Cost-Benefit Analysis of Mandatory Event Data Recorder Applications - Approach and Results

Erwin Petersen, Jörg Ahlgrimm

Abstract

The European Commission and the European Parliament are considering potential Europe-wide requirements for mandatory applications of event data recorders (EDRs) for road vehicles. This paper describes the approach and results of a cost-benefit assessment for potential legislative measures. Going beyond known studies the measures are differentiated by dedicated vehicle category. In addition, not just the EDR installation costs and benefits due to accident reductions, but also costs for the necessary infrastructure and read-out of data sets as well as benefits by utilizing the EDR data sets for expert reports and further processes are taken into account. In spite of “conservative” parameter settings and “halved” accident costs within the period under consideration, this assessment shows significant economic net benefits of more than two billion euros in the ramp-up phase and 350 million euros in the first “full-year” – valid for mandatory EDR installation in all motor vehicles in Germany. The corresponding benefit-cost ratio over the full year is higher than five for “all” and at least higher than four for each vehicle category. Both for buses and heavy trucks the benefit-cost ratio is several times higher than for light trucks, cars and motorcycles.

1 Introduction

There have been calls for the widespread application of event data recorders (UDS, UDR) in road vehicles by accident researchers and councils of transport authorities for many years. However, current uses in Europe primarily concern selected applications in emergency vehicles, for insurance companies and in targeted research projects. In the USA, standardised (accident) event data recorders (EDRs) have been widely used for a long time. Unlike flight recorders (black boxes), such event data recorders do not monitor the driver continuously, but simply record physical data on vehicle dynamics and driver reactions in the brief pre-crash and crash phase. Following an initiative of the US National Highway Safety Administration, from autumn 2014 all light motor vehicles (cars etc.) in the USA must be equipped with such EDRs as a compulsory requirement [1]. The European Commission, supported by the Transport Committee of the European Parliament [2], has focussed specifically on the mandatory introduction of event data recorders across Europe since 2011. This may take place gradually, differentiated by dedicated vehicle category, initially for those in commercial applications [3].

The public discussion about event data recorders is not always conducted in an objective manner in Germany. With a view to regulatory measures possibly being introduced in the EU, the German Road Safety Council (DVR) examined the issue, investigated the contexts in which event data recorders are used [4] and prepared a position paper containing recommendations for further action [5].

This paper deals with cost-benefit assessments of potential mandatory applications of standardised event data recorders. It starts by looking at the approaches taken by an existing EU study and then goes on to demonstrate an approach and present results based, in Germany, on valid data sets, differentiated by dedicated vehicle category and introduction scenario as well as for various parameters.

1.1 European cost-benefit assessment from 2006

A cost-benefit assessment of potential safety measures [6] commissioned by the European Commission takes account of event data recorders. It is based on the entire European car population as well as the accident figures and accident cost rates established for Europe over the period under consideration from 2006 to 2025. In the approach taken, the benefit-cost ratio is essentially determined by the accident reduction potential on the one hand and installation costs on the other.

The cost of equipping all motor vehicles with event data recorders as mandatory original equipment from 2007 is estimated to be 100 euros or, taking limit values into consideration, 70 euros and 150 euros per vehicle. For the potential reduction, through EDR, of the frequency and seriousness of accidents resulting from preventive driver behaviour a rate of 10% (7% to 15%) was chosen. With a value of 7.1 (3.6 to 10.7), the corresponding benefit-cost ratio is high – especially by comparison with the other measures considered.

1.2 The influence of EDR on the frequency of accidents

The values used in the EU study for the reduction of the frequency of accidents through EDR are taken from several published studies and projects in European countries [6, 7], but are not interpreted with respect to their boundary conditions. It is to be noted, however, that these values generally come from specific project implementations, e.g. of emergency vehicles, in which "support measures", the selection of the application, that of the group of drivers, and/or other influences will have contributed to the overall effect. This means that the results are not simply transferable to broad mandatory applications.

After significant "crash recorder" applications in cars of young clients had been analysed over several years, in 2012 AXA Winterthur [7] reported a 15% decrease in accident frequency over a comparison group. However, it is expressly pointed out that it cannot be determined what proportion of this result is generated by the "selection" of the group of drivers (young drivers who use EDRs in order to reduce the insurance premium and intend driving with more awareness) and what proportion by generally applicable preventive driver behaviour just due to the existence of the EDR "per se". This latter proportion – unpublished – is estimated to be approximately one third, i.e. approx. 5%.

There is clearly a lack of scientifically substantiated research specifically quantifying the preventive benefit exclusively due to equipping vehicles with EDRs "per se" to justify the widespread mandatory introduction of EDRs. It is, however, plausible that in the case of wide range EDR applications such effects will, in principle, arise, since speed checks and other traffic technology measures have certain effects also. For example, with EDRs, following an accident, the initial speed can be determined, as can whether this was above a valid speed limit or unreasonably high for the road conditions. If this is brought to the attention of drivers, it should have a reducing effect on 37% of all accidents for which an "unreasonable speed" is registered as the cause.
If event data recorders were recording not just data from real accidents but also data from near miss accidents and other critical driving situations in the sense of "naturalistic driving monitoring" and displaying this data to the driver in an appropriate form, this is expected to have a major effect on driving behaviour. However, this study does not take such approaches into consideration. Instead, comparatively "conservative" rates are used for corresponding EDR effects through preventive driver behaviour. In addition, after several years of application the effect of accident research, improved through the use of EDR data, leading to a reduction in the incidence of accidents, is included [5].

2. Differentiated cost-benefit study for the mandatory introduction of EDRs, approach

This cost-benefit study is following up a background paper on the position of the German Road Safety Council on EDRs [5], in which a plausibility approach to the efficiency of EDRs in dedicated vehicle categories is determined on the basis of 2011 accident data sets in Germany. According to this study, the mandatory introduction of EDRs in heavy motor vehicles, i.e. heavy trucks and buses, would be "more efficient" than in light trucks and cars in respect of the availability of EDR data sets for serious accidents [4].

2.1 Accidents considered, casualties and accident costs

The calculation model developed for this study is adapted from the methodology of industrial amortisation calculations. Initially, the potential of EDRs to reduce the costs of accidents, the costs of the mandatory equipping of the vehicle population in Germany, and, as its quotient, the "pure" EDR benefit-cost ratio, are determined. And this, not only in total for "all motor vehicles" but also

differentiated by vehicle category with vehicle population and accident rates for 2011 [8, 9, 10]. Heavy trucks and articulated tractor semitrailer combinations are subsumed under heavy trucks. As for motorcycles, merely those displaying a registration number (>50 cm³) are taken into consideration (Table 1).

Table 1: Road traffic accidents and personal injuries in 2011 by vehicle category involved in the accident [8-11]

Road traffic accidents 2011 with	Heavy Trucks >7.5 t	Light Trucks <=7.5 t	All Goods Vehicles	Buses	Motor cycles >50 cm³	Cars	All Motor Vehicles
personal injury	10,920	19,926	32,766	5,546	29,514	249,176	306,266
deaths & serious injuries	3,075	3,823	7,245	945	10,464	46,619	64,036
serious property damage	4,888	6,852	12,802	779	1,202	78,434	81,487
Injured persons in road traffic accidents by vehicle category in 2011							
Fatalities	549	318	889	64	738	3,061	4,009
Seriously injured	3,200	4,228	7,835	1,052	10,439	51,741	68,985
Slightly injured	11,277	22,396	35,508	7,883	23,099	276,081	323,380

Based on the actual figures for 2011 (Table 1) the accident figures have been predicted for the years 2015 to 2032 in individual calculations per vehicle category. First of all, for 2020 the targets of the German Ministry of Transport (40% fewer deaths than in 2010) are used and e.g. adjusted for persons with serious and slight injuries in proportion to their lower changes from 2000 to 2010 (e.g. - 40/51 x 39% = - 30% and - 40/51 x 3% = - 18%). Accordingly, until 2032 different, but in all cases lower, annual reductions are applied for each category of damage and accident. The figures, which are calculated individually for each vehicle category, differ considerably. For example, the reduction rates of the figures for buses are much lower than those for cars, etcetera.

Table 2: Economic costs of road traffic accidents in Germany, 2011 [11]

Personal injury costs, total	€14.08 billion	Property damage costs, total	€18.05 billion
		per accident with personal injury	€15,355
per fatally injured person	€1,177,980	with fatally injured persons	€42,880
per seriously injured person	€112,834	with seriously injured persons	€20,400
per slightly injured person	€4,482	with slightly injured persons	€13,676
		per serious road traffic accident with only property damage	€20,442
		per other road traffic accident with property damage (inc. alcohol)	€5,839

On the basis of these accident data scenarios the annual accident costs are calculated using the accident cost rates established by the Federal Highway Research Institute (BASt) for 2011 (Table 2). Initially, these cost rates are averaged over all vehicle categories and do not take into account the higher property damage costs resulting from accidents with heavy vehicles involved. When contacted, the BASt was able to show differentiated adjustment factors for the vehicle categories considered here (Table 3). Accordingly, accident costs in 2011 for serious accidents causing personal injury and/or property damage involving heavy trucks (or buses) are, at 5,258 (4,946) euros per registered vehicle, 12.7 (11.9) times higher than the average value for all vehicles (414 euros) (Table 3).

Last year's accident cost rates published by the BASt varied with no identifiable trend. Therefore, in this study the valid cost rates and factors for 2011 over the period under consideration until 2032 are assumed to be constant. They form the basis for the calculation of the annual accident costs with annually falling accident and casualty figures for each vehicle category. The accident costs for the first "full year", i.e. after "full" penetration has been reached, and the accumulated accident costs, i.e. accumulated over the period from 2015 to the relevant full year, are shown separately. If, as in the case of motorcycles, the ramp-up until "full" penetration extends beyond 2032, the accident figures and accident costs are extrapolated for the "full year", whereas the accumulation only lasts until 2032.

Table 3: Multipliers for property damage cost rates in accordance with Table 2 for road traffic accidents in 2011 with the dedicated vehicle category involved, by vehicle category [11] .
Accident costs for related serious accidents in 2011 and predicted for 2020 and 2032.

	Heavy Trucks >7.5 t	Light Trucks <=7.5 t	All Goods Vehicles	Buses	Motor-cycles >50cm³	Cars	All Motor Vehicle
Multipliers for property damage cost rates of road traffic accidents							
with personal injury	3.599	1.521	2.154	1.513	0.451	1.027	1.0
with serious prop. damage	1.774	1.121	1.344	1.249	0.455	0.967	1.0
Accident costs for all accidents causing personal injury or serious property damage by vehicle category							
in 2011 € million	1,832	1,574	3,526	378	2,366	16,161	20,324
per vehicle vs. average	12.7	1.8	3.3	11.9	1.5	0.9	1.0
in 2032 € million	1,137	1,008	2,220	297	1,060	8,281	10,412
Partial accident costs as potentially be influenced by EDRs							
in 2011 € million	1,671	1,416	3,190	334	2,295	14,677	18,607
Forecast 2020 € million	1,229	1,067	2,373	294	1,411	9,968	12,491
Forecast 2032 € million	990	871	1,924	261	1,014	7,337	9,301

2.2 Accident costs and accident cost reduction by EDR

Although, for accidents and accident costs potentially influenced by EDR all accidents resulting in fatalities and serious injuries are taken into consideration, accidents generating slight injuries and serious accidents generating property damage are only taken into account partially (up to 70% and up to 90% respectively), while other accidents resulting in property damage are not taken into account at all. While the economically relevant accident costs in Germany for 2011 (Table 2) amount to 32.12 billion euros, the cost basis that may be influenced by EDR is calculated here as “only” 18.6 billion euros for 2011 (Table 3) and, as a result of the predicted fall in the number of accidents 2032 as 9.3 billion. If all accidents resulting in personal injury and all “serious“ accidents, but not other accidents with “only slight property damage“ are taken into consideration, the cost basis increases by 10% to 20.3 billion euros (Table 3). The inclusion of other accidents with property damage, e.g. alcohol-related accidents, would further increase the basis.

As the cost basis potentially be influenced by EDR is calculated here as “only” 18.6 billion euros, i.e. just 60% of all accident costs, clearly – compared to the EU study [6] – “conservative“ factors are used for the reduction of accidents and hence of these costs also. These factors comprise a factor of initially 3%, effective from the start of EDR use, which only takes the preventive effect without “support measures“ into account, and an add-on of 2%, applied after several years, totalling 5%. The 2%, correspond to the effectiveness of transport and vehicle technology measures, which are initiated by accident research especially improved by means of EDR.

2.3 EDR installation costs and introduction scenarios

The unit costs for EDRs, installed as original equipment and standardised in terms of data content as well as read-out and evaluation processes, are taken as 25 euros for cars, 30 euros for trucks and buses and 80 euros for motorcycles. For cars and vans they are based on a technology optimised for original equipment, e.g. integrated into an airbag module, and are similar to the EDRs which are customary in the USA (unit costs according to NHTSA [1] approx. USD 20). Such devices are also used, without statutory measures, by global car manufacturers in Europe [5]. However, for mandatory car and van applications this study assumes the introduction of improved EDRs from 2020, for example, which meet higher EU requirements in accordance with VERONICA [3, 12, 13].

Similarly, integrated technologies and the higher EU requirements are taken into account for heavy motor vehicles [5]. Instead of car type EDRs being integrated into airbag modules, it may be advantageous for heavies to have EDR integrated into the mandatory fitted ESP or emergency braking

system. Higher unit costs are assumed for motorcycles, since the system data network typically used in cars and commercial vehicles cannot be assumed for the entire range of models. This results in, among other things, higher own expenditure on sensors.

Following the amortization of development costs and rationalisation, the initially unit costs will be reduced from approximately 2020 and 2025 by10% and will continue to fall by a further few percentage points. Since such integrated electronic storage units are maintenance free, no further costs, such as maintenance or replacement costs, are incurred. In the event of device failure, this would affect the carrier unit.

In accordance with political directives the years during which all initially registered vehicles will start to be equipped with mandatory EDRs can be the same or different for dedicated vehicle categories, for example 2018 for heavy trucks and buses and 2020 for cars, light trucks and motorcycles. The period of time until “full” penetration of the vehicle population depends on the number of vehicles registered per year. According to relevant data from the Federal Motor Vehicle Transport Authority (KBA), this is expected to be about 6 years for heavy trucks, 8 years for light trucks, 12 years for buses and cars, and 24 years for motorcycles. In order to prevent results being distorted by “exotic long-runners“ a “full year” is understood to be one with a penetration of at least 90% of the relevant vehicle population. Should statutory measures initially relate only to vehicles with new type approval, this will lead to later application dates and longer ramp-up times.

2.4 EDR benefit-cost ratio

The basic data and parameters explained above are inputs to individual spreadsheets for each vehicle category. In such spreadsheets accident figures as well as the trend in accident costs, EDR market penetration, the resulting installation costs and reduction in accident costs and, as their quotient, the “pure” EDR benefit-cost ratio for the individual year, then for the cumulated ramp-up phase as well as for the “first full year“ are calculated over the time axis and displayed as partial results.

Limited voluntary EDR fitments are considered as shares of the total penetration rates and are incorporated into the calculation of accident cost reductions and investment costs. However, extended voluntary EDR applications in advance of mandatory applications are not taken into consideration here. This could be appropriate if, for example, the voluntary application of US-specified EDRs in Europe assumed significant rates. This would not, however, have an impact on full-year results.

2.5 Infrastructure costs of the read-out and storage of EDR data sets

Other than in the EU study [6], not only are the EDR installation and accident reduction costs taken into account, but to some extent also “infrastructure“ and data application costs. These include the procurement and/or adaptation and maintenance of accident databases and readers as well as the read-out and use of EDR data sets.

In Europe so far processes for the read-out, storage and evaluation of EDR data sets are set up differently by device manufacturers and/or projects. However, they still have to be defined and harmonised for efficient high-volume mandatory applications [4, 5]. Afterwards the exact costs can be verified. For the estimated costs according to Table 3 – based on VERONICA concepts [3] – it is generally assumed that the authorised police officer recording an accident would contact the vehicle diagnosis interface (OBD) using an adaptor. He or she then downloads the currently stored and password-protected data into a laptop, or similar, equipped with the relevant software and later adds the EDR data to the digital “accident file“. This accident file, with the data and sketches of the conventional accident report form, photographs, etc., supplemented by the EDR data set and, if applicable, “printouts“ of an automatic basic evaluation, forms the basis for expert reports and in depth research procedures. In accordance with current accident reporting procedures, which are regulated by law, a still to be defined anonymised part of the EDR data is incorporated – possibly in condensed or partially evaluated form – into the statistics of the state and federal offices as well as the BASt and other research centres [4].

If vehicle damage means that a read-out via the OBD interface is not possible, the event data recorder, or its "carrier unit", must be expanded, contacted and read out by an expert with an extended adapter set. In Table 4 this more complex process is taken into account for 10% of the serious accidents.

Table 4: Cost components and total costs of EDR infrastructure and read-out processes

Categories of costs	Factors	Costs - „All vehicles" cum. before 2032	Costs - „All vehicles" in 2032
Data systems creation/adaptation		€1.9 million	
ongoing maintenance p.a.	€0.1 million	€1.5 million	€0.1 million
Read-out adapter & software Total units	5.000		
Initial procurement, complete set & software	€1.010	€5.05 million	
Annual software update from year 4	€24	€1.44 million	€0.12 million
Replacement 5% p.a. from year 4	€510	€1.53 million	€0.13 million
Read-out and storing of EDR data sets of			
Accidents w. fatal/serious injuries 90% & serious accidents w. property damage 85%	€42	€22.4 million	€3.2 million
Accidents w. slight injuries 70%	€30	€21.8 million	€2.9 million
Total costs:		€55.6 million	€6.5 million

The legislator has to stipulate from which categories of accident the EDR data are to be read out and stored. Data of relevance to an accident can only be read out if an existing recorder has "recognised" the accident as such and "triggered" a recording. This depends on the quality of the device. In accordance with further EU requirements under VERONICA [3], here, different rates for accidents resulting in deaths or serious injuries (90%), serious property damage (85%) and slight injuries (70%) are applied to calculate the read-out frequency and costs (Table 4). Lower rates have to be applied for US-specified EDRs (triggers primarily through airbag deployment).
The amount of investments and current costs for the EDR data systems depends on whether a new central database will be created or existing state or federal databases or those of the BASt or others are simply to be expanded and used. In the latter case the amount shown in Table 4 may be too high.

2.6 Potential savings resulting from the use of EDR data sets

Through the use of EDR data, infrastructure and read-out costs are offset by generated cost reductions for investigation expert reports, for processes in insurance companies and for accident research processes (Table 5). Today, some 40,000 accident-related expert reports are produced in Germany each year. It is estimated that a significant proportion (at least 20%) of the reports normally produced by accident experts could be dispensed with entirely if authorised police officers, staff in insurance companies, inter alia, could personally have access to the necessary EDR data and an automated basic evaluation with, for example, information on speed, vehicle standstill or the sequence in which accidents occurred in simple cases. Moreover, the preparation of the remaining, more complex, reports is simplified for properly trained experts. To secure the details, further analyses are to be carried out.
With growing EDR penetration there is an increasing number of EDR read-out processes and hence reports influencing these processes. On the basis of the data recording and read-out principles described above, EDR data should be available after a few years of the ramp-up phase for most and then, in the full years, for almost all accidents for which an expert report is drawn up. These significant savings in the area of expert reports – of approx. 20 million euros in the full year and 230 million euros in the ramp-up phase – relieve, first and foremost, the parties who pay for judicial inquiries, i.e. the parties liable for costs and also the judicial cash offices, from criminal and civil proceedings.

Besides these benefits, the systematic applications of EDR data make further reductions for processes in insurance companies possible. Approximately 10% of claims require further clarification as to who caused the accident and the extent of the liability of the parties involved. In these cases, expenditure on investigations can be reduced by the EDR assessment supplying the facts. Often lengthy investigations and also civil disputes can be shortened or totally avoided.

Table 5: Potential cost reductions resulting from the use of EDR data for expert reports for the settlement of insurance claims and in accident research

Potential reductions	Factors	Benefit - "All motor vehicles" cum. before 2032	Benefit - "All motor vehicles" in 2032
Expert reports Number	40,000 p.a.		40,000
Costs per expert report	€2,000		
Potential elimination through the EDR use	20%	€191 million	€16 million
Cost savings per remaining report	€100	€38 million	€3.2 million
Other potential savings			
in collecting and forwarding accident data		N.N.	N.N.
in insurance processes		N.N.	N.N.
In accident research processes		N.N.	N.N.
Benefit:		€229 million	€19.2 million

In addition, through the systematic use of EDR data not only improvements in quality but also cost reductions can be achieved in the recording and forwarding of accident data and in the accident research processes of government and private institutions and organisations such as GIDAS [14], for OEMs inter alia. There are currently no figures available for these items. The columns provided for them in Table 5 are therefore only "methodical placeholders" and leave potential benefits open.

The availability of EDR data opens up possibilities and may prompt "desires" to extend the quality and scope of reports beyond necessary levels. Unnecessary evaluations could partly offset the potential cost savings. This is not assessed in this study, as these are diminishing transitory phenomena. On the other hand, the availability and benefit of EDR accident data improve the quality of the claims settlement procedures of insurance companies and the dispensation of justice. These, rather ideal, benefits are not quantified here either.

The (labour) costs incurred for read-out and storage processes as well as the – with the data sets possible - savings on expert reports are determined individually for the vehicle categories using the factors set out in Tables 4 and 5 and then added to their full-year costs and benefits for "all motor vehicles". By contrast, the infrastructure costs and the cost reductions for insurance processes and in accident research are initially compiled across the board for "all motor vehicles" and then apportioned to the individual vehicle categories in proportion to the number of accidents resulting in death and serious injury. They are then added to the total amounts together with the values of the EDR installation costs and accident cost reductions. This apportionment assumes that EDRs will be mandatory for "all motor vehicles" in the foreseeable future. If this was to happen initially only for commercial applications over many years, the apportionment of infrastructure costs would have to shift further to these applications.

2.7 Overall cost-benefit ratio

The quotients of the annual total savings and total costs taking into account infrastructure costs on the cost side and the effects of using data on the cost reduction side give rise to the (overall) benefit-cost ratios both for "all motor vehicles" and for the individual vehicle categories. These develop individually for each vehicle category initially over the EDR preparation and ramp-up years, cumulatively from 2015 until "full" 90% penetration as well as for the first "full year". It is to be noted that the result values established for each vehicle category cannot be added and compared to the values of all vehicles. This is due to the double counting of the victims and, more importantly, the fact that the full years coincide with different calendar years with different accident figures and accumulation takes place over ramp-up times of varying lengths.

3 Basic results and parameter variation

The results are calculated on the basis of the data set out in Tables 1 to 5 and the parameters mentioned as examples in the text and hereinafter described as "Conservative varied". Table 6 shows, for each vehicle category, the start and ramp-up years, the time to break even, the "pure" EDR benefit-

cost ratio, the overall benefit-cost ratio, as well as the net benefit, the difference of the total savings and the total costs of the measure.
Parameter variations according to Table 7 are carried out to secure the result. In all cases, the times to 90% penetration for each vehicle category are differentiated in accordance with Table 6. By contrast, for the "Conservative 2016" scenario, the start year for mandatory fitting is established uniformly as 2016. "Conservative varied 2" differentiates not only the start years but also the factors for accident reduction for each vehicle category, with the prevention-oriented initial values for heavy goods vehicles and buses (professional drivers) reduced from 3% to 1% and those for cars, light trucks and motorcycles to 2%. On the other hand, a greater influence of accident research on heavy goods vehicles and buses is assumed ("add-on" 3%; total 4%), while that for cars, light trucks and motorcycles remains the same (2%; total 4%). "Conservative varied 3" leaves the reduction rates at 3% and 5%, but puts the EDR costs at inflated levels of 50 euros, 40 euros and 100 euros respectively. For an additional extreme limit consideration, "Minimum varied", the same inflated EDR costs are combined with minimised accident reduction rates of 1% and 1% (total 2%), whilst the costs indicated in Table 4 are increased by 12.5%.

Table 6: "Pure" EDR and (overall) benefit-cost ratio, as well as net benefits for the first full year and accumulated over the ramp-up phase

Scenario "Conservative varied"		Heavy Trucks >7.5 t	Light Trucks <=7.5 t	All Goods Vehicles	Buses	Motor-cycles >50cm³	Cars	All Motor Vehicles
Start year of mandatory fitment		2018	2020	2018	2018	2020	2020	2018
1st full year (90%)		2024	2028	2028	2032	2044	2032	2032
Time to "break even"	a	<1	3	3	1	8	4	6
EDR Benefit-Cost Ratio	Ramp-up	13.2	3.2	5.9	38.3	1.2	2.4	2.6
	1st full year	**36.2**	7.0	16.2	**85.6**	3.9	4.6	**5.7**
EDR Net Benefit € m.	Ramp-up	108	115	334	68	32	1.240	1.867
	1st full year	**49.8**	35.6	86.8	**11.8**	27.3	259	**341**
Benefit/Cost Ratio	Ramp-up	11.7	3.2	5.7	26.3	1.4	2.4	**2.7**
	1st full year	**29.1**	6.6	14.1	**46.2**	4.1	4.5	**5.5**
Net Benefit € m.	Ramp-up	**111**	120	**346**	**70**	52	1,354	**2,041**
	1st full year	**50**	36	**88**	**12**	30	267	**354**

Table 7: Parameters for scenarios "Conservative 2016", "Conservative varied 2/3" and "Minimum varied". (Note: "Heavy T&B" = heavy trucks & buses; "others" = cars, light trucks and motorcycles)

Scenarios	Accident reduction initially		from 2022	EDR unit costs			Start year mandatory	
	Heavy T&B	Others	All Mot. Veh.	Trucks & Buses	Car	Motor-cycle	Heavy T&B	Others
Conserv. varied	**3%**		**5%**	**€30**	**€25**	**€80**	**2018**	**2020**
Conserv. 2016	3%		5%	€30	€25	€80	**2016**	**2016**
Conserv. varied 2	**1%**	**2%**	**4%**	€30	€25	€80	2018	2020
Conserv. varied 3	3%		5%	**€50**	**€40**	**€100**	2018	2020
Minimum varied	**1%**		**2%**	€50	€40	€100	2018	2020

4 Discussion and conclusions

The following can be concluded from the results of the main scenario "Conservative varied" according to Table 6, supplemented by the variants according to Tables 7 and 8:

- The benefit-cost ratio for mandatory EDR applications in "all motor vehicles" amounts, in the full year, to more than five. The rates for the individual vehicle categories amount to more than four, over the relevant ramp-up phase cumulated for all other than motorcycles more than two (Tab. 6).

- For buses, coaches and heavy goods vehicles the benefit-cost ratios are several times higher than for light trucks, motorcycles and cars (Tables 6, 8). This reflects the higher relative accident costs per vehicle, overlapped by relatively low registration rates and hence annual EDR installation costs for buses, coaches, motorcycles and cars.

- Even in the case of conservative approaches, the reduction in accident costs brought about by EDRs and EDR installation costs determine the values of both the net benefits and the benefit-cost ratios (Table 6). The additional significant savings as well as the costs of the EDR infrastructure and data use increase the absolute net benefits, but do not substantially influence the benefit-cost ratios. Only the extreme benefit-cost ratios of heavy commercial vehicles are smoothed out by these, compared to those of "pure" EDR benefit-cost ratios (Table 6). Variations in the values according to Tables 4 and 5 only have an insignificant influence on the overall results.

Table 8: (Overall) benefit-cost ratios and (overall) net benefits for parameter settings
according to Table 7, each for the 1st full year of individual vehicle category according to Table 6

Variation results In the (1st) full year		Heavy Trucks >7.5 t	Light Trucks <=7.5 t	All Goods Vehicles	Buses	Motor-cycles >50cm³	Cars	All Motor Vehicles
Benefit/Cost Ratio		**29.1**	**6.6**	**14.1**	**46.2**	**4.1**	**4.5**	**5.5**
Net Benefit	€ m.	**50**	**36**	**88**	**12**	**30**	**267**	**354**
Benefit/Cost Ratio		30.1	7.0	12.4	46.7	4.4	4.9	5.2
Net Benefit	€ m.	52	39	93	12	33	298	380
Benefit/Cost Ratio		23.4	5.3	11.3	37.1	3.3	3.6	4.5
Net Benefit	€ m.	40	28	70	10	23	201	271
Benefit-Cost Ratio		19.1	4.1	9.0	34.2	3.3	2.9	3.7
Net Benefit	€ m.	49	32	84	12	28	224	316
Benefit-Cost Ratio		7.5	1.7	3.6	13.2	1.5	1.2	**1.6**
Net Benefit	€ m.	19	7	28	5	6	25	**66**

- Despite "halved" accident costs within the period under consideration, the mandatory installation of EDRs in all motor vehicles in Germany leads to significant economic net benefits, i.e. after deduction of all costs, of more than two billion euros in the ramp-up phase and 350 million euros in the first full-year, thereafter possibly decreasing in line with the number of accidents. This is due primarily to the "many" cars, but all vehicle categories. Even the "few" buses contribute 70 and 12 million euros respectively. Buses and goods vehicles together generate savings of, in full years, 100, accumulated in the ramp-up phases, over 400 million euros (Table 6).

- As early as the start-up phase, the mandatory equipping of every vehicle category quickly leads to significant net benefits. The "break even" point is reached in the first or second year of deployment in the case of heavy goods vehicles and buses and coaches, and within the first half of the ramp-up period in the case of the remaining vehicle categories (Table 6).

- Even with minimum EDR influence rates of 1%, inflated installation costs and higher data read-out costs, the cost-benefit ratio is more than one for all vehicle categories, 7.5 for heavy goods vehicles and 13 for buses. Net savings of 66 million euros are calculated in the full year, to which each vehicle category contributes (Table 8).

- The earlier the dates for mandatory applications, the higher the net benefits. Extended voluntary applications of US-type EDRs (of presumably lower recording quality) in EU cars in advance of

mandatory measures reduce net benefits and the benefit-cost ratio in the ramp-up phase, but do not influence the full-year values.

The mandatory initial equipping of all new motor vehicles with modern, integrated and standardised event data recorders and the utilisation of their data for the analysis, appraisal and in-depth research of road traffic accidents point to annual economic cost savings of several hundred million euros in Germany, even assuming a conservative assessment of the benefits. Investments for installing EDRs and for infrastructure would be amortised within a few years. Mandatory EDRs for buses, coaches and heavy goods vehicles exhibit the highest benefit-cost ratios and shortest amortisation times by far, while EDRs for cars exhibit the highest absolute savings due to their high numbers.

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Notes:

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The authors

Dr.-Ing. Erwin Petersen, formerly Head of Development and Member of the Management Board of WABCO GmbH, is a Member of the Board of the German Road Safety Association of Lower Saxony, a Member of the DVR Board Committee "Automotive Technology" and Head of the DVR Working Group "Event Data Recorders"
Contact: Landesverkehrswacht Niedersachsen e.V., Arndt-Straße 19, 30167 Hanover, Germany
email: Erwin.Petersen@t-online.de

Jörg Ahlgrimm is Head of the Accident Analysis Department of DEKRA Automobil GmbH in Stuttgart and a Member of the DVR Board Committee "Automotive Technology"
Contact: DEKRA Automobil GmbH, Handwerkstraße 15, 70565 Stuttgart