Cost-Benefit Analysis of the Electronic Stability Program (ESP)

BY HERBERT BAUM, SÖREN GRAWENHOFF AND TORSTEN GEIßLER, COLOGNE

Contents

1. Aim and approach of the study
2. Cost-Benefit Analysis
2.1 Methodical approach
2.2 Benefits of ESP
2.2.1 Accident avoidance potential of ESP – Literature review
2.2.2 Accident avoidance potential of ESP estimated in this study
2.2.3 Calculation of accident savings in the EU-25
2.2.4 Monetary valuation of accident savings in the EU-25
2.3 Costs of ESP
2.4 Benefit-Cost Ratio for ESP
3. Benefits of a mandatory ESP equipment of all cars from 2008 onwards
3.1. Forecast of equipment rates with and without a mandatory equipment
3.2 Benefit-Cost Results with and without a mandatory equipment
3.2.1 Fatality avoidance for the Trend Scenario and the Scenario „Mandatory Equipment“
3.2.2 Accident cost avoidance and equipment cost development for the Trend Scenario and the Scenario „Mandatory Equipment“
3.2.3 Aggregated Results

1. Aim and approach of the study

Traffic safety is one of the main issues of national and European transport policy. In the year 2001, the European Commission set the goal to halve the number of people killed on roads between 2000 and 2010.[1] The reason for the prioritisation of road safety can be seen in the costs to society arising from accidents. Estimations assume that

Authors' address:
Prof. Dr. Herbert Baum
Dr. Sören Grawenhoff
Dr. Torsten Geißler
Institute for Transport Economics at the University of Cologne
Universitätsstr. 22
50923 Cologne, Germany
e-mail: h.baum@uni-koeln.de

Revised version of the study "Cost-Benefit Analysis of the Electronic Stability Program (ESP)", Cologne 2007.

[1] European Commission, White Paper – European transport policy for 2010: time to decide, Brussels 2001, p. 66

these costs accrue to € 160 billion per year in the European Union.[2] In Germany, accident costs amounted to about € 30.9 billion in the year 2004.[3]

There is worldwide consensus that the improvement of road safety requires a holistic approach which covers the three pillars vehicle technology, infrastructure and the human driver. On European Union level, beyond action taken in the Road Safety Action Programme[4] and the eSafety initiative[5], this view is also adopted by the CARS 21 group.[6]

The importance of new vehicle technologies for achieving the aim of an improved road safety is emphasised in all road safety programs. The Electronic Stability Program (ESP) is widely regarded as one of the most promising safety-relevant technologies, which often are referred to as Driver Assistance Systems. ESP has been introduced onto the market over 10 years ago. Therefore, the potential of ESP to avoid or mitigate accidents has been analysed and proven in several studies.

In the following a socio-economic impact assessment will be carried out for the Electronic Stability Program. It will be quantified which amount of accidents and accident costs might be avoided in the European Union with the help of the ESP-equipment of cars. There are two main results of the study:

- In a first step the accident cost savings, which can be achieved with ESP-equipment of cars, are compared with the costs of equipping cars with the system. This enables the calculation of a Benefit-Cost-Ratio.
- It is further examined, how effective measures to foster market penetration could be in the future in terms of higher accident (cost) savings. Therefore, future accident (cost) savings are calculated for two forecast scenarios. In the first scenario (Trend Scenario), the development of ESP-equipment-rates is forecasted under the assumption that ESP continues to be an optional system. In the second scenario (Scenario "Mandatory Equipment"), the equipment rates are forecasted under the assumption that from 2008 onwards all newly registered cars in the European Union are equipped with ESP.

The geographical scope of the study comprises the European Union of 25 member states. In order to gain spatially differentiated results, the EU-25 is subdivided into the following areas: Germany, France, Italy, Spain, United Kingdom, EU-15, EU-25.

---

2 European Commission, Road Safety – Results from the transport research program, Brussels 2001, p. 2

3 Bundesanstalt für Straßenwesen (Bast), Volkswirtschaftliche Kosten durch Straßenverkehrsunfälle in Deutschland 2004, BASt-Info 02/06, Bergisch Gladbach 2006

4 European Commission, European road safety action programme, COM (2003) 311, Brussels 02.06.2003

5 European Commission, Information and Communication Technologies for Safe and Intelligent Vehicles, COM (2003) 542, Brussels 15.09.2003.

6 European Commission. Enterprise and Industry Directorate-General, CARS 21 – A Competitive Automotive Regulatory System for the 21st Century, Final Report, Luxembourg 2006, p. 32

2. Cost-Benefit Analysis

2.1 Methodical approach

The Cost-Benefit-Analysis (CBA) is an economic assessment tool, which provides methods for evaluating the social desirability of investments in certain projects, services, systems etc. The fundamental idea of a CBA is that public decisions should be based on economic considerations as it is done in the private sector (e.g. profit and loss accounts).

The result of a Cost-Benefit-Analysis constitutes the calculation of a Benefit-Cost-Ratio, which can be formally expressed as follows:

$$BCR = \frac{\sum_{t=0}^{T-1} Bt(1+i)^{-t}}{\sum_{t=0}^{T-1} Ct(1+i)^{-t}}$$

BCR = Benefit-Cost-Ratio
T = Time horizon of analysis (pre-defined)
Bt = Benefits for the year t
Ct = Costs for the year t
i = discount rate

Subject of the CBA in this study are the costs and benefits which are connected with the ESP-equipment of cars. The benefits lie in the improved vehicle stability due to ESP which leads to accident cost savings. Two steps are needed to assess the benefits: First, the benefits have to be quantified in physical terms. This means that the number of avoided accidents has to be determined. Secondly, the resulting physical benefits have to be valued monetarily in order to compare them with the costs. The costs consist of the costs to install and operate the ESP. After the temporal harmonisation of benefits and costs the relation of benefits and costs, the so called Benefit-Cost-Ratio, can be calculated constituting the final result of the analysis. If the benefits exceed the costs, the Benefit-Cost-Ratio is larger than one and the measure is profitable for society.

2.2 Benefits of ESP

2.2.1 Accident avoidance potential of ESP – literature review

ESP assists the driver actively in keeping track and direction by direct intervention into the braking and motor-management system. The system constantly measures the longitudinal and lateral dynamics of the vehicle depending on the driver action and identifies critical driving situations. It then stabilises the vehicle by braking the different wheels individually and by lowering the engine torque. With these functionalities ESP is able to avoid skidding of vehicles and is thus also able to avoid accidents due to the loss of vehicle control. Several analyses of accident statistics show that skidding accidents roughly constitute 20 % of all car accidents. The different results are shown in Table 1.

Table 1: Share of car skidding accidents in relation to all car accidents

Authors of the study	Publication year	Analysed area / Data used	Car skidding accidents / all car accidents: Injury accidents	Car skidding accidents / all car accidents: Fatal accidents
Langwieder, K., Gwehenberger, J., Hummel, T.	2004	International field tests	25 %	35 – 40 %
Unselt, T., Breuer, J., Eckstein, L., Frank, P.	2004	Germany	21 %	43 %
Sferco, R., Page, Y., LeCoz, J.Y., Fay, P.	2001	European accident Causation Survey (EACS)	18 %	34 %
Page, Y., Cuny, S.	2004	France	20 %	40 %

Source: Knoll, P. M., Langwieder, K., Der Sicherheitseffekt von ESP in Realunfällen, Überlegungen zum volkswirtschaftlichen Nutzen von prädiktiven Fahrerassistenzsystemen, Vortragsunterlagen anlässlich der 2. Tagung "Aktive Sicherheit durch Fahrerassistenz" am 4./5. April 2006, Garching bei München.

It can be seen that the potential accident avoidance of ESP lies at about 20 % for injury accidents and ca. 40 % for fatal accidents. The higher potential of ESP to avoid fatal accidents than injury accidents stems from the fact, that the ESP-relevant skidding accidents are over-proportionally very severe accidents. The share of skidding accidents in all accidents is therefore higher for fatal accidents than for injury accidents.

These skidding accidents constitute the theoretically possible accident avoidance potential of ESP, since these accidents can be influenced with the help of ESP. The second relevant question is, how many of these accidents will actually be prevented by ESP. This questions aims at answering the effectiveness of ESP concerning the relevant accidents.

In general it can be said, that the larger the referred accident group, the lower is the effectiveness rate. The more precisely the relevant accidents are consisting only of ESP-relevant accidents, the higher is the effectiveness rate. If, for example, ESP is able to avoid 50 % of all skidding accidents (effectiveness rate = 50 %) and skidding accidents make up 30 % of all accidents, than the effectiveness rate of ESP referring to all accidents is 15 %.

Analyses of real accident data started in 2002 and 2003, verifying the effectiveness estimations:

– Tingvall e.a. used the "induced exposure method" to analyse the effectiveness of ESP.[7]

[7] Tingvall, C., Lie, A., Krafft, M., Kullgren, A., The effectiveness of ESC (Electronic Stability Control) in reducing real life crashes and injuries, in: Traffic Injury Prevention, vol. 7, issue 1, March 2006, pp. 38-43

This method consists of analysing the accident events of vehicles with and without ESP. First, an accident type which is insensitive to ESP is chosen (e.g. rear end crashes). The crash number relation between ESP-equipped vehicles and not equipped vehicles for this accident type is taken as a reference. Deviations from this relation concerning ESP-sensitive accidents are taken as a result of the ESP. Related to all accidents (excluding rear end accidents), 16.7 % of crashes with personal injuries could be avoided by ESP. For fatal accidents, this effectiveness rate increased to 21.6 %.

– Other studies have proven effects in about this magnitude. A study conducted by the NHTSA showed a reduction of 35 % of single vehicle accidents[8], another study by Unselt e.a. found out a 40 % reduction referring to loss-of-control crashes.[9] These results are underlined by two similar studies from DaimlerChrysler and Volkswagen. After the introduction of ESP as standard equipment in Mercedes-Benz cars, the share of driving accidents dropped from about 20 % to 12 %, a reduction of 40 %. Vehicles from other manufacturers showed a reduction of 2.5 percentage points, which equals a reduction of only 13 %. This can be explained by the fact that only some of the other vehicles had been equipped with ESP at that time. A similar analysis has been undertaken by Volkswagen. Here, accidents, where a car left the road have been chosen as the accident category sensitive to ESP. The share of this accident category decreased from ca. 13 % to about 7 %, a reduction of about 46 %.[10]

The different studies mentioned above show fairly similar results. The findings ba-sed on real accident events with and without ESP show, that around 40 % of ESP-sensitive car accident types (= driving accidents; accidents, where a vehicle leaves the road; single vehicle accidents etc.) are actually avoided. These accidents make up about 15 % to 40 % of all car accidents depending on the category used to define ESP-sensitive accidents. This means that referring to all car accidents, 6 % to 16 % reduction of personal damage accidents can be attributed to ESP.

2.2.2 Accident avoidance potential of ESP estimated in this study

Basis of the EU-wide accident avoidance estimation in this study are the "Statistics of road traffic accidents in Europe and North America" issued by the United Nations.[11]

---

8 Dang, J., Preliminary results analysing the effectiveness of Electronic Stability Control (ESC) systems, DOT HS 809 790, Washington 2004, in: Anders, L., Tingvall, C., Krafft, M., Kullgren, A., The effectiveness of ESC…, loc. cit.

9 Unselt, T., Breuer, J., Eckstein, L., Frank, P., Avoidance of „loss of control crashes" through the benefit of ESP, FISITA Conference Paper No. F2004V295, Barcelona 2004, in: Anders, L., Tingvall, C., Krafft, M., Kullgren, A., The effectiveness of ESC…, loc. cit.

10 Knoll, P. M., Langwieder, K., Der Sicherheitseffekt…, loc. cit.

11 United Nations Economic Commission for Europe (UNECE), Statistics of Road Traffic Accidents in Europe and North America, New York and Geneva 2003, 2004, 2005

It is an appropriate data source because it contains accident data for nearly all 25 EU-member states and also distinguishes between the following kinds of accidents:

- Accidents between vehicle and pedestrian,
- Single vehicle accidents,
- Accidents between vehicles, of which:
  - Rear-end collisions,
  - Collisions due to crossing or turning,
  - Head-on collisions,
  - Others (including collisions with parked vehicles).

The most relevant kind of accident for ESP is the single vehicle accident, which is defined as "Accident involving no collision with other road users, even though they may be involved, i.e. vehicle trying to avoid collision and veering off the road, or accident caused by collision with obstructions or animals on the road".[12] There might be accidents in other accident categories, where ESP could help mitigating the accident. However, this effect is marginal compared to the accident avoidance effect of ESP. Accidents which can be avoided by ESP are nearly exclusively single vehicle accidents.

Therefore, Table 3 displays the number of single vehicle accidents, the killed and injured persons reflecting the accident situation of the year 2003. In the EU-25 the share of single vehicle accidents ranges between 15% (United Kingdom) and more than 30% (Sweden, Finland). In Germany the share is 27.5% while the average in the EU-25 amounts to 22%. Concerning the persons killed in single vehicle accidents, more than 30 % of the fatalities in the European Union are due to single vehicle accidents. The share of injured persons due to single vehicle accidents (20%) is roughly the same as the accident quota.

However, the displayed data refers to all types of vehicles, not only cars. Moreover, ESP helps to avoid accidents by preventing the skidding of cars. Therefore, only single vehicle accidents with a previous skidding of the car, which caused the accident, can be avoided. These two conditions limit the number of single vehicle accidents where ESP helps. Information about skidding is only available from in-depth databases. In the case of Germany, they show that about half of all car accidents (50.6%) where the car was the main causer involve skidding. In addition, cars have been the main causers in roughly two third of all single vehicle accidents (67.72%). In the result, it means that 34.27% of all single vehicle accidents are caused by skidding cars in Germany.

[12] United Nations Economic Commission for Europe (UNECE), Statistics…, loc. cit., New York and Geneva 2003, 2004, 2005, p. 126

Table 2: Number of single vehicle accidents and persons killed and injured in single vehicle accidents (2003)

	Single vehicle accidents			Single vehicle accidents / All Accidents [%]		
	Number of acci-dents	Number of killed persons	Number of injured persons	Share of acci-dents	Share of killed persons	Share of injured persons
Belgium	11,083	637	13,387	23.4	42.9	20.5
Czech Rep.	8,752	513	11,406	32.0	35.5	32.2
Denmark	1,607	117	1,934	23.8	27.1	23.0
Germany	97,357	2,795	116,478	27.5	42.3	25.2
Estonia	570	41	864	29.5	25.0	34.0
Greece	2,779	582	3,297	17.6	36.3	15.9
Spain	26,970	2,024	38,746	27.0	37.5	25.7
France	19,176	2,258	22,915	21.3	39.4	19.8
Ireland	1,192	98	1,094	19.9	29.3	13.2
Italy	38,558	1,794	48,110	16.2	26.6	14.2
Cyprus	512	32	689	21.7	32.7	20.2
Latvia	1,324	184	1,837	26.0	35.5	29.2
Lithuania	1,316	218	1,822	22.1	30.7	25.1
Luxemburg	269	19	347	37.4	35.8	33.0
Hungary	4,626	310	6,466	23.2	23.4	24.3
Malta	3,033	6	237	21.7	32.7	20.2
Netherlands	6,580	364	7,492	20.8	33.5	19.7
Austria	9,755	321	11,706	22.5	34.5	20.6
Poland	10,171	1,403	13,924	19.9	24.9	21.8
Portugal	6,795	271	9,096	16.4	20.0	16.5
Slovenia	812	33	1,025	8.8	11.9	8.1
Slovakia	1,856	211	2,287	21.7	32.7	20.2
Finland	2,299	111	3,041	33.3	29.3	33.5
Sweden	5,531	186	7,299	30.1	35.2	26.9
U.K.	32,135	847	40,947	15.0	24.1	14.3
TOTAL	**295,058**	**15,375**	**366,446**	**21.7**	**32.7**	**20.2**

Source: United Nations Economic Commission for Europe (UNECE), Statistics of Road Traffic Accidents in Europe and North America, New York and Geneva 2003, 2004, 2005, Own calculations

This resulting proportion of relevant single vehicle accidents is based on accident figures for Germany, thus relating to German road traffic conditions. Due to differences in the traffic conditions throughout the European Union, the accident avoidance potential of ESP in cars in other countries can differ from the situation in Germany.

First it is taken account of the fact that the share of cars in the vehicle fleet differs in the member states. Thus a weighting factor is calculated based on the proportion of cars in the vehicle fleet. The weighting factors for the different analyzed areas are displayed in Table 3. They are used to adopt the above stated proportion of single vehicle accidents which are caused by a skidding car in Germany (34.27 %) to the diverse traffic conditions in the different areas.

Table 3: Weighting factor reflecting the share of cars in total vehicle stock

Member State(s)	Proportion of cars compared to total vehicle stock (Cars, Bus, Goods vehicles, Powered two-wheelers)	Weighting factor	Share of single vehicle accidents caused by skidding cars (Germany: 34.27)
U. K.	85.9 %	1.02	34.96
Germany	84.5 %	1.00	34.27
Italy	72.5 %	0.86	29.47
Spain	76.4 %	0.90	30.84
France	77.5 %	0.92	31.53
EU-15	78.9 %	0.93	31.87
EU-25	79.0 %	0.93	31.87

Source: European Commission, Directorate – General for Energy and Transport, Energy & Transport in figures 2005, Own calculations

Different traffic situations are accounted for by using the number of single vehicle accidents in the member states as a calculation basis. As stated above, single vehicle accidents make up 27.5 % of all accidents in Germany leading to an overall proportion of relevant accidents of 9.4 % (referring to all accidents, see Table 3). In other European member states the share of single vehicle accidents in all accidents is varying between 15 % and 37 % (see Table 3).

With this method, the number of ESP-relevant accidents in the European member states is calculated. However, it cannot be assumed that all of these accidents are actually avoided by ESP. An effectiveness rate has to be determined, which specifies how many of the single vehicle accidents caused by skidding cars are really avoided with the help of ESP. Zobel states this rate with 80 %.[13]

[13] Biber, C., Unfallforscher fordern zum Umdenken bei den Sicherheitsprüfungen auf, Meldung vom 10.06.2005 unter www.auto-reporter.net (Artikelnummer 20050610-000004), Zugriff am 08.08.2006

The main conclusions for the accident savings calculations due to ESP can be summarized:

- The accident avoidance potential of ESP is restricted to single vehicle accidents (as defined according to the UN-Statistics), which constitute between 15 % and 37 % of all injury accidents in the member states of the EU-25 (see Table 3).
- 34.27 % of the single vehicle accidents are caused by skidding of cars e.g. in Germany. This proportion is adopted to different traffic situations in other member states by using a weighting factor based on the proportion of cars in the vehicle fleet (see Table 3).
- 80 % of these single vehicle accidents caused by skidding cars are avoided due to the equipment of ESP (= Effectiveness rate of ESP).

These assumptions lead to an accident avoidance potential, which is in line with the findings of other studies presented in the previous chapter. This can be shown for Germany with the help of the following Table 4, where the estimated accident / fatality reduction for Germany relating to all accidents / fatalities is calculated:

Table 4: Calculated accident avoidance potential of ESP in Germany in percent

Effects in Germany	Share of single vehicle accidents in all accidents (See Table 2)	34.27 % of the single vehicle accidents are caused by a skidding car (see Table 3)	Effectiveness of ESP = 80 %, Result: Share of avoided accidents by ESP in cars concerning all accidents	Only 67.72 % of all accidents are caused by cars, Result: Share of avoided accidents by ESP in cars concerning all car accidents
Injury accidents	27.5 %	9.4 %	7.5 %	11.1 %
Killed persons	42.3 %	14.5 %	11.6 %	17.1 %

Source: Own calculations

First, the share of single vehicle accidents is extracted from Table 2. In a second step, this number of single vehicle accidents is reduced, because only 34.27 % of these single vehicle accidents are caused by a skidding car. Given the assumed effectiveness rate of 80 %, the accident avoidance potential of ESP calculated in this study is rather small, shown in the second column from the right. In order to compare these shares with the findings from most of the other studies, it has to be considered, that these studies are referring the stated accident avoidance potential to car accidents only. The calculated shares in the second column from the right in Table 4 are however reflecting the accident avoidance potential of ESP in cars concerning all accidents (caused by cars, trucks, motor bikes etc.). In order to compare the accident calculations in this study with the results of other studies, the accident avoidance potential of ESP in cars has to be referred to car accidents only. They make up about 67.72 % of all accidents (in the case of single vehicle accidents).

Besides that, Knoll and Langwieder have synthesised accident analyses of ESP and summed up that a reduction of injury accidents by 7 – 11 % and a fatality reduction by 15 – 20 % in Germany can be expected.[14] Hence, their results are nearly similar to the conclusions in this study.

For the EU-25 it has been assumed in a study published by the eSafety-Forum, that in the year 2020 roughly 2,900 to 3,900 lives could be saved, if the ESP equipment rate in the vehicle stock amounts to 73 %.[15] Consequentially, the maximum accident avoidance potential (= 100 % penetration) of ESP is in this study assumed to be between 3,970 and 5,300. With 3,988 avoided fatalities calculated as the maximum accident potential in this study (See Table 6), the results of this study are also well comparable.

2.2.3 Calculation of accident savings in the EU-25

In some of the member states ESP already reached significant car penetration rates. This means that parts of the accident reduction potential of ESP was already realised in 2003. It is assumed, that there exists a linear functional relation between car equipment rate with ESP and avoided accidents. For example, if 50 % of the cars are equipped with ESP, also 50 % of the accidents, which could be avoided if all cars were equipped with ESP, are avoided.

Based on German figures reflecting the year 2003 conditions this means that the number of single vehicle accidents (= 97,357, see Table 2) cannot be reduced by 27.42 %[16] due to ESP in the future, because some of the vehicles had already been equipped with ESP. It is estimated, that in 2003 about 14.2 % of the German car fleet had been equipped with ESP. This means that about 3.9 % (0.142 x 27.42 %) of the single vehicle accidents were already being avoided at that time. By extending the car penetration rate from 14.2 % to 100 %, a further 23.52 % accident reduction (27.42 % – 3.9 % = 23.52 %) could be achieved. The hypothetical number of single vehicle accidents in Germany without the use of ESP can be calculated as follows:

$$97{,}357 / (1-(0.3427 \times 0.8 \times 0.142)) = 101{,}301$$

The relationship between car penetration rate and accident avoidance for this example is illustrated in Figure 1. In order to take account of this circumstance, the virtual accident figures for 2003 are calculated in Table 5 according to the above stated formula under the premise that no car had been equipped with ESP in this year. Therefore, the estimated ESP-penetration rate of the vehicle stock is included in Table 5. Finally, the number of single vehicle accidents as well as the killed and injured persons is calculated as explained above for the hypothetical situation that no car had been equipped with ESP in 2003.

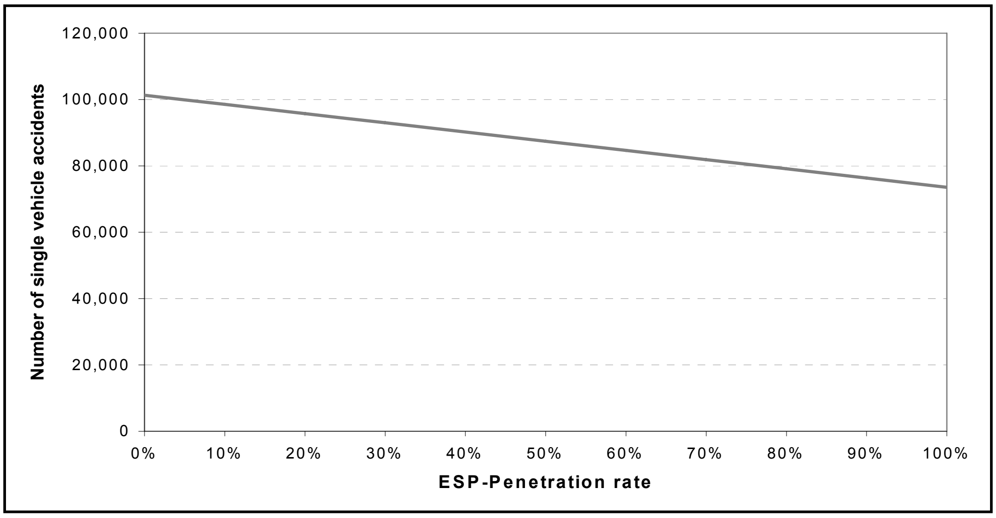
---

14 Knoll, P. M., Langwieder, K., Der Sicherheitseffekt…, loc. cit., Ch. A.4

15 E-Safety-Forum, Final Report and Recommendations of the Implementation Road Map Working Group, Brüssel 2005, S. 51

16 34.27 % single vehicle accidents caused by skidding cars with an effectiveness of 80 % results in an overall single vehicle accident avoidance of 27.42 %.

Figure 1: Relationship between ESP-penetration rate of car stock and single vehicle accident avoidance in Germany



Source: Own figure

Starting from these hypothetical single vehicle accident figures, the avoidable accidents due to 100 % penetration of the car stock for the year 2003 can be calculated. To refer again to the German example, there would have been 101,301 single vehicle accidents in Germany without any ESP-equipment. Under the premise that in Germany 34.27 % of all single vehicle accidents are caused by a skidding car and that ESP can avoid 80 % of these, then 27,773 accidents could have been avoided if all cars had been equipped with ESP:

$$101{,}301 \times 0.3427 \times 0.8 = 27{,}773$$

That would have reduced the number of single vehicle accidents to 73,528 (101,301 – 27,773). Under the equipment rate in Germany of 14.2 % in 2003, 3,944 accidents were actually avoided:

$$101{,}301 \times 0.3427 \times 0.8 \times 0.142 = 3{,}944$$

This led to a realised number of single vehicle accidents of 97,357 (101,301 – 3,944, see Table 5). The resulting accident avoidance potential, which is defined as the difference between the number of single vehicle accidents without ESP (Equipment rate = 0 %) and the number of single vehicle accidents with an ESP-equipment rate of 100 %, is calculated in Table 6. In the EU-25, nearly 4,000 fatalities could be avoided, if all cars were equipped with ESP. In Germany alone, the avoidance potential amounts to 800 fatalities.

Table 5: Persons killed and injured due to single vehicle accidents without ESP-equipment

	Single vehicle accident situation in 2003 under given ESP-Penetration rates (Figures from UN-statistics)				Share of single vehicle accidents caused by skidding car [%]	Effectiveness of ESP	Hypothetical single vehicle accident situation without ESP-equipped cars		
	Accidents	Persons killed	Persons injured	Estimated ESP-Equipment rate of car stock			Accidents	Persons killed	Persons injured
U.K.	32,135	847	40,947	4.3	34.96	0.8	32,526	857	41,445
Germany	97,357	2,795	116,478	14.2	34.27		101,301	2,908	121,196
Italy	38,558	1,794	48,110	2.6	29.47		38,796	1,805	48,407
Spain	26,970	2,024	38,746	6.3	30.84		27,396	2,056	39,358
France	19,176	2,258	22,915	8.6	31.53		19,601	2,308	23,423
EU-15	262,086	12,424	325,889	7.5	31.87		267,195	12,666	332,242
EU-25	295,058	15,375	366,446	6.7	31.87		300,186	15,642	372,815

Source: Own calculation based on manufacturer information and United Nations Economic Commission for Europe (UNECE), Statistics…, loc. cit., 2003, 2004, 2005

Table 6: Potential accident avoidance due to ESP-equipped cars in the European Union (2003)

	Hypothetical single vehicle accident situation without ESP-equipped cars (0 % ESP-penetration)			Share of single vehicle accidents caused by skidding car	Effectiveness of ESP	Accidents avoided …	Fatalities avoided…	Injured persons avoided…
	Accidents	Persons killed	Persons injured			…with full ESP-penetration of car stock (100 % ESP-penetration)		
U.K.	32,526	857	41,445	34.96	0.8	9,097	240	11,591
Germany	101,301	2,908	121,196	34.27		27,773	797	33,227
Italy	38,796	1,805	48,407	29.47		9,147	426	11,412
Spain	27,396	2,056	39,358	30.84		6,759	507	9,710
France	19,601	2,308	23,423	31.53		4,944	582	5,908
EU-15	267,195	12,666	332,242	31.87		68,124	3,229	84,708
EU-25	300,186	15,642	372,815	31.87		76,535	3,988	95,053

Source: Own calculations

In order to demonstrate the differences between fatalities in single vehicle accidents, the number of actually avoided fatalities under given ESP car-penetration rates and the potential total number of avoidable fatalities if all cars were equipped with ESP, these three figures are stated in Table 7.

Table 7: Number of fatalities in single vehicle accidents, fatalities avoided due to ESP-equipment of cars and maximum ESP avoidance potential in cars

	Fatalities in single vehicle accidents without ESP	Number of avoidable fatalities with full equipment of cars with ESP	Fatalities avoided with actual ESP-car equipment rate (2003)
United Kingdom	857	240	10
Germany	2,908	797	113
Italy	1,805	426	11
Spain	2,056	507	32
France	2,308	582	50
EU-15	12,666	3,229	242
EU-25	15,642	3,988	267

Source: Own calculations

2.2.4 Monetary valuation of accident savings in the EU-25

While the calculation of the physical benefits of ESP on basis of accident statistics is rather straightforward, the monetary valuation of accidents is a controversial matter. However, it is needed to give information about the cost-effectiveness of safety measures like ESP.

Traditionally, the monetary valuation of accident costs has been based on economically measurable effects of accidents. These effects include reproduction costs (e.g. medical treatment, vehicle repair costs, administrational costs) and costs due to lost economic output (e.g. periods of disability or death). More recently another approach has become popular, which is based on the consideration that measuring only the economical effects of injury and death is insufficient and that other consequences like pain, grief and suffering of the victim and its family should be included in accident cost calculations. Because this approach takes into account that there exists a value of life independently from economic considerations, it is also referred to as the Human-Cost-Approach whereas the first calculation method is usually termed Damage-Cost-Approach.

Both methods are used by the EU member states. For example Sweden and the United Kingdom include Human Costs in some way in their accident calculations on the basis of surveys asking for the respondents' willingness to pay for a reduction in accident risk. Other countries like Germany restrict their calculation to economically measurable damages.

Table 8: Cost rates for monetary evaluation of accident cost savings in the European Union

	EU-Cost-Rates [€]
Fatality	1,000,000
Seriously injured person	135,000
Slightly injured person	15,000

Source: European Commission, Proposal for a Directive of the European Parliament and of the Council amending Directive 1999/62/EC on the charging of Heavy Goods Vehicles for the use of certain infrastructure, Brussels 2003, p. 33

In most safety evaluations on a European level, accident cost rates are used which have been proposed by the European Commission. Since the accident data employed in this study does not differentiate between seriously and slightly injured persons, other data has to be used. In Germany, about 30 % of all persons injured in single vehicle accidents suffered from severe injuries while 70 % only have been slightly injured. It is assumed that this proportion holds true for all member states of the European Union, which leads to an average cost rate for an injured person of € 51,000. It is further assumed that additional property damage costs per accident of € 6,000 arise on average.[17]

Congestion costs consist of additional consumption of time and fuel as well as of additional emissions of air pollutants and Carbon Dioxide. They have been stated with € 15,000 for fatal accidents and € 5,000 for injury accidents.[18] Here, congestion costs are cautiously estimated with € 5,000 for fatal and injury accidents. This leads to the following accident cost rates used in this study:

Table 9: Accident cost rates for monetary evaluation of ESP-safety benefits

Personal damage costs per killed / injured person	Costs in €
Killed person	1,000,000
Injured person	51,000
Property damage and congestion costs per accident	**Costs in €**
Property damage costs	6,000
Congestion costs	5,000

Source: European Commission, Proposal…, loc. cit., p. 33; Statistisches Bundesamt, Verkehr – Verkehrsunfälle 2003, Fachserie 8 / Reihe 7, Wiesbaden 2005, p. 64; Abele, J., Baum, H., Exploratory study…, loc. cit., Brussels 2005, p. 117

17 Abele, J., Baum, H., Exploratory study…, loc. cit., Brussels 2005

18 ICF Consulting, Cost-Benefit Analysis of Road Safety Improvements, London 2003

With this accident cost information and the number of avoidable accidents (see Table 6) the monetary benefits of ESP can be calculated. The results are displayed in Table 10. For example in Germany, the accident analysis showed, that with a 100 %-penetration of the car stock 27,773 accidents could be avoided (based on accident figures for 2003, see Table 6). According to the cost rates, this results in property damage and congestion cost savings of € 305.5 Mill (27,773 x (€ 6,000 + € 5,000)). Together with these accidents, 797 lives could have been saved and 33,227 injuries of persons could have been avoided. With the determined cost rate of € 1 Mill. per fatality this results in cost savings of € 797 Mill. for fatalities. The cost savings due to avoided injuries accrue to € 1,694.6 Mill. (33,227 x € 51,000). The total accident cost savings for Germany sum up to € 2,996.4 Mill.

Table 10: Potential accident cost savings due to ESP (100 % ESP-penetration of cars) in the European Union

	Personal damage costs in Mill. € (killed persons)	Personal damage costs in Mill. € (injured persons)	Property damage and congestion costs in Mill. €	SUM in Mill. €
United Kingdom	240.0	591.1	100.1	931.2
Germany	797.0	1,694.6	305.5	2,797.1
Italy	426.0	582.0	100.6	1,108.6
Spain	507.0	495.2	74.3	1,076.5
France	582.0	301.3	54.4	937.7
EU-15	3,229.0	4,320.1	749.4	8,298.5
EU-25	3,988.0	4,847.7	841.9	9,677.6

Source: Own calculations

2.3 Costs of ESP

In the previous chapter, the accident cost savings have been calculated as the difference between a situation without any ESP-equipment and a situation with a penetration of 100 %. Accordingly, the costs for equipping the whole car fleet with ESP have to be calculated. Therefore, the following information is needed:

- Number of cars in the reference year (2003),
- Costs of ESP-equipment (investment and operation),
- Useful life of ESP.

The number of cars in the reference year is given in Table 11. Additionally, the costs of equipping one car with ESP are stated with € 130.[19] This value reflects the additional equipment costs for ESP as an addition to an existing Antilock Braking System (ABS), which is standard in EU-25. Operation costs normally do not occur, so that the total costs of equipping the whole car fleet with ESP equals the multiplication of the car number with the costs.[20]

Table 11: Number of cars in the EU-25 in 2003 and investment costs for ESP-equipment (100 % equipment rate)

	Car Stock 2003 in Mill.	Costs of equipping one car with ESP in €	Investment costs in Mill. €
United Kingdom	26.992	130	3,508.96
Germany	44.657		5,805.41
Italy	32.584		4,235.92
Spain	18.688		2,429.44
France	29.360		3,816.80
EU-15	189.672		24,657.36
EU-25	212.496		27,624.48

Source: European Commission, Directorate –General for Energy and Transport, Energy & Transport in figures 2005, Own calculations

However, ESP would not only avoid accidents and the resulting costs for one year, but for each year until it is taken out of use. Since ESP cannot be retrofitted, the lifetime of ESP is equal to the lifetime of a car. The average lifetime of a car in the European Union is 12 years.[21] From this follows that the investment costs have to be spread over 12 years, because ESP is avoiding the calculated accidents in each of the twelve years. The yearly costs can be calculated with the annuity method. This method takes into account possible interest earnings, which could have been realized at the capital market if the money had not been spent for ESP at the beginning of the useful life (= Opportunity costs). The calculation of the yearly costs is as follows:

---

19 The cost estimation was verified by experts in the eIMPACT Market Scenario Workshop, Brussels 25 Sep 2006, mimeo.

20 Obviously it is impossible to equip the total car fleet with ESP immediately, since ESP cannot be retrofitted. Thus, only new cars could be equipped and total stock penetration cannot be reached before the last not equipped car is phased out. Normally, this takes about 12 years, which is the average useful life of cars in the European Union. However, for Cost-Benefit-Calculations, this is not of importance, because the benefit-cost-ratio is assumed to be independent from the actual penetration rate. If only 10 % of the vehicle fleet is equipped, only 10 % of the benefits can be realized, but only 10 % costs incur as well.

21 Abele, J., Baum, H., Exploratory study on the potential socio-economic impact of the introduction of Intelligent Safety Systems in Road Vehicles, Study on behalf of the European Commission – DG INFSOC, Brussels 2005, p. 117

$$g = K_0 \bullet \frac{i \bullet (1+i)^n}{(1+i)^n - 1}$$

g = yearly costs
K_0 = investment sum (material and labour costs)
i = interest rate
n = economic lifetime

The interest rate is determined with 3 %. The resulting yearly costs are shown in the following table:

Table 12: Costs for ESP-equipment of car stock

Member States	Investment costs (K_0) in Mill. €	Yearly costs (g) in Mill. €
United Kingdom	3,508.96	352.52
Germany	5,805.41	583.22
Italy	4,235.92	425.55
Spain	2,429.44	244.07
France	3,816.80	383.44
EU-15	24,657.36	2,477.13
EU-25	27,624.48	2,775.21

Source: European Commission, Directorate – General for Energy and Transport, Energy & Transport in figures 2005, Own calculations

2.4 Benefit-Cost-Ratio for ESP

Finally, the benefits and costs of equipping cars with ESP can be compared and a Benefit-Cost-Ratio can be calculated (see Table 13). The resulting Benefit-Cost-Ratios vary between 2.4 and 4.8, showing the efficiency of investing into ESP-equipment in the EU-25. The highest Benefit-Cost-Ratio has been calculated for Germany, the lowest for France. The average Benefit-Cost-Ratio for the EU-25 lies at 3.5. The differences between the different member states follow mainly from varying numbers of single vehicle accidents, killed and injured persons in the member states. For example in Germany, there are about 5 times more single vehicle accidents and injured persons than in France in the hypothetical single vehicle accident situation (see Table 6). However, the number of cars in Germany is only 1.5 times higher than in France (see Table 11), which explains the difference in the Benefit-Cost-Ratio.[22] The main conclusion to be drawn is that the investment into the ESP-equipment of cars is cost-efficient throughout the European Union. According to the calculations, € 3.5 of accident costs to society are saved in the EU-25 for each € spent for ESP-equipment of cars.

22 Especially in the case of France it has been stated, that in France a very high share of accidents remains unreported, which leads to substantial undercounting. In fact it has been assumed, that the number of reported accidents has to be corrected by the factor 2.5 in order to receive an estimation of the number of all accidents. For Germany, no undercounting has been assumed, for most other member states a factor of 1.38 has been employed (See ICF Consulting, Cost-Benefit Analysis of Road Safety Improvements, London 2003, pp. 3-4). This seems to be the most plausible explanation for the low Benefit-Cost-Ratio in France.

Table 13: Benefit-Cost-Ratios for ESP in the EU-25

Member States	Yearly benefits in Mill. €	Yearly costs in Mill. €	Benefit-Cost-Ratio
United Kingdom	931.2	352.52	2.6
Germany	2,797.1	583.22	4.8
Italy	1,108.6	425.55	2.6
Spain	1,076.5	244.07	4.4
France	937.7	383.44	2.4
EU-15	8,298.5	2,477.13	3.4
EU-25	9,677.6	2,775.21	3.5

Source: Own calculations

There is some evidence that the actual Benefit-Cost-Ratios could even be higher than calculated in this study. This stems from the fact that the employed accident database includes only personal damage accidents and cost calculations thus only include accidents with personal damage. While for humanitarian reasons this focus on personal damage accidents is sensible, it leads to an underestimation of the real safety benefits to society. In Germany for example, costs caused by accidents with personal damage (personal damage costs and property damage costs in accidents with personal damage) only account for slightly more than 60 % of the total accident costs. The other 40 % of the total accident costs consist of property damage costs arising in accidents with only property damage (= accidents without injuries and fatalities). Thus, the inclusion of property damage only accidents into the calculations could increase the accident cost savings due to ESP significantly. If it is assumed that this relationship between the costs of personal damage accidents and property damage accidents holds true for ESP-sensitive accidents throughout Europe, the Benefit-Cost-Ratio for EU-25 would rise to about 5.8, if property damage accidents were included into the calculations (see Table 14).

Table 14: Estimated Benefit-Cost-Ratios for ESP in the EU-25 including property damage accidents costs

Member States	Yearly benefits in Mill. €	Yearly costs in Mill. €	Benefit-Cost-Ratio
United Kingdom	1,552.0	352.52	4.4
Germany	4,661.8	583.22	8.0
Italy	1,847.7	425.55	4.3
Spain	1,794.2	244.07	7.4
France	1,562.8	383.44	4.1
EU-15	13,830.8	2,477.13	5.6
EU-25	16,129.3	2,775.21	5.8

Source: Own calculations

The attainable accident cost savings due to property damage only accidents are transferred from Germany to the European level. A more accurate calculation would be possible when the database for property damage only accidents will be improved in the future.

Table 15: Results of selected Cost-Benefit-Calculations for Driver Assistance Systems

Analysed Driver Assistance System	Benefits in Mill. € (rounded)	Benefit-Cost-Ratio	Remarks	Study
ESP	10,000 – 16,000	3.5 – 5.8	Calculations for EU-25 Full penetration in car fleet	This study
Information and Warning Functions	40 – 300	1.2 – 1.5	Calculations for EU-15 Varying results for different penetration rates	Baum, H., Schulz, W. H. et al., Socio-Economic-Assessment of CarTALK 2000-Applications, Final Report, September 2004
Communication-based Longitudinal Control	50 – 1,000	1.1 – 4.0		
Tow-Bar-System for Heavy Goods Vehicles	55 – 105	4.1 – 4.4	Calculations for Germany Varying results for different penetration rates	Geißler, T., Automated Highway Systems – Konzept, Bewertungsmethodik und empirische Auswirkungsanalyse des CHAUFFEUR-Systems, Köln 2001
Longitudinal Control	50 – 140	0.8 – 1.3	Calculations for Germany Varying results for different penetration rates	Zackor, H., Keller, H. u.a., Entwurf und Bewertung von Verkehrsinformations- und –leitsystemen unter Nutzung neuer Technologien, Berichte der BASt, Heft V70, Bergisch Gladbach 1999
Adaptive Cruise Control	500 – 1,000	0.9 – 1.2	Calculations for EU-25 Varying results for different penetration rates	Abele, J., Baum, H., Exploratory study on the potential socio-economic impact of the introduction of Intelligent Safety Systems in Road Vehicles (SEiSS), Teltow 2005
Lane Departure Warning and Lane Change Assistance	170 – 1,500	2.0 – 2.1		
Automated Speed Control	n/a	1	Calculations for Great Britain Calculations for many Driver Assistance Systems	Perrett, K.E., Stevens, A., Review of the potential benefits of road transport telematics, TRL Report 220, 1996
Driver and Vehicle Monitoring	n/a	0.5		
Integrated Automated Driving	n/a	1.1		

Source: Own compilation

When comparing the absolute benefits of different systems it also becomes clear that ESP represents one of the most beneficial systems for the European transport system. This makes clear that ESP represents a building block of an Intelligent Transport System in the European Union.

3. Benefits of a mandatory ESP-equipment of all cars from 2008 onwards

After having shown that equipping cars with ESP is cost-effective, it is analysed how many accident and accident cost savings could be achieved, if from 2008 onwards every car will be mandatory equipped with ESP (Scenario "Mandatory Equipment"). These savings are compared to a situation without any activity to support ESP market penetration (Trend Scenario).

3.1 Forecast of equipment rates with and without a mandatory equipment

The forecast of equipment rates of the car stock is based on information about actual and past ESP-equipment rates for newly registered cars in the European Union. Time series for ESP-equipment rates of newly registered cars since 1995 in the different analysed areas of the European Union have been established.

With the penetration rates for newly registered cars the penetration of the car stock can be figured out as follows:

- Number of car stock and newly registered cars per year based on historical data and car park development forecasts.
- With the ESP-penetration of new cars, which has been estimated on basis of information from Robert Bosch GmbH, the number of newly registered vehicles with ESP and the share of these vehicles regarding the total vehicle stock can be calculated.
- Each year, newly registered cars with ESP (according to the ESP-penetration rate amongst newly registered cars) add to the car stock.
- Twelve years after market introduction, the cars with ESP registered in the first year of market introduction have to be subtracted from the vehicle stock, because according to the assumption about average useful life of cars and ESP, they are taken out of service.
- For the Scenario "Mandatory equipment", the ESP-penetration rate for newly registered cars is set to 100 % from 2008 on.

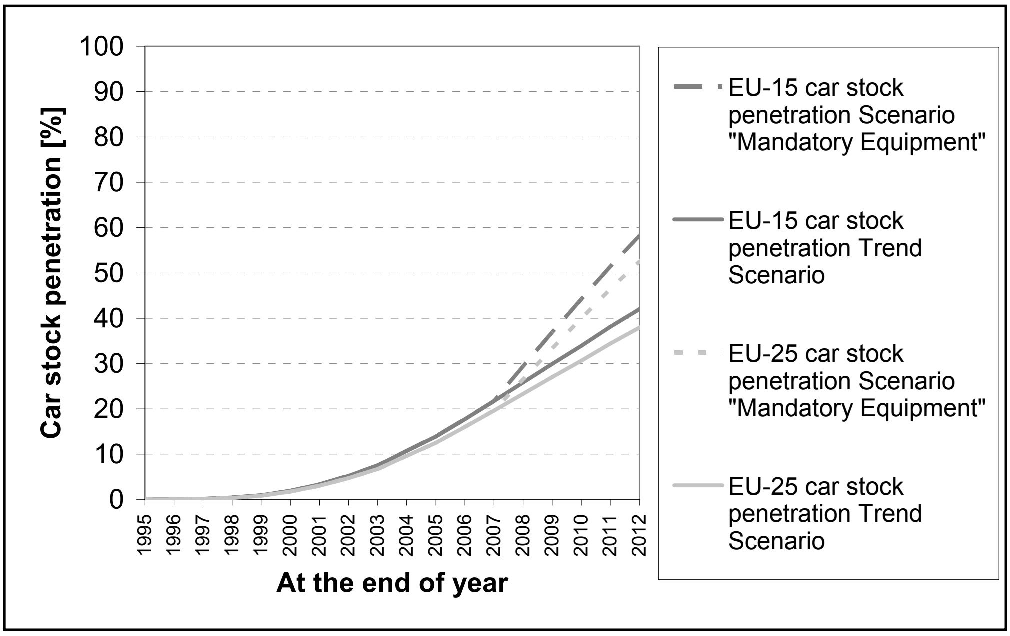
The ESP-penetration of the total EU car stock is displayed in Figure 2. The figures behind the graphs in this figure are listed in the following Table 16. With the estimation of these equipment rates for the two scenarios, the differences in accident and accident cost savings can be calculated.

Table 16: Car stock penetration with ESP for the Scenarios "Trend" and "Mandatory Equipment" in the European Union and selected member states

Member State	Scenario	At the end of Year								
		1995	1996	1997	1998	1999	2000	2001	2002	2003
United Kingdom	Trend	0.0	0.0	0.1	0.2	0.4	0.9	1.6	2.6	4.3
	Mandatory Eq.	0.0	0.0	0.1	0.2	0.4	0.9	1.6	2.6	4.3
Germany	Trend	0.0	0.0	0.2	0.8	1.7	3.6	6.4	10.1	14.2
	Mandatory Eq.	0.0	0.0	0.2	0.8	1.7	3.6	6.4	10.1	14.2
Italy	Trend	0.0	0.0	0.0	0.2	0.6	1.0	1.6	2.6	3.7
	Mandatory Eq.	0.0	0.0	0.0	0.2	0.6	1.0	1.6	2.6	3.7
Spain	Trend	0.0	0.0	0.1	0.3	0.7	1.3	2.4	3.9	6.3
	Mandatory Eq.	0.0	0.0	0.1	0.3	0.7	1.3	2.4	3.9	6.3
France	Trend	0.0	0.0	0.1	0.4	0.9	2.0	3.8	5.9	8.6
	Mandatory Eq.	0.0	0.0	0.1	0.4	0.9	2.0	3.8	5.9	8.6
EU-15	Trend	0.0	0.0	0.1	0.4	0.9	1.9	3.3	5.2	7.5
	Mandatory Eq.	0.0	0.0	0.1	0.4	0.9	1.9	3.3	5.2	7.5
EU-25	Trend	0.0	0.0	0.1	0.3	0.8	1.7	3.0	4.7	6.7
	Mandatory Eq.	0.0	0.0	0.1	0.3	0.8	1.7	3.0	4.7	6.7
Member State	Scenario	At the end of Year								
		2004	2005	2006	2007	2008	2009	2010	2011	2012
United Kingdom	Trend	6.7	9.5	12.6	15.8	19.1	22.4	25.6	29.0	32.2
	Mandatory Eq.	6.7	9.5	12.6	15.8	23.7	31.5	39.1	46.7	53.9
Germany	Trend	19.1	24.1	30.0	35.9	41.8	47.6	53.1	58.6	63.2
	Mandatory Eq.	19.1	24.1	30.0	35.9	43.9	51.6	59.1	66.3	72.6
Italy	Trend	5.6	7.9	10.7	13.9	17.1	20.3	23.5	26.9	30.5
	Mandatory Eq.	5.6	7.9	10.7	13.9	22.0	30.2	38.1	45.9	53.7
Spain	Trend	9.5	13.0	17.6	22.5	27.5	32.7	38.0	43.8	49.7
	Mandatory Eq.	9.5	13.0	17.6	22.5	32.2	41.6	50.6	60.0	69.1
France	Trend	11.7	14.4	18.0	21.9	26.0	30.2	34.5	38.9	43.0
	Mandatory Eq.	11.7	14.4	18.0	21.9	30.1	38.2	46.1	53.8	60.9
EU-15	Trend	10.7	13.9	17.7	21.7	25.8	29.9	33.9	38.1	42.0
	Mandatory Eq.	10.7	13.9	17.7	21.7	29.4	36.9	44.2	51.4	58.2
EU-25	Trend	9.6	12.5	16.0	19.6	23.3	27.0	30.6	34.4	37.9
	Mandatory Eq.	9.6	12.5	16.0	19.6	26.5	33.3	39.9	46.4	52.5

Source: Own estimations, information from manufacturers

Figure 2: Car stock penetration with ESP for the Trend Scenario and the Scenario "Mandatory Equipment" in the European Union



Source: Own estimations, information from manufacturers

3.2 Cost-Benefit-Results with and without a Mandatory Equipment

Starting point of the calculations is the single vehicle accident situation in 2003 as stated in Table 5. Avoidable due to equipment of cars with ESP is only a fraction of these accidents, killed and injured persons, because only 30 to 35 % of these single vehicle accidents are caused by skidding cars. Furthermore, an effectiveness of 80 % in avoiding these accidents has been assumed.

The resulting figures in Table 6 at the right side represent the maximum avoidable accidents, fatalities and injured persons (Car equipment rate = 100 %). In order to compare the accident avoidance for the Trend scenario and the scenario "Mandatory Equipment", the accident avoidance potential is multiplied with the penetration rate in that year (see Table 16). Since the penetration of cars in the two scenarios starts to differ from 2008 onwards, the accident avoidance for the two scenarios grows apart from that point in time.

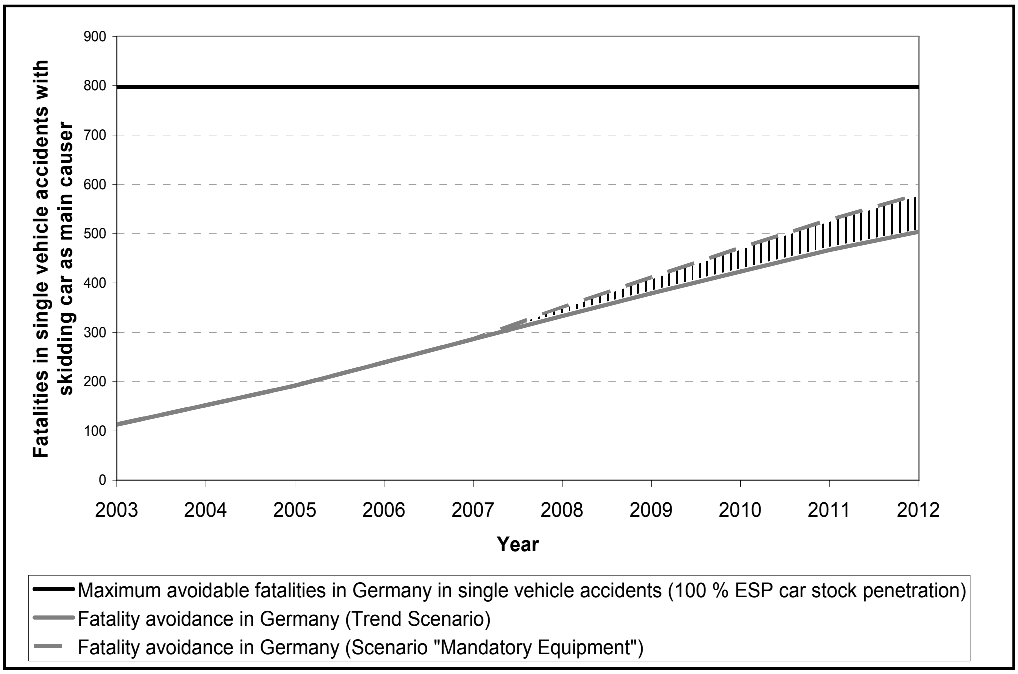
The calculations for comparing the accident situation for the Trend Scenario and the Scenario "Mandatory Equipment" have been performed for all relevant accident variables:

- Accidents,
- Fatalities,
- Injured Persons,
- Accident costs (= Benefits),
- Equipment Costs.

3.2.1 Fatality avoidance for the Trend Scenario and the Scenario “Mandatory Equipment”

The calculations are exemplified for the fatality savings in Germany for the Trend Scenario and the Scenario “Mandatory Equipment”. Figure 3 shows the number of avoided fatalities for the Trend-Scenario and the Scenario “Mandatory Equipment” from 2003 until 2012.

Figure 3: Avoidance of fatalities until 2012 for the Scenarios “Trend” and „Mandatory Equipment“ on the basis of accident data from 2003



Source: Own calculations

The black line represents the maximum avoidance potential of ESP, if all cars are equipped with the system. The figure is based on the calculations carried out in chapter 2 and equals the accident avoidance potential stated in Table 6 (797 avoidable fatalities). Under the equipment rate of 14.2 % in 2003 in Germany (see Table 16), 113 fatalities are avoided in this year (797 x 0,142). Given the assumed penetration development, the number of avoided fatalities rises from that year on. Until 2007, there is no difference in accident and fatality savings between the two scenarios, since in accordance with the assumptions the penetration rates are identical (see Table 16).

Table 17: Avoided fatalities between 2008 and 2012 for the Scenarios "Trend" and „Mandatory Equipment" on the basis of accident data from 2003

Member States	Scenario	Avoided fatalities in the year					
		2008	2009	2010	2011	2012	SUM
United Kingdom	Trend	46	54	61	70	77	**308**
	Mandatory Equip.	57	76	94	112	129	**468**
	Difference	**11**	**22**	**33**	**42**	**52**	**160**
Germany	Trend	333	379	423	467	504	**2,106**
	Mandatory Equip.	350	411	471	528	579	**2,339**
	Difference	**17**	**32**	**48**	**61**	**75**	**233**
Italy	Trend	73	86	100	115	130	**504**
	Mandatory Equip.	94	129	162	196	229	**810**
	Difference	**21**	**43**	**62**	**81**	**99**	**306**
Spain	Trend	139	166	193	222	252	**972**
	Mandatory Equip.	163	211	257	304	350	**1,285**
	Difference	**24**	**45**	**64**	**82**	**98**	**313**
France	Trend	151	176	201	226	250	**1,004**
	Mandatory Equip.	175	222	268	313	354	**1,332**
	Difference	**24**	**46**	**67**	**87**	**104**	**328**
EU-15	Trend	833	965	1,095	1,230	1,356	**5,479**
	Mandatory Equip.	949	1,192	1,427	1,660	1,879	**7,107**
	Difference	**116**	**227**	**332**	**430**	**523**	**1,628**
EU-25	Trend	929	1,077	1,220	1,372	1,511	**6,109**
	Mandatory Equip.	1,057	1,328	1,591	1,850	2,094	**7,920**
	Difference	**128**	**251**	**371**	**478**	**583**	**1,811**

Source: Own calculations

From 2008 onwards, there is a growing difference in the number of saved fatalities for the two scenarios, because the penetration rates develop differently. Thus in 2008, there would be 17 more fatalities avoided, if mandatory equipment was introduced in 2008. In 2009, this figure would rise to 32, in 2012, the difference would equal 75 fatalities. During the 5 years from 2008 to 2012, 233 additional lives could be saved. This figure would rise further in the years after 2012, because the differences in the market penetration of ESP would persist for a long time beyond 2012.

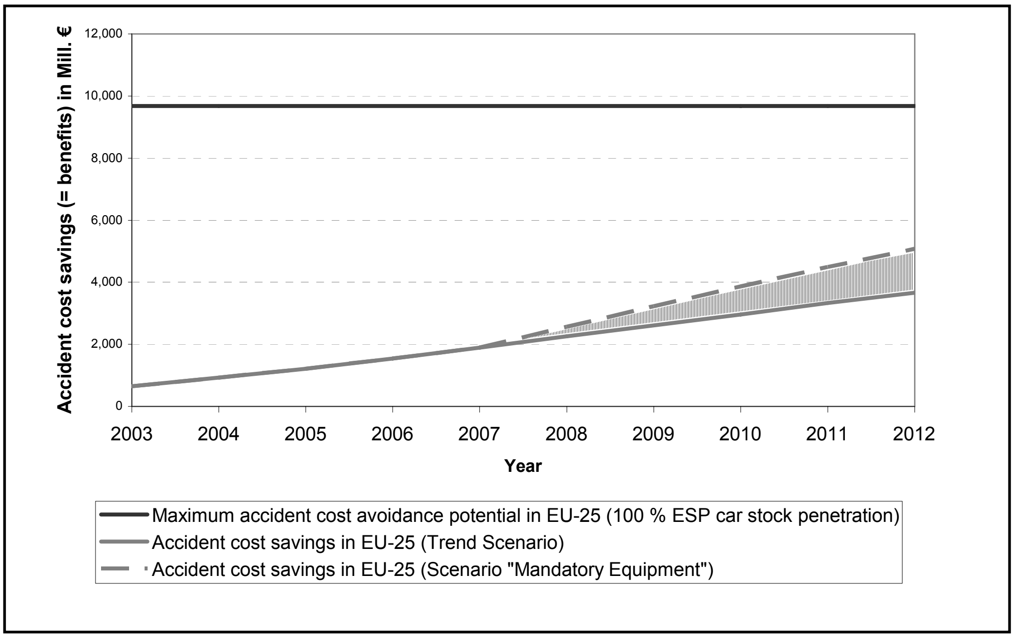
The development of the fatality savings for the two different scenarios in Germany is also displayed in Table 17. The figures in the table for Germany are identical with the figures, which lie behind the graphs in Figure 3 for the time period from 2008 to 2012. The aggregated difference between the Trend Scenario and the scenario "Mandatory Equipment" between 2008 and 2012 (= 233 fatalities) represents the hatched area in Figure 3. Additionally, the results for the other investigated areas for the years from 2008 to 2012 are given in Table 17. They are all calculated by multiplying the maximum number of avoidable fatalities, if all cars are equipped with ESP (see Table 6), with the ESP-penetration in the respective year (see Table 16). It can be seen that, with an equipment of all newly registered cars from 2008 onwards in the EU-25, about 1,800 additional fatalities could be avoided until 2012 in the EU-25 compared to the Trend Scenario. In the years after 2012, further deaths could of course be prevented.

3.2.2 Accident cost avoidance and equipment cost development for the Trend Scenario and the Scenario "Mandatory Equipment"

As outlined before, the calculations in the previous chapter have been carried out for the other accident variables as well (Accidents, Injured persons, accident cost savings, equipment costs). The calculations concerning the accident cost savings and the equipment costs development for the Trend Scenario and the Scenario "Mandatory Equipment" are presented in this chapter.

Similar to figure Figure 3, Figure 4 shows the development of accident cost savings for the Trend Scenario and the Scenario "Mandatory Equipment". Again, the black line represents the maximum achievable accident cost savings in the EU-25, if all cars are equipped with ESP (Car equipment rate = 100 %). It amounts to slightly less than € 10 billion, if only the accident cost savings in personal damage accident costs are considered (see also Table 13). The grey lines illustrate the development of the accident cost savings in the years 2003 to 2012 for the Trend Scenario and the Scenario "Mandatory Equipment". They are calculated by multiplying the maximum accident cost savings for the EU-25 stated in Table 13 (€ 9,677.6 Mill.) with the market penetration rates given in Table 16. It can be seen, that the maximum potential accident cost savings are utilised to a larger extent in the scenario "Mandatory Equipment" from 2008 onwards. If mandatory equipment for all newly registered cars with ESP in the EU-25 becomes effective in 2008, then about € 5.1 billion accident cost savings can be achieved in 2012. This represents about half of the maximum potential accident cost savings. In the Trend Scenario, only € 3.7 billion accidents costs are saved in 2012.

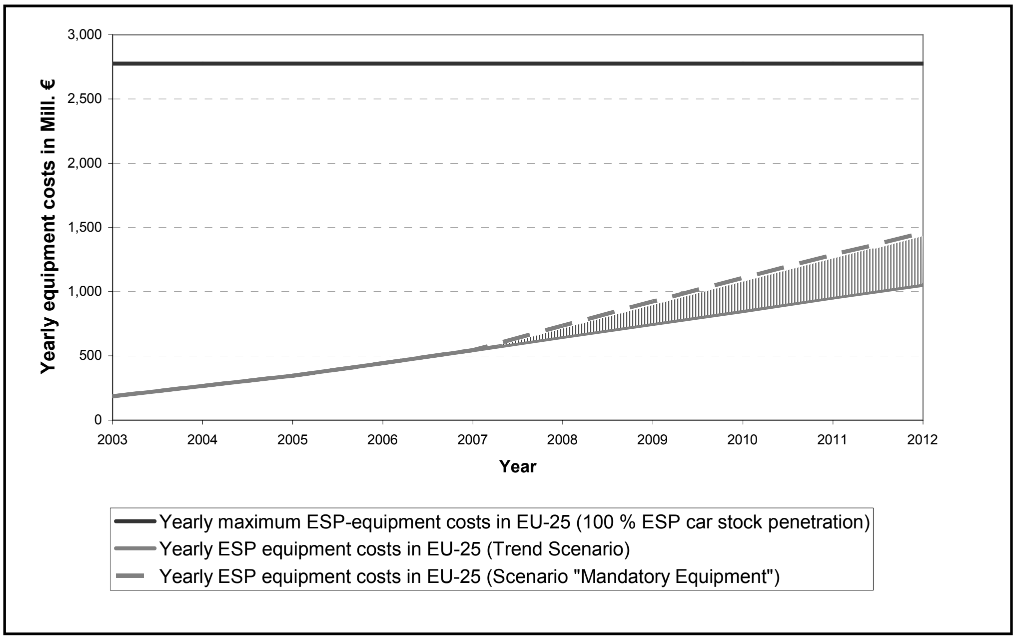
Figure 4: Development of accident cost avoidance in the EU-25 for the Trend Scenario and the Scenario „Mandatory Equipment“



Source: Own calculations

The additional accident costs savings (= benefits) due to higher ESP equipment rates of cars are obviously connected with higher equipment costs. Given the fixed investment costs of € 130 and a fixed average useful life of ESP of 12 years, the costs develop proportionally to the benefits. They can be calculated by multiplying the maximum yearly equipment costs for a car penetration rate of 100 % in EU-25 (= € 2,775.21 Mill., see Table 13) with the actual penetration rates in the different years (see Table 16). The equipment cost developments for the Trend Scenario and the scenario “Mandatory Equipment” are displayed in Figure 5. As in the two figures before, the black line represents the yearly maximum equipment costs in the EU-25, if all cars (= 100 %) are equipped with ESP. The grey lines display the cost development for the two scenarios. Due to higher equipment rates in the Scenario “Mandatory Equipment” the equipment costs rise to a greater extent than in the Trend Scenario from 2008 onwards. According to the benefits, the yearly equipment costs in the Scenario “Mandatory Equipment” in 2012 amount to about half of the maximum yearly equipment costs for a car equipment rate of 100 %. This is due to the fact that – according to the market penetration calculations – 52.5 % of the car stock in the EU-25 is equipped with ESP in 2012 (see Table 16). As a result, the Benefit-Cost-Ratios are independent from the market penetration rate and remain unchanged for different years and scenarios.

Figure 5: Development of equipment costs in the EU-25 for the Trend Scenario and the Scenario „Mandatory Equipment“



Source: Own calculations

The fact that Benefit-Cost-Ratios stay constant under given model assumptions becomes clearer in Table 18, where the values for the EU-25 underlying Figure 4 and Figure 5 are presented for the years 2008 to 2012. Here, the development of the accident cost savings for the two different scenarios and the development of the equipment costs for the two scenarios are stated. Additionally, the Benefit-Cost-Ratios for both scenarios and for each year are calculated by dividing the benefits by the costs. It can be seen, that they remain unchanged by scenario or year. The also calculated differences in benefits and costs for the two scenarios represent the hatched areas in Figure 4 and Figure 5. It can be seen, that the additional benefits arising due to mandatory equipment between 2008 and 2012 accrue to € 4.39 billion. In 2012 alone, additional accident cost savings worth nearly € 1.4 billion can be achieved. Obviously, there will be even more additional accident cost savings in the years after 2012. The additional accident cost savings are always 3.5 times higher than the additional equipment costs.

Table 18: Development of accident cost savings, yearly equipment costs and Benefit-Cost-Ratios between 2008 and 2012 for the Trend Scenario and the Scenario „Mandatory Equipment“ in the EU-25

		Year					
		2008	**2009**	**2010**	**2011**	**2012**	**SUM**
Accident cost savings (= benefits)	Maximum accident cost savings in Mill. € (100 % ESP car stock penetration)	9,677.6	9,677.6	9,677.6	9,677.6	9,677.6	**48,388.0**
	Accident cost savings in Mill. € (Trend Scenario)	2,254.9	2,613.0	2,961.3	3,329.1	3,667.8	**14,826.1**
	Accident cost savings in Mill. € (Scenario „Mandatory Equipment“)	2,564.6	3,222.6	3,861.4	4,490.4	5,080.7	**19,219.7**
	Difference (Scenario “Mandatory Equipment” – Trend Scenario)	**309.7**	**609.6**	**900.1**	**1,161.3**	**1,412.9**	**4,393.6**
Yearly equipment costs	Maximum yearly equipment costs in Mill. € (100 % ESP car stock penetration)	2,775.2	2,775.2	2,775.2	2,775.2	2,775.2	**13,876.0**
	Yearly equipment costs in Mill. € (Trend Scenario)	646.6	749.3	849.2	954.7	1,051.8	**4,251.6**
	Yearly equipment costs in Mill. € (Scenario „Mandatory Equipment“)	735.4	924.1	1,107.3	1,287.7	1,457.0	**5,511.5**
	Difference (Scenario “Mandatory Equipment” – Trend Scenario)	**88.8**	**174.8**	**258.1**	**333.0**	**405.2**	**1,259.9**
Benefit-Cost-Ratio (Trend Scenario)		**3.5**	**3.5**	**3.5**	**3.5**	**3.5**	**3.5**
Benefit-Cost-Ratio (Scenar. „Mandatory Equipment“)		**3.5**	**3.5**	**3.5**	**3.5**	**3.5**	**3.5**

Source: Own calculations

3.2.3 Aggregated Results

The same calculations, which were presented in the previous two chapters for fatality savings, accident cost savings and equipment costs, have also been carried out for the development of the avoidance of accidents and injured persons. These results are displayed together with the fatality savings and accident cost savings in Table 19 in an aggregated form. For each member state resp. for EU-15 and EU-25 as a whole, the aggregated yearly differences between the Trend Scenario and the Scenario "Mandatory Equipment" in accident figures for the time period from 2008 to 2012 are shown. The additional fatalities avoided are therefore identical with the sum of differences shown in Table 17. Likewise, the additional accident cost savings for the EU-25 in the years 2008 to 2012 (= € 4,393.6 Mill.) are identical with the sum of differences shown in Table 18.

Table 19: Additional accident savings between 2008 and 2012 due to a mandatory ESP-equipment of all newly registered cars from 2008 onwards compared to the Trend Scenario

Member States	Additional accidents avoided	Additional fatalities avoided	Additional injured persons avoided	Additional accident costs saved in Mill. € (without PDO accidents)	Additional accident costs saved in Mill. € (including PDO accidents)
United Kingdom	6,058	160	7,721	620.2	1,033.7
Germany	8,109	233	9,703	816.7	1,361.2
Italy	6,547	306	8,170	793.8	1,323.0
Spain	4,177	313	6,001	665.4	1,109.0
France	2,794	328	3,340	529.8	883.0
EU-15	34,335	1,628	42,692	4,182.3	6,970.5
EU-25	34,746	1,811	43,156	4,393.6	7,322.7

Source: Own calculations

Besides the 1,800 additional lives saved between 2008 and 2012, about 43,000 more injured persons could be circumvented by a mandatory equipment in the EU-25 compared to a situation, where ESP-equipment of cars remains voluntary. Together with the property damage and congestion costs of the 34,746 avoided accidents, the additional accident cost savings of such a mandatory equipment amount to nearly € 4.4 billion. In order to achieve this additional benefit sum, € 1.26 billion (see Table 18) have to be invested into the equipment of cars with ESP between 2008 and 2012 (Benefit-Cost-Ratio = 3.5).

As argued earlier, the inclusion of property damage only accidents will increase the benefits (and with that the benefit-cost ratio to 5.8). Hence, it will also increase the additional benefits which stem from the mandatory equipment compared to the trend scenario. This effect is illustrated in the last column of Table 19. Including an estimation for PDO accident costs, the additional benefits of the mandatory equipment amount to € 7.3 billion in the period 2008 – 2012.

It has to be noted that road safety has improved in the past. The number of injured persons in road traffic in the member states of the EU-25 declined from about 1.9 Mill. in 1992 to 1.74 Mill. in 2004 (which equals a yearly growth rate of about -0.64 %). The number of fatalities decreased even stronger in that time period from 66,558 (1992) to 43,358 (2004), which means a yearly reduction of -3.5 %.[23] Reason for this is a multitude of other measures besides ESP (e.g. improvement of infrastructure, better inspection regimes for vehicles, other technical improvements etc.) that help improving road safety. If this trend continues in the future, accident numbers will decline even without further diffusion of ESP. As a consequence, the accident avoidance potential of ESP might decrease in the future.

Under the presumption, that the number of fatalities declines by -3 % and the number of injured persons and accidents declines by -1 % each year from 2003 onwards, the additional fatality savings would amount to roughly 1,400 only. The additional accident cost savings would equal about € 3.8 billion. This smaller accident avoidance potential of ESP would influence the calculations for both scenarios and would also lead to a yearly declining Benefit-Cost-Ratio. This can of course not be taken as an argument against the promotion of ESP as a safety-enhancing measure. Because every effort to improve road safety could be considered as redundant, if one argues that road safety increases anyway due to other measures which are implemented. The question to be answered is, which of the measures is the most cost-effective one based on actual accident figures. Therefore the calculations have been carried out on the database of 2003.

Abstract

The introduction of the Electronic Stability Program (ESP) is widely regarded as one of the most effective measures for accident prevention in road vehicles. Single vehicle accidents caused by skidding cars could be largely prevented with this system. The profitability of ESP from the society of point of view is proven by a cost-benefit analysis for the EU-25 (base year: 2003). When full equipment of the car stock is assumed, about 75,000 accidents – resulting in 4,000 fatalities and 100,000 injuries – could be avoided. The benefit-cost ratio amounts to 3.5 without appraisal of property damage only accidents. It accounts for 5.8 when property damage is included. It is also investigated which additional impact can be realised when every new car will be equipped with ESP from 2008 onwards (scenario "mandatory equipment") compared to the trend scenario. The calculations show that 1,800 fatalities and 43,000 injuries could be additionally prevented due to the faster deployment. The additional benefits in the period 2008-2012 amount to 4.4 bill. € (without property damage) or 7.3 bill. € (including property damage). In the light of these results ESP turns out to be a very efficient measure for improving road safety.

[23] European Commission – Directorate General Energy and Transport, available under "http://ec.europa.eu/transport/roadsafety/road_safety_observatory/doc/ historical_evol.pdf

Literature

Abele, J., Baum, H. et al., Exploratory study on the potential socio-economic impact of the introduction of Intelligent Safety Systems in Road Vehicles, Study on behalf of the European Commission – DG INFSOC, Brussels 2005

Baum, H., Schulz, W. H. et al., Socio-Economic-Assessment of CarTALK 2000-Applications, Final Report, September 2004

Biber, C., Unfallforscher fordern zum Umdenken bei den Sicherheitsprüfungen auf, Meldung vom 10.06.2005 unter www.auto-reporter.net (Artikelnummer 20050610-000004), Zugriff am 08.08.2006

eIMPACT, Documentation of Market Scenario Workshop, Brussels 25 Sep 2006

E-Safety-Forum, Final Report and Recommendations of the Implementation Road Map Working Group, Brussels 2005

European Commission – Directorate General Energy and Transport, available under "http:// ec.europa.eu/transport/roadsafety/road_safety_observatory/ doc/historical_evol.pdf

European Commission, Directorate General for Energy and Transport, Energy & Transport in figures 2005

European Commission. Enterprise and Industry Directorate-General, CARS 21 – A Competitive Automotive Regulatory System for the 21st Century, Final Report, Luxembourg 2006

European Commission, European road safety action programme, COM (2003) 311, Brussels 02.06.2003

European Commission, Information and Communication Technologies for Safe and Intelligent Vehicles, COM (2003) 542, Brussels 15.09.2003

European Commission, Proposal for a Directive of the European Parliament and of the Council amending Directive 1999/62/EC on the charging of Heavy Goods Vehicles for the use of certain infrastructure, Brussels 2003

European Commission, Road Safety – Results from the transport research program, Brussels 2001

European Commission, White Paper – European transport policy for 2010: time to decide, Brussels 2001

Geißler, T., Automated Highway Systems – Konzept, Bewertungsmethodik und empirische Auswirkungsanalyse des CHAUFFEUR-Systems, Köln 2001

ICF Consulting, Cost-Benefit Analysis of Road Safety Improvements, London 2003

Knoll, P. M., Langwieder, K., Der Sicherheitseffekt von ESP in Realunfällen, Überlegungen zum volkswirtschaftlichen Nutzen von prädiktiven Fahrerassistenzsystemen, Vortragsunterlagen anlässlich der 2. Tagung "Aktive Sicherheit durch Fahrerassistenz" am 4./5. April 2006, Garching bei München

Perrett, K.E., Stevens, A., Review of the potential benefits of road transport telematics, TRL Report 220, 1996

Sferco, R., Page, Y., LeCoz, J.Y., Fay, P., Potential effectiveness of Electronic Stability Programs (ESP) – What European Field Studies tell us, 17th International ESV Conference, Amsterdam, June 2001

Statistisches Bundesamt, Verkehrsunfälle 2003, 2004, 2005, Fachserie 8 / Reihe 7, Wiesbaden 2004, 2005, 2006

Tingvall, C., Lie, A., Krafft, M., Kullgren, A., The effectiveness of ESC (Electronic Stability Control) in reducing real life crashes and injuries, in: Traffic Injury Prevention, vol. 7, issue 1, March 2006, pp. 38-43

United Nations Economic Commission for Europe (UNECE), Statistics of Road Traffic Accidents in Europe and North America, New York and Geneva 2003, 2004, 2005

Unselt, T., Breuer, J., Eckstein, L., Frank, P., Avoidance of „loss of control crashes" through the benefit of ESP, FISITA Conference Paper No. F2004V295, Barcelona 2004

Zackor, H., Keller, H. u.a., Entwurf und Bewertung von Verkehrsinformations- und –leitsystemen unter Nutzung neuer Technologien, Berichte der BASt, Heft V70, Bergisch Gladbach 1999