factors. If insufficient information of a pipe is encountered, we will take "on the safe side" approach which chooses the maximum point value.

4.1 Material Type Factor

Steel			PE	DI	GI
Submerged Arc Weld	Seamless	Electrical Resistance			
1	1	5	3	10	10

Table 1   Material Type Factor

In the GIS, we have the pipe materials information, 10 points will be directly given to galvanized iron (GI), ductile iron (DI) pipes, and 3 points to polyethylene (PE) pipes. On the safe side, 5 points will be given to steel pipe while the welding type is uncertain.

4.2 Protection Factor

Protection Measure	DI pipe without Any Protection	DI pipe with External & Internal Coating	DI pipe with coating + PE Sleeving	DI pipe with coating + PE Sleeving + Steel Plate
Point	10	10	5	0

Table 2   Protection Factor (DI pipe)

Protection Measure	GI pipe without Any Protection	GI pipe with Tapes at Screw Joints (CAT)	GI pipe CAT + Steel Plate	GI pipe with Selected Material Surround + Concrete Protection + Steel Plate
Point	10	7	5	0

Table 3   Protection Factor (GI pipe)

In this factor, 2 points and 5 points are assigned to PE pipe with or without warning tape respectively. On the safe side, 10 points will be given to other pipes.

4.3 Material Wall Thickness & Stress Factor

Wall Thickness	Working Pressure / Material	Point
Any Class	MP / DI	10
Any Class	LP / DI	5

Table 4   Material Wall Thickness & Stress Factor (1)

Wall Thickness	Working Pressure / Material	Pipe Size	Point
Heavy	MP / GI	> 50mm	Not Allowed
Heavy	MP / GI	< & =50mm	7
Heavy	LP / GI	All	5

Table 5   Material Wall Thickness & Stress Factor (2)

In the GIS, we have pressure and material information of pipe. Hence the above point values could be directly assigned to them. Other than above, they will be assigned to zero.

4.4 Joint Type Factor

Joint Type	Welding	Fusion	Mechanical	Screwed
Point	0	0	10	10

Table 6   Joint Type Factor

Judging from the pipe material, we know the joint type, hence 10 points will be given to DI and GI while zero point will be assigned to the other materials.

4.5 Proximity distance Factor

This factor considers those pipes having proximity distance to buildings.

Working Pressure	Distance from Building				
	< 1m	1m - < 2m	2m - < 3m	3m - < 5m	5m & above
IPA	10	7	5	3	0
MP	7	5	3	0	0
LP	5	3	0	0	0

Table 7   Proximity distance Factor

In the GIS, we have pipe and building individual geographic layer information, and they can be overlapped to visualize. In figure 2a, we can see the building of Towngas, and in figure 2b, it shows gas pipes overlapping with buildings layer.
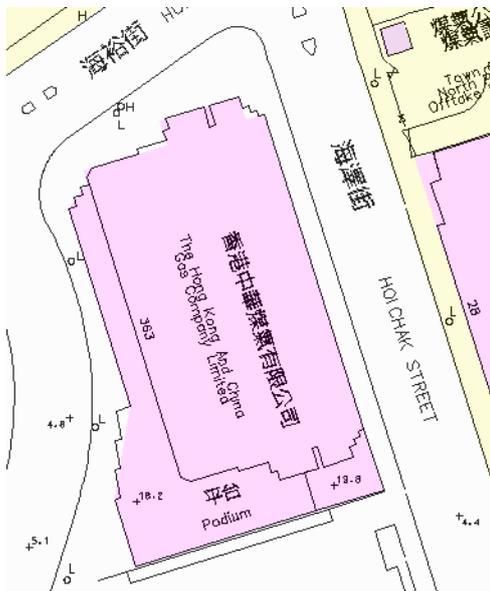

Fig. 2a buildings layer

Fig. 2b buildings and pipes overlap

However, we do not have the distance data to tell us how close a pipe to the building is. Hence, we need to make use of spatial tools to calculate and identify pipes having 5m or less away from buildings. To use spatial tools, we need to convert data into geospatial data format in the database first and then apply Structured Query Language (SQL) to call a function to find out the shortest distance point of a line (pipe) from polygons (buildings). We may conceive that there is a 5 meter width buffer zone formed around a building, for those pipes fall into this zone, we will give them a point value, see the figure 2c below. We will assign zero point to those pipes which do not fall in the above situation.
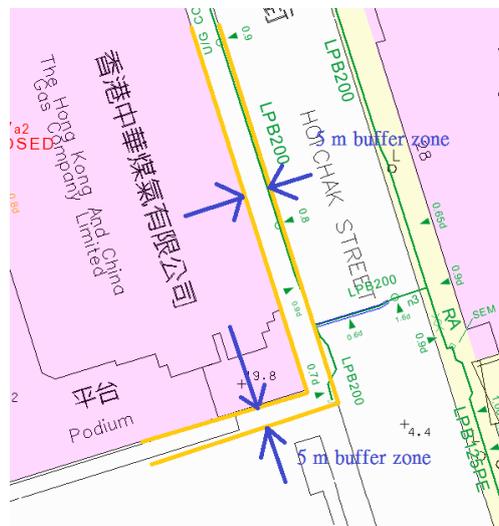

Fig. 2c 5m buffer zone around building

4.6 Age Factor

Age (Year)									
System Type	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	>40
Steel Pipe with CP	0	0	0	0	0	0	0	5	10
Steel Pipe w/o CP	0	0	0	5	10	10	10	10	10
Ductile Iron pipe	3	3	3	5	10	10	10	10	10
P.E. Pipe SDR 11	0	0	0	0	0	0	0	0	0
P.E. Pipe SDR 17.6	0	0	0	0	0	0	0	5	10
G.I. pipe	0	0	5	7	10	10	10	10	10

Table 8   Age Factor

In the GIS, we have the pipe installation year and cathodic protection (CP) information which can be used to assign point values according to the above table.

4.7 Ground Condition Factor

Type of Ground	Dry Condition	Wet Condition	
		pH Level 5 - 6	pH Level below 5
Rock	0	5	10
Sand	0	5	10
Soil	0	5	10

Table 9   Ground Condition Factor

This factor considers if pipes were buried in an acidic environment. In the GIS, we overlay pipes and roads together, and use spatial analysis tools to determine if the pipe is on a carriageway, footpath or back lane. Back lanes are generally assumed with poor state of the environment, people wander in and out, more accumulation of debris and sewage, leaky sewage flowing into underground will make the soil with highly acidity less than 5, and hence 10 points would be given to pipes at back lane. On footpaths and private area where control of backfill during construction stage may be less stringent, PH is around 5-6 slightly acidic, 5 points will be given to pipes at footpaths or private area. Carriageway condition is presumably dry, control of backfill during construction stage is stringent, PH is around 7, and hence pipes in carriageway are given to zero point.

4.8 Pipe Cover Factor

This factor considers the depth of pipe is buried.

Depth of Pipe (m)	below 0.6	0.6 - < 0.7	0.7 - < 0.8	0.8 - < 0.9	0.9 & above
Point	10	7	5	3	0

Table 10   Pipe Cover Factor (At carriageway)

Depth of Pipe (m)	below 0.3	0.3 - < 0.4	0.4 - < 0.5	0.5 - < 0.6	0.6 & above
Point	7	5	3	1	0

Table 11   Pipe Cover Factor (At footpath)

In the GIS, we have depth point information of a pipe, and we know the road type where a pipe is laid. Hence, we could assign directly the point values. If a pipe section has several depth values, we consider the smallest value, which is the conservative approach.

4.9 Leakage Type Factor

In the Emergency Log System, we have pipe leakage information which tells us the leak pipe facility ID, leak types and incident date. We could use the leak types below to assign point values.

NATURE	Point
Crack line	10
Widespread Corroded Pipe	10
Corroded Syphon standpipe	7
Leaking Joint of PE Pipe	7
Localized corrosion	7
Joint seepage - with corroded bolt & nuts	7
PE valve seepage	7
Joint seepage - without corroded bolt & nuts	5
PE/Metallic transition fitting seepage	3
PE branch fitting seepage	3
Plug seepage	3
Pressure / Purge Point on PE Pipe	3
Syphon standpipe seepage – without corrosion	3
Valve spindle seepage	3
Third Party Damage	0
Physical Damage	0

Table 12   Leakage Type Factor

4.10 Leakage Frequency Factor

Leakage	0	1	2	*3 & >3
Point	0	2	5	10

Table 13   Leakage Frequency Factor

* If all the cases happened in a period of 12 months along the same pipeline, additional 5 points shall be given.

4.11 Score Calculation

Through the above exercise, all segments in the GIS have their corresponding point values. We now calculate the score based on the score formula: Score = Point x Weighting

	Factor	Weighting	Point	Score
A	Material Type	0.75		
B	Protection	0.50		
C	Material Wall Thickness & Stress	0.75		
D	Joint Type	0.75		
E	Proximity Distance	1.00		
F	Age	1.25		
G	Ground Condition	1.00		
H	Pipe Cover	0.50		
I	Leakage Type	1.50		
J	Leakage Frequency	2.00		
			Total Score	

Table 14   Score Calculation [1]

5. SYSTEM FEATURES

After computing total score on each pipe, we designed an interface for users to access it. It is a web-based interface running on internet browser so that users can easily access it. We designed to have an intuitive overview of the risk-based pipes showing in different colors according to scores as shown in Fig. 3a & 3b. Users can also select the pipe color layers to switch on or off on the map.
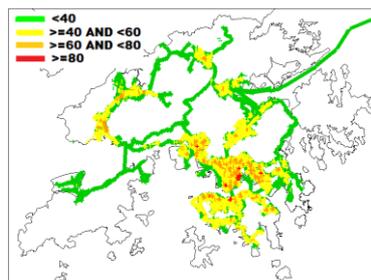

Fig. 3a The overview of risk-based pipes in different colors according to the scores

Fig. 3b The overview of risk-based pipes on Hong Kong Island

6. SYSTEM FUNCTIONS

6.1 Attribute review

It provides an attribute review function that user can select a pipe on map and popup the score details as in Fig. 4

Pipe Score	
FID	227826
Install_date	1971-DEC-26
Last_incident_date	No
Total_Score (Max 110)	49
Protect_with_CP	No
Shallow_Depth	No
Road_Type	No
BACKLANE	Yes
Warning_Tape	No
Material_Score (Max 7.5)	7.5
Protection_Score (Max 5)	5
Wall_Thickness_Score (Max 7.5)	3.75
Joint_Score (Max 7.5)	7.5
Building_Proximity_Score (Max 10)	3
Pipe_Age_Score (Max 12.5)	12.5
Ground_Condition_Score (Max 10)	10
Pipe_Cover_Score (Max 5)	No
Pipe_Leakage_Score (Max 15)	No
Leakage_Frequency_Score (Max 30)	No

Fig. 4 The score details of a selected pipe

6.2 Query on pipe attributes

It provides attribute selection function for user to choose operating pressure, material and range of score, and then immediately list out the score of pipes and highlight them in colors. For example, we select the operating pressure to be LP and material to be DI, score range to be 60-110, the result is

shown in Fig. 5. It can be exported to a csv file. In addition to attribute selection function, it also provides function to draw a polygon on map and then select pressure, material and range of score to extract pipe score information inside it. Map printing function is also available to users.
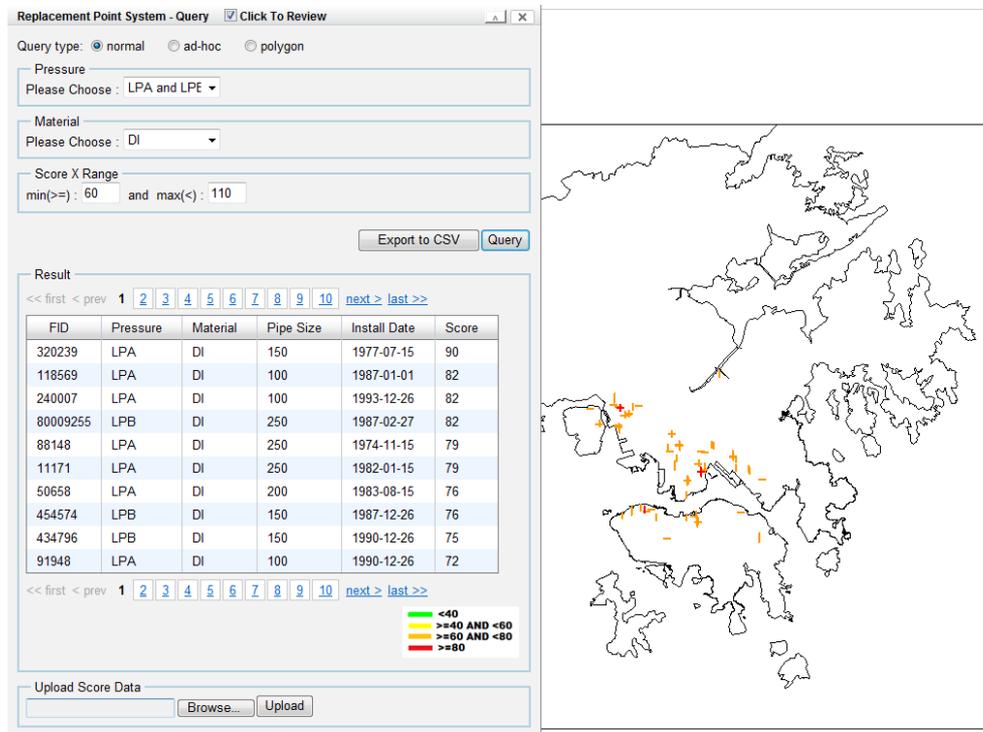

Fig. 5 The overview of LP DI pipes

7. CONCLUSION

Towngas has put much effort into re-vitalizing Company engineering innovation and technology so as to further enhance the public safety and reliability of its comprehensive gas distribution system. The Replacement Point System is an example. It is one of a pioneer risk-based pipelines replacement system built on top of the existing sophisticated GIS asset management system. It has an intuitive design interface to use and provides useful functions to generate a map view of risk-based pipes in individual color. With the automation of the RPS and direct linkage to the GIS database, coupled with refinement of the data through years of effort, the risked based RPS is now at the fingertips of planning engineers for their prioritization and scheduling of replacement of ageing pipework in Towngas' network, which is a great leap forward in Towngas' asset management system. We are also refining the Asset Management system with linkage to the ERP systems so that asset life cycle cost could be predicted and evaluated effectively for the planning engineers.

REFERENCES:

[1]   Point System for Replacement of Gas Pipes