Cost-benefit assessment and prioritisation of vehicle safety technologies

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1. Introduction

The approach to and results of the economic cost-benefit assessment of vehicle safety technologies carried out for the European Commission are summarised in this paper.

2. Background

In 2002, close to 50,000 people lost their lives and millions were injured as a result of road accidents in Europe (see Table 0-1).

The total annual costs for society are - on the basis of the valuation of accidents presented in the table below - estimated at € 229 billion per year.

Table 0-1 Number of fatalities/injuries per year, unit costs per accident and costs to society per year - EU-25 (based on data for 2002)

	No.	€ per fatality/injury	Costs to society (billion €)
Fatalities	49,686	1,018,200	51
Severe injuries	480,043	143,100	69
Slight injuries	4,730,451	23,100	109
Total	-	-	229

Source: CARE, adjusted for non-reported accidents

Note: The number of fatalities/injuries is projected to decline over the coming years even if nothing is done to promote the use of the technologies under consideration.

3. Technologies

The objective of this study is to assess the introduction of 21 vehicle safety technologies based on existing literature, data and knowledge. A short description of each of the technologies under consideration is provided in the table below.

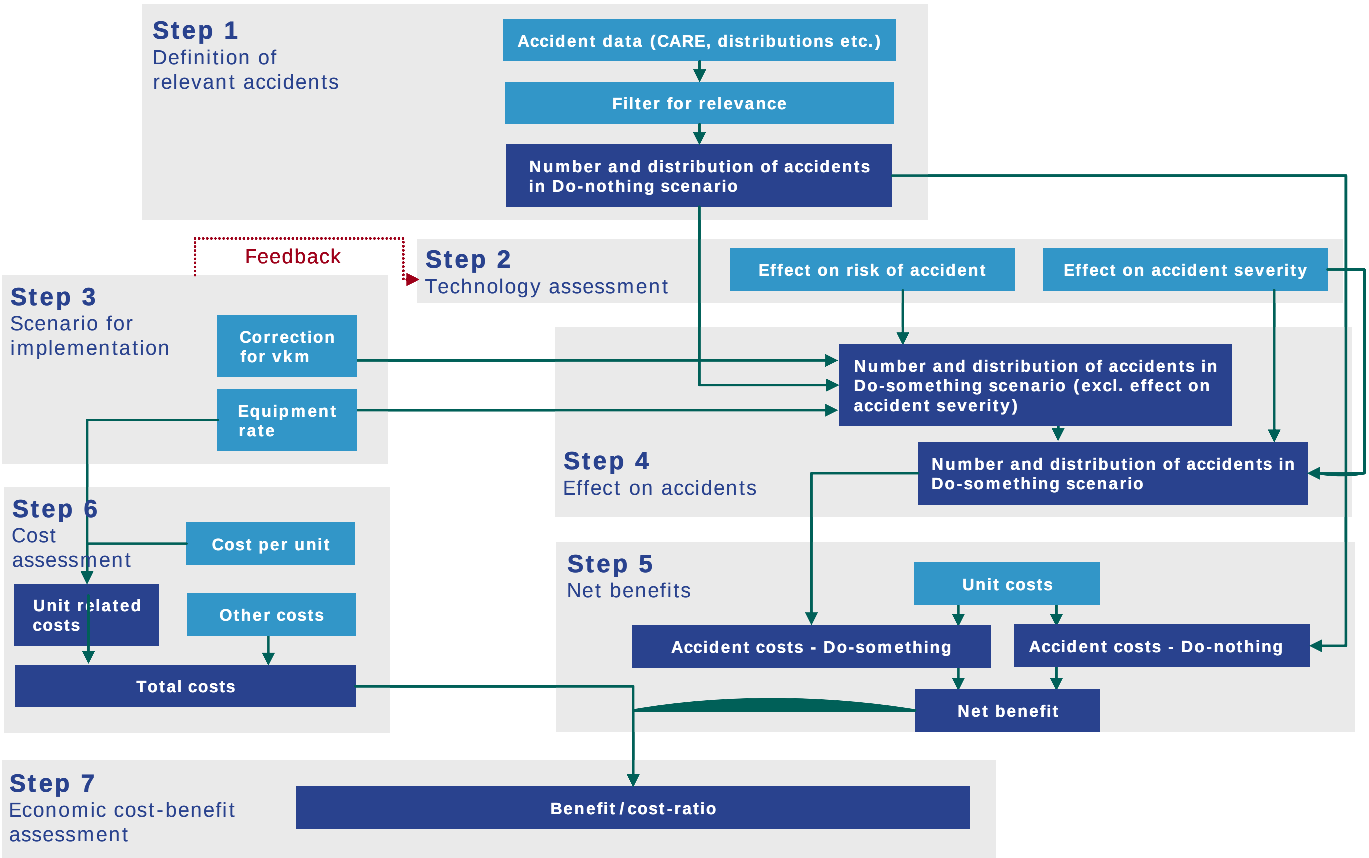
Table 0-1 List and short description of safety technologies

Type of device	Safety device		Short description
1. Avoiding collisions, mitigating their severity and their consequences	1.1	Electronic stability control (ESC)	Stability enhancing system which improves vehicles' lateral stability.
	1.2	Brake assist system (BAS)	System which helps to reduce the braking distance when an emergency brake is detected.
	1.3	Improved vehicle compatibility	Technology to reduce the severity of accidents involving vulnerable road users by improvements of the front design.
	1.4	Under-run protection	Under-run guard rails and side under-run protection
	1.5	eCall	Automatic call sent to emergency service in case of an accident.
	1.6	Soft nose on trucks	Absorption of energy in case of accidents with cars and trucks
	1.7	Collision warning and similar systems	The system informs the driver of dangerous situations in advance or activates a potential pre-crash /crash avoidance system.
	1.8	Adaptive cruise control (ACC)	A system which enables the vehicle to maintain a driver-defined distance from the preceding vehicle while driving within a maximum speed limit - set by the driver.
2. Linked to lack of perception	2.1	Daytime running lights	The use of daytime running lights improves vehicle visibility in all light conditions.
	2.2	Conspicuity marking	Contour-marking of HGV to increase visibility.
	2.3	Retro-fitting of blind spot mirrors	Installation in wide angle/close proximity mirrors on existing trucks to avoid blind spot accidents.
3. Linked to inappropriate speed	3.1	Intelligent speed adaptation (ISA)	Intelligent speed adaptation warns or prevents the driver from exceeding the local or preset speed limit.
4. Linked to lack of use and/or improper use of restraint systems	4.1	Seat belt reminders	Detectors in the seat inform the system if the seat is occupied and if the seat belt is not fastened.
	4.2	Improved seats and headrests	Improved design of seats and headrests to avoid whiplash injuries.
	4.3	Universal anchorage systems (ISOFIX)	Standard for installing child seats correctly into cars.
5. Linked to tyre problems	5.1	Tyre pressure monitoring systems	System which informs the driver of reduced pressure in one or more tires.
	5.2	Brake measurement devices	System which automatically tests the brakes.
6. Linked to driver distraction/impairment/behaviour	6.1	Alcohol ignition interlocks	The system checks the alcohol level of the driver (breath test).
	6.2	Fatigue detectors	The system monitors the condition of the driver, including tracking and warning of drowsiness, distraction and inattention.
	6.3	Event or accident data recorders	Accident data recorder is an on-board event recorder. In case of accidents (or events), data on the vehicle's speed, acceleration, brake use, etc. just prior to, during and after the accident is recorded.
	6.4	Lane departure warning	The system assists drivers in keeping their lanes by warning drivers when their car is in danger of leaving the lane unintentionally.

4. Approach

The assessment of each the 21 vehicle technologies is based on seven general steps, as illustrated in the figure below.

Figure 1 Assessment framework



The seven steps are briefly described below.

Step 1: Definition of relevant accidents

The first step is to identify the accidents which are relevant for the technology under consideration. For example, for the brake assistant system (BAS) only rear end and head on collisions, merging and intersection collisions, vehicle-pedestrian collisions, collisions with obstacles and left roadway accidents are relevant.

The identification of relevant accidents is based on compiled accident data (CARE[1] etc.) and existing literature.

The result is a scenario for the future development in the number of fatalities, severe injuries and slight injuries in a situation where the current development continues, as nothing

[1] Community database on Accidents on the Roads in Europe

extraordinary is done to promote the safety technology under consideration, i.e. the Do-nothing scenario.

Step 2: Technology assessment

The effectiveness of each of the technologies under consideration is assessed on the basis of a review of the relevant literature.

The benefits of implementing a certain safety technology can be in the form of reduced collision probability and/or severity of accidents in case an accident occurs.

Step 3: Scenario for implementation

The scenario for implementation refers to the diffusion of the safety technology within the vehicle fleet in the Do-something scenario, which is compared to the Do-nothing scenario, where nothing extraordinary is done to promote the use of the safety technology under consideration.

To ensure that the technologies are evaluated on equal premises the assessment compares costs and benefit of installing each technology in all (relevant) new vehicles from 2007 (except for *retro-fitting of blind spot mirrors).*

It is taken into account that some of the technologies are already installed in some vehicles and that market penetration will possibly increase over the coming years even if nothing extraordinary is done to promote the use of the safety technology.

Step 4: Effect on accidents

The effect on the number of fatalities, severe injuries and slight injuries of making the installation of the technology in all new vehicles mandatory is assessed on the basis of the effectiveness of the technology (step 2) and the scenario for implementation (step 3).

Step 5: Net benefits

The economic net benefits are defined as a reduced number of fatalities/injuries. The net benefits are evaluated by assessing the accident costs in the Do-something scenario and the accidents costs in the Do-nothing scenario. The net benefits are estimated on the basis of the standard unit costs for accidents which were presented in Table 0-1.

The applied unit values have a large impact on the estimated benefit/cost-ratio. If higher values are used the benefit/cost-ratio will increase, and vice versa for lower unit values. The level of the applied unit values does not affect the relative ranking of the technologies.

Step 6: Cost assessment

The costs of installing the relevant technologies in all new vehicles are assessed in step 6.

Step 7: Economic cost-benefit assessment

The final step is to assess whether it is economically beneficial to implement the safety technology under consideration. The net benefits of the system (step 5) are compared to the net costs of installing the system in all new vehicles (step 6). If the net benefits outweigh the net costs, the introduction of the safety system will be beneficial to society. The robustness of the results to the values used for key parameters (e.g. unit cost per technology, effectiveness of system) is evaluated through a number of sensitivity analyses.

Finally, the technologies are ranked according to the estimated benefit/cost-ratio.

5. Key input figures

The economic cost-benefit assessment is, as mentioned, based on the assessment of a number of parameters for each technology.

The most important parameters for each of the technologies are summarised in the table below. Please note that the information on the effectiveness of the technologies presented in the table only reflects the effectiveness in terms of avoiding fatal accidents or reducing the severity of the previously fatal accidents to severe or slight injury. A similar assessment is made for severe and slight injuries.

The table shows, for example, that the brake assistant system (BAS) will result in a 8% reduction in the risk of collision for rear end and head on collisions, merging and intersection collisions, vehicle-pedestrian collisions, collisions with obstacles and left roadway accidents, which account for approximately 50% of all fatal accidents. Likewise, it is estimated that the risk of the accident being fatal is reduced by 8% (reduced to severe injury) for the above mentioned type of accidents. Furthermore, it can be seen that it is estimated that 5% of the current fleet of vehicles have the brake assistant system installed. This figure is estimated to increase to 20% in 2025 even if nothing extraordinary is done to promote the system. Finally, the table shows that it has not been possible to obtain any solid cost estimates on the brake assistant system.

The data on the share of vehicles with the technology installed in 2006 and 2025 and the evaluation of the effectiveness of the technology are used to estimate the number of saved fatalities/injuries.

Table 0-1 Overview - key input data for each technology

Technology	Do-nothing scenario		Effectiveness of technology (fatalities)			Unit costs
	Share of vehicles 2006	Share of vehicles 2025	Reduction, risk of collision	Reduction, severity	Accident group	
Electronic stability control (ESC)	9%	50%	18%	0%[5]	All	€250
Brake assist system (BAS)	5%	20%	8%	8%	Rear end and head on/merging and intersection/vehicle-pedestrian collisions, collisions with obstacles and left roadway accidents (50% of all)	N/A
Improved vehicle compatibility	0-1%	50%	0%	28%	Vulnerable road users hit by front of car (14% of all)	N/A
Under-run protection	0-1%	10%	0%	39%	Vulnerable road users hit by a HGV turning right and cars hitting trucks in the side (2.5% of all)	€1250
eCall	0-1%	0-1%	0%	4%	All	€90-€500
Soft nose on trucks	Virtually no cost-benefit data					
Collision warning and similar systems	0-1%	20%	12%	8%	Rear and head/side/merging and intersection/vehicle-pedestrian collisions, collisions with obstacles and left roadway accidents (60% of all)	N/A
Adaptive cruise control (ACC)	1%	10%	25%	20%	Rear end collisions (4-6% of all)	€750
Daytime running lights	10%[1]	10%[1]	15%	0%[5]	Multi-party daytime accidents (40% of all, ex. countries where DRL is compulsory)	€25
Conspicuity marking	5%	5%	86%	0%[5]	Accident during night-time or dusk/dawn on street without lighting involving a car hitting a HGV at the rear or at the side (0.45% of all)	€204
Retro-fitting of blind spot mirrors	14%	100%[2]	40%	0%[5]	Vulnerable road users hit by a HGV turning right (1.25% of all)	€210
Intelligent speed adaptation (ISA)	0-1%	20%	50%	0%[5]	Rear end and head on collisions, merging and intersection collisions, vehicle-pedestrian collisions, collisions with obstacles and left roadway acc. (50% of all)	€500
Seat belt reminders	0%[3]/ 10%[4]	0%[3]/ 90%[4]	0%[3]/ 0%[4]	46%[3]/ 43%[4]	Accidents with drivers not wearing seat belts (33% of all in EU-15 and 50% of all in NMS)	€60[3]/ €50[4]
Improved seats and headrests	Virtually no cost-benefit data					
Universal anchorage systems (ISOFIX)	Virtually no cost-benefit data					
Tyre pressure monitoring systems	0-1%	0-1%	100%	0%	Accidents caused by tyre pressure problems (0.08% of all)	€125
Brake measurement devices	Virtually no cost-benefit data					
Alcohol ignition interlocks	0-1%	10%	75%	0%[5]	Accidents with at least one drunk driver involved (30% of all in EU-15 and 40% of all in NMS)	€500
Fatigue detectors	0-1%	10%	10%	0%[5]	(95% of all)	N/A
Event or accident data recorders	0-1%	10%	15%	0%	All accidents with cars, trucks and buses (95% of total)	€100
Lane departure warning	0-1%	10%	25%	15%	Head on accidents, single accidents and side collisions (50% of total)	€400

[1] In countries where DRL is not compulsory, [2] As mandatory in all new trucks, [3] Version which blocks the vehicles, [4] Version which gives a discreet visual and/or audio signal, [5] For some of these technologies it could be argued that there is an effect on the severity in case an accident occurs. However, this effect is not explicitly taken into account here due to a lack of data. For some technologies the effect is 'included' in the estimate on the reduction in the risk of accidents.

6. Effect on the number of fatalities/injuries

The estimated effects on the total number of fatalities, severe injuries and slight injuries are presented in Figure 2 - Figure 4 below for selected years. The estimated effects depend on:

- The definition of 'relevant accidents'
- The Do-nothing scenario
- The estimated effectiveness in terms of reducing the risk of collision and/or severity of injuries in case an accident occurs.

Figure 2 Reduction in the number of fatalities in EU-25 in 2010 and 2020

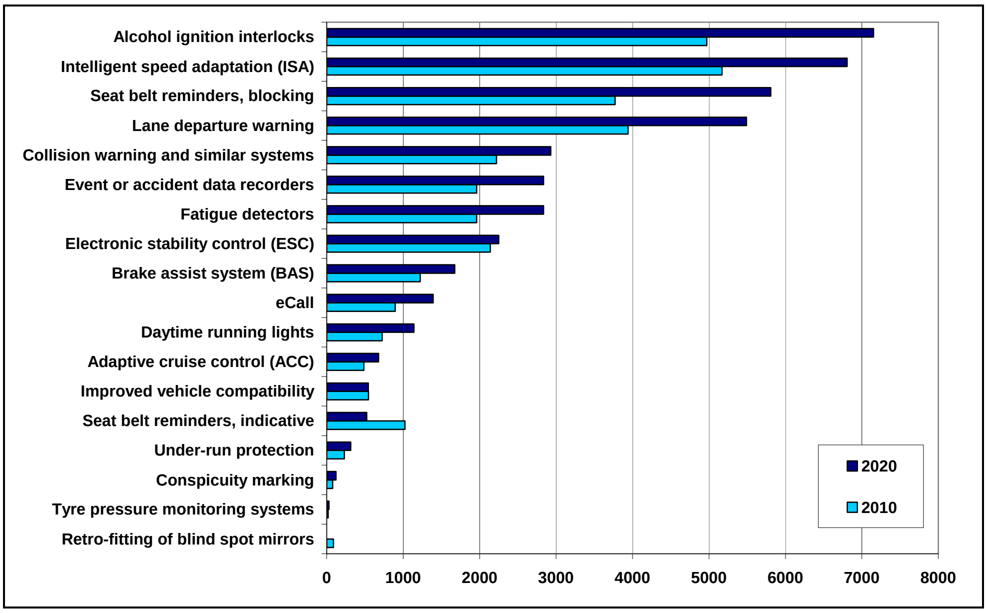


Figure 3 Reduction in the number of severe injuries in EU-25 in 2010 and 2020

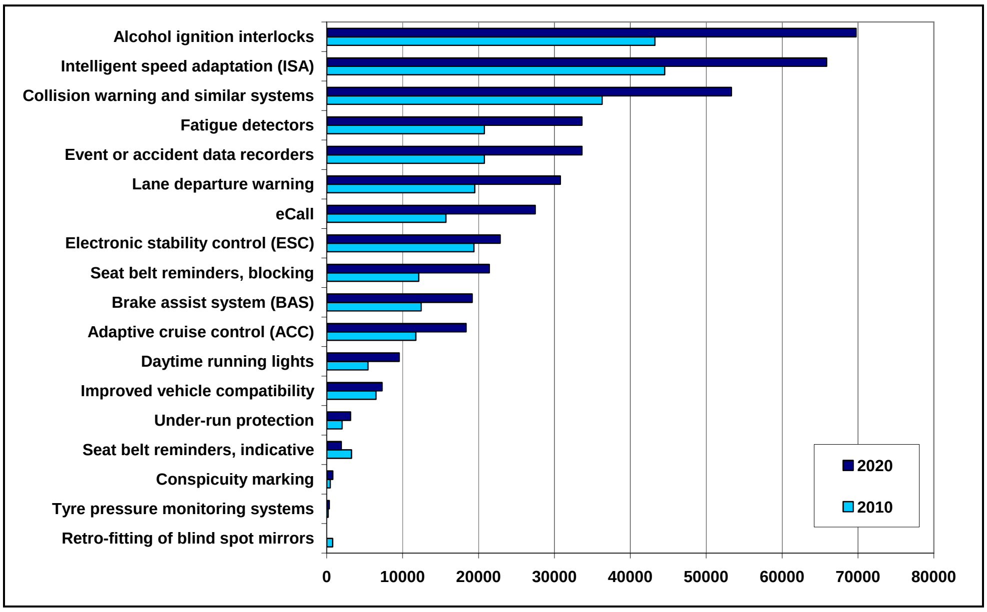
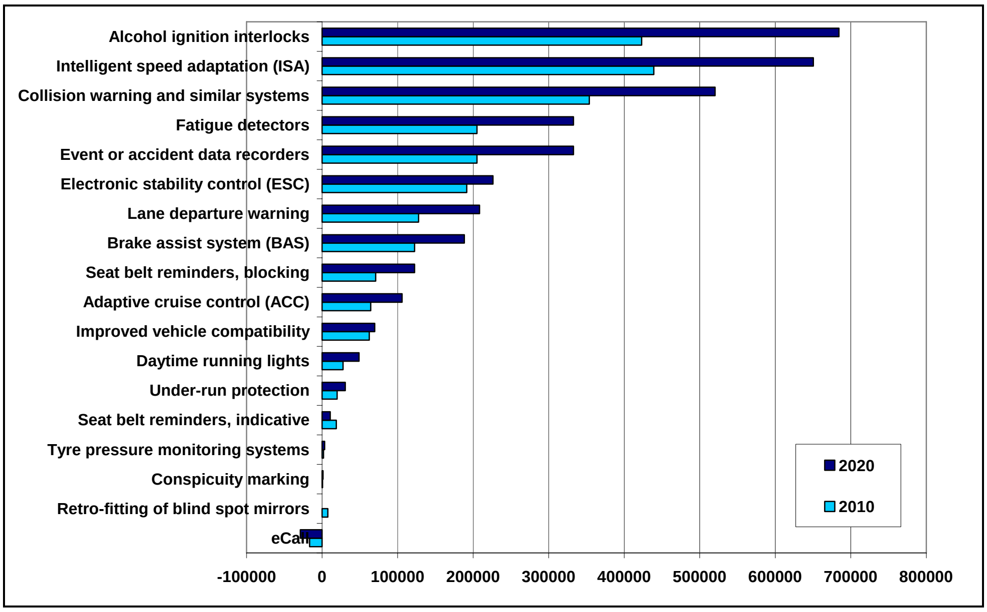


Figure 4   Reduction in the number of slight injuries in EU-25 in 2010 and 2020



It can be seen that:

– Some of the technologies will have a very large impact on the number of fatalities/injuries in EU-25
– The technologies with the largest impact are:
  - Alcohol ignition interlocks
  - Intelligent speed adaptation (ISA)
  - Seat belt reminders (depending on system)
  - Lane departure warning system
  - Collision warning and similar systems
  - Event or accident data recorders
  - Fatigue detectors
– The technologies with the lowest impact in total are:
  - Tyre pressure monitoring systems
  - Retro-fitting of blind spot mirrors
  - Conspicuity marking
  - Under-run protection.

It is worth noting that some of the technologies with the lowest total impact are efficient in terms of reducing specific type of accidents.

The benefits of a reduced number of fatalities/injuries are compared to the cost of installing the technology in all new cars in the next section.

7. Results and conclusions

The results of the economic cost-benefit analysis are summarised in the table below.

The benefit/cost-ratio is estimated for 13 of the 21 technologies. For 4 additional technologies the break-even unit costs have been estimated, as no solid cost estimates are available in the existing literature. If the actual unit costs are lower than the estimated break-even unit costs, the technology can be considered as being cost-effective. For 4 of the technologies virtually no cost-benefit data is available.

Table 0-1 Summary - main results of economic cost-benefit assessment (Benefit/cost-ratio, BCR)

Category - according to economic cost-effectiveness	Technology	Benefit/cost-ratio (BCR) Central estimate	Comment
1. Cost-effective (BCR>3)	▪ Seat belt reminders	7.6-8.2	Depending on system
	▪ Event or accident data recorders	7.1	
	▪ Electronic stability control (ESC)	3.8	
	▪ Retro-fitting of blind spot mirrors	3.8	
	▪ Intelligent speed adaptation (ISA)	3.3	
	▪ Alcohol ignition interlocks	3.1	
2. Most likely cost-effective (1<BCR<3)	▪ Conspicuity marking	2.5	
	▪ Under-run protection	2.4	
	▪ Daytime running lights	1.8	
	▪ Lane departure warning	1.7	
3. Most likely not cost-effective (0.25<BCR<1)	▪ Adaptive cruise control (ACC)	0.4	
4. Not cost-effective (BCR<0.25)	▪ Tyre pressure monitoring systems	0.04	
Difficult to categorise	▪ eCall	0.4-2.0	Depending on cost estimate
Break-even cost calculated	▪ Collision warning system	Break-even costs = €1,200/vehicle	
	▪ Fatigue detectors	Break-even costs = €710/vehicle	
	▪ Improved vehicle compatibility	Break-even costs = €285/vehicle	
	▪ Brake assistant systems	Break-even costs = €460/vehicle	
Virtually no cost-benefit data	▪ Soft nose on trucks		
	▪ Improved seats and headrests		
	▪ Brake measurement devices		
	▪ Universal anchorage systems (ISOFIX)		

It can be concluded that:

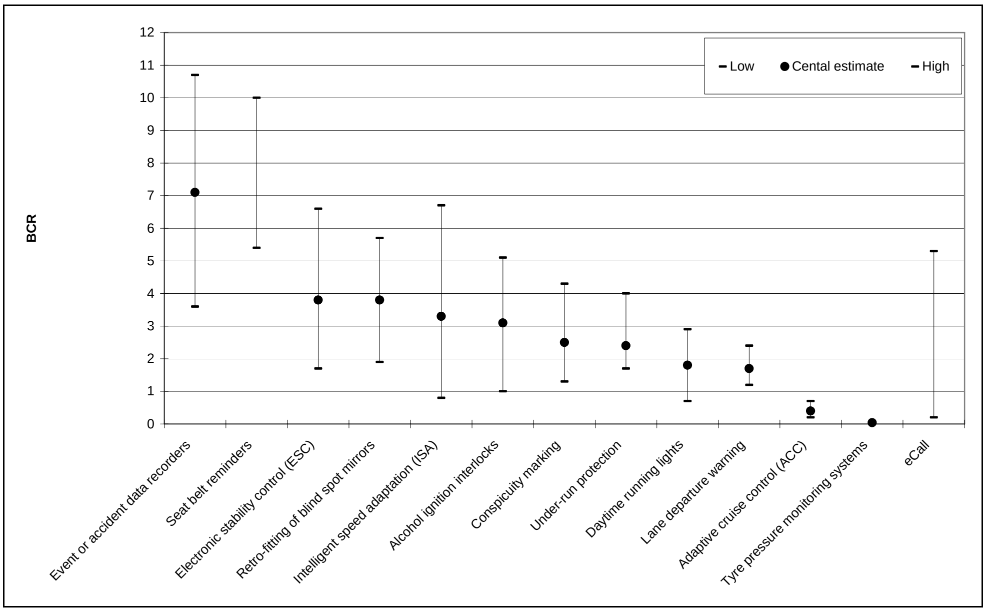
- A large number of the technologies under consideration appear to be either *cost-effective* (benefit/cost-ratio>3) or *most likely cost-effective* (benefit/cost-ratio between 1 and 3)
- *Seat belt reminders* and *event or accident data recorders* appear to be the most cost-effective vehicle technologies, but it also appears that *electronic stability control (ESC), retro-fitting of blind spot mirrors, intelligent speed adaptation (ISA)* and *alcohol ignition interlocks* are very promising.
- The 3 vehicle technologies which directly address accidents involving HGV; *retro-fitting of blind spot mirrors, conspicuity marking* and *under-run protection* are considered to be *cost-effective* or *most likely cost-effective*. The cost-effectiveness of retro-fitting of blind spot mirrors depends crucially on the year of implementation. The sooner the initiative is implemented the more cost-effective.
- It has proven difficult to provide solid evidence on the cost-effectiveness of the in-vehicle emergency system *eCall* to due a lack of solid estimates of the total cost of the system.
- *Adaptive cruise control (ACC)* and *tyre pressure monitoring systems* appear to be less cost-effective measures to improve road safety.
- For 4 technologies, no benefit/cost-ratio has been estimated due to a lack of solid cost estimates. Some of these systems seem to be effective, but further research is needed to determine their cost-effectiveness.
- For the final 4 vehicle technologies, virtually no cost-benefit data is available. Due to the nature of the technologies, it could prove difficult to assess the cost-effectiveness of the systems, even if further research is conducted. This does however not necessarily mean that the technologies are not cost-effective measures for improving the safety on the European roads.

The robustness of the results has been analysed through a number of sensitivity analyses for each of the technologies. The results of the sensitivity analyses are summarised in Figure 5 for the technologies for which a benefit/cost-ratio is estimated and in Figure 6 for the technologies for which a break-even unit cost is estimated.

The fact that a large number of the technologies under consideration appear to be either *cost-effective* or *most likely cost-effective* is robust to the assumptions made.

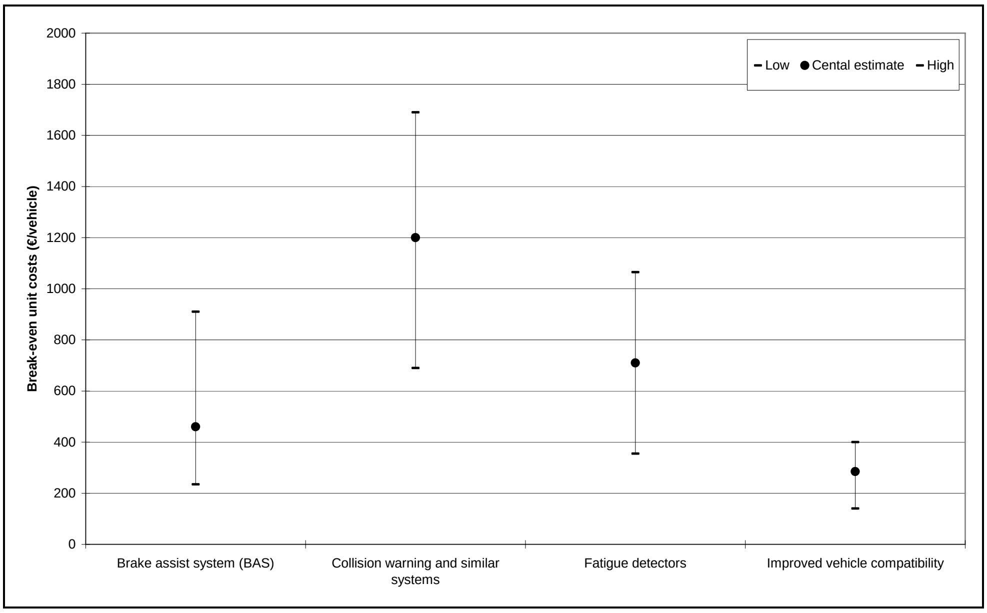
The sensitivity analyses show that the results are highly dependent on the unit cost estimate and the assessed effectiveness of the technology. The results are insensitive to the assumed market penetration rates for the Do-nothing scenario and the assumed lifetime of the vehicle.

Figure 5 Range of BCR for each technology based on sensitivity analyses



Note: No central estimate is given for seat belt reminders and eCall, as more than one scenario is assessed (ref. Table 0-1)

Figure 6 Range of break-even unit costs for each technology based on sensitivity analyses



Finally, it should be noted that the costs of the technologies tend to decrease over time, which could make some of the currently least cost-effective measures cost-effective in the future.