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Development of Road Safety Performance Indicators for the European Countries

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ABSTRACT

Safety performance indicators (SPIs) are measures reflecting the operational conditions of the road traffic system that influence the system's safety performance. Within the European project SafetyNet, SPIs were developed for seven road safety-related areas: alcohol and drugs; speed; the use of protective systems; daytime running lights; vehicles (passive safety); roads and trauma management. A common procedure for the development of SPIs in each area was applied, starting with a definition of unsafe operational conditions of the traffic system and continuing with a conversion of this information into measurable variables. Based on a literature survey, a relationship between the problem area and road safety was ascertained. Characteristics of the system's performance were analyzed aiming to select those which can be quantified. The data were collected in cooperation with national experts from 29 European countries enabling to verify the applicability of the SPIs developed and to conduct country comparisons. It was demonstrated that, in some areas, e.g. the use of protective systems, sufficiently good data are available in Europe, while in other areas, e.g. speed and alcohol, data quantity and quality vary strongly. For passive vehicle safety, trauma management and roads, completely new approaches were developed for the SPIs' estimation. Given the data are collected on a common basis, SPIs can become valuable tools in future knowledge- and data-driven policy-making in Europe.

Keywords: road safety, safety performance indicators, monitoring, European country, comparison

INTRODUCTION

Similar to the previous decade, the European Union (EU) has renewed its commitment to improving road safety by setting a target of halving the number of road fatalities by 2020 [6-7]. Today, both European and world-wide organizations encourage countries to adopt national road safety programs as a background condition for systematic work on promoting road safety [12,25,27]. Many countries have developed and are currently enacting their national safety plans [28]. It is generally accepted that safety plans and targets need to be monitored periodically, to verify the progress made and to adopt necessary changes based on recent trends observed [12,25,27,28].

When monitoring the progress, road safety is usually assessed in terms of accidents, injuries or their social costs. However, simply counting accidents or injuries mostly does not offer enough insight into the underlying processes. Typically, accidents or injuries are only the tip of the iceberg, because they occur as the 'worst case' of unsafe operational conditions of the road traffic system. At the same time, those managing road safety need to take into account as many factors that affect safety as possible or, at least, those factors that they are able to adjust or control and that have a major influence. Hence, safety performance indicators other than accident/injury numbers are required to provide a means for monitoring the effectiveness of safety actions applied.

A report written by a group of European road safety experts in 2001 [11], detailed the reasons behind the need for safety performance indicators. Among others, they stated that, in order to develop effective measures to reduce the number of accidents/ injuries it is necessary to understand the processes that lead to accidents, where safety performance indicators can serve this purpose.

The same report [11] strengthened the need for the development of a set of road safety performance indicators (SPIs) in the EU, which was further supported by the European road safety action programme [6]. Both sources defined seven road safety related areas, for which the development of SPIs is required. These areas were: alcohol and drugs; speed; protective systems; daytime running lights; vehicles; roads and trauma management. These areas were stated as core issues for road safety activities in Europe, based on the potential of different road safety domains for promoting road safety as well as on the experiences and data available in the countries.

Next, in the period 2004-2008, within the European Commission (EC) funded SafetyNet project, a study was undertaken aimed at developing SPIs for the seven predefined areas. The study's purpose was to develop meaningful SPIs that, on the one hand, would have a solid theoretical basis and, on the other hand, could in the short term realistically be applied in the EU, given the availability of relevant data now and in the future. The SafetyNet team worked closely with representatives from each of the 27 member states, complemented with representatives from Norway and Switzerland. The representatives provided the data for their respective countries as well as feedback on the study's results.

This paper gives an overview of the SPIs developed for the evaluation and comparison of the European countries, explaining the approach applied for selecting meaningful and applicable indicators in general (Section 2), and in particular in each safety area (Section 3), and showing, as examples, some results of applying the indicators to the European countries (Section 3). Furthermore, Section 4 summarizes the experiences of developing common SPIs for use by the European countries, in various safety areas, and discusses recent developments on the issue that occurred in the post-SafetyNet period.

AN APPROACH APPLIED FOR SPI DEVELOPMENT

A basic model

The place of SPIs in a safety management system was originally illustrated by New Zealand's Land Traffic Safety Authority in 2000 [23] and later by ETSC [11]. The original model defined the essential elements of a safety management system: safety measures/programs, safety performance indicators (as intermediate outcomes), the numbers of crash fatalities/injuries (as final outcomes), and the social costs of crashes/injuries. This model allocated SPIs on the level of intermediate outcomes but did not differentiate explicitly between SPIs and the outcomes of programs or countermeasures.

The SPI Theory report prepared by the SafetyNet [19] provided further methodological fundamentals for SPI development. A core issue in the development of SPIs was that they should be able to reflect unsafe operational conditions of the road traffic system and should therefore be of a more general nature than direct outputs of specific safety interventions. In order to demonstrate a more general character of SPIs and their independence from interventions, the layer of 'intermediate outcomes' was further divided into 'operational conditions of the road traffic system' and 'outputs' (from measures/ interventions).

The SafetyNet concept of the place of SPIs in a safety management system is shown in Fig 1. Ideally, SPIs should reflect the unsafe operational conditions of the road traffic system and should be sensitive to their changes. These changes in operational conditions can be caused by outputs of a road safety program or road safety measures. For example, in the case of speeding, the unsafe operational conditions of the road traffic system (i.e. speeding) are affected by outputs from specific safety measures (e.g. speed enforcement). The outputs are the physical deliverables of the intervention (e.g. speed cameras), whereas the outcomes should be seen in improving the operational conditions (e.g. lower level of speeding), which can be measured by SPIs. The improved operational conditions will result in crash or injury reductions, whereas the whole process should reduce the social costs.

Consequently, the definition of SPIs suggested by SafetyNet was as follows [19]: safety performance indicators are the measures (indicators), reflecting those operational conditions of the road traffic system, which influence the system’s safety performance. The SPIs' purpose is:

- to reflect the current safety conditions of a road traffic system (i.e. they are considered not necessarily in the context of a specific safety measure, but in the context of specific safety problems or safety gaps);
- to measure the influence of various safety interventions, but not the stage or level of application of particular measures;
- to compare between different road traffic systems (e.g. countries, regions, etc).

Development procedure for SPIs in certain safety areas

A common procedure for the development of SPIs was used to make the process more consistent across different road safety areas [19]. When SPIs are developed for a certain safety area, they should reflect the factors contributing to road crashes and injuries and characterize the scope of the problem identified. Developing SPIs should begin with a definition of the problem, i.e. the operational conditions of the road traffic system which are unsafe and lead to crashes and injuries as the 'worst case', and continue with a conversion of this information into a measurable variable. Under normal circumstances the optimal indicator for an issue is a direct indicator. However, often this cannot be realized, for example due to a lack of appropriate data. In that case indirect variables which describe the problem can be used as indirect indicators. If this is not possible either, the problem can be divided into several sub-problems and the indicator can be established for each of those. When the measurement is possible only for outputs of certain road safety measures, the limitations of this consideration should be clearly stated. This way, the difference between the ideal and the realizable SPIs is recognized.

According to [11], a large number of potential safety performance indicators is possible. However, not all of them are equally important. In general, the importance of a safety performance indicator can be assessed in terms of the strength of its relationship with accident or injury occurrence, whether it makes a major contribution to accidents and whether it can be influenced by road safety measures. A natural starting point would be the main behavioural indicators: speeding, drink-driving and seat-belt use. Thereafter, quality indicators concerning other components of the road traffic system such as road networks and vehicle fleets should be added as well as the post-crash treatment of road accident victims. Thus, seven problem areas were selected for the development of SPIs which are:

- Alcohol and drugs;
- Speed;
- (use of) Protective systems;
- (use of) Daytime running lights (DRL);
- Vehicles (passive safety);
- Roads;
- Trauma management.

To note, the seven areas are related to different levels of the road safety system. While *Alcohol and drugs* and *Speed* address road safety problems (or unsafe system conditions), the areas *DRL* and *Protective systems* reflect countermeasures which are intended to prevent accidents or to reduce accident consequences, respectively. The areas *Roads* and *Vehicles* are related to a wide area of road safety interventions, whereas *Alcohol* or *Speeds* are related to human behaviour as the cause of accidents. The area *Trauma management* presents an additional category of road safety issues focusing on tertiary injury prevention.

For each of these areas, SPIs were developed according to the above described common development procedure [19]. A detailed development of the SPIs for each problem area used a common structure as follows. First, based on a literature survey, a relationship between the problem area and road safety is defined, and the scope of accident/ injury reduction potential associated with better system's operational conditions (e.g. lower speeding, better passive vehicle safety) is stated. Second, characteristics of the system's performance, user behaviour, etc are analyzed in order to select those of them which can be measured and quantified. Using a literature survey, examples of SPIs in use by different bodies (countries, authorities) and/ or research studies, are considered. Third, the SPI concept in a specific problem area is developed, which stems from the structure of the area considered, the available experiences with measurements of similar characteristics, etc.

Finally, a questionnaire was distributed to the 27 member states (plus Norway and Switzerland) to collect the data available and to reflect the current measurement practices, in each one of the predefined safety areas. The originally developed SPIs were verified for their applicability based on the responses to these questionnaires [30].

Applying the developed SPIs in Europe

Once the SPIs were defined, the data for estimating SPIs were collected by means of a series of questionnaires distributed to the countries, via national experts. The process was iterative and included multiple data verifications. The data problems and intermediate results were discussed with the national experts, both at the general meetings (twice a year) and through direct correspondence. Depending on the area, the data were collected and the SPIs estimated for the years 2003-2007, which enabled to perform country comparisons. The whole set of comparisons can be found in [35-36].

Furthermore, for the areas of alcohol, speed and roads, additional pilot studies were executed to further investigate the applicability of the SPIs suggested [29,31,38].

Recognizing that a prerequisite for using SPIs for monitoring and comparisons lies in sufficient data quality where the data should also be collected in a harmonised fashion, an SPI Manual [18] was developed. This Manual demonstrates existing practices for the underlying data measurements, provides good practice examples (when available), and details the procedures which are necessary to collect and process the required data for the estimation of the SPIs' set on a national level. It was assumed that the SPI Manual would assist countries in setting up or upgrading their SPI data collection systems.

RESULTS

Table 1 gives an overview of the SPIs developed for each one of the predefined areas. Following are the major considerations which led to the SPIs selected, in each area, accompanied by examples of country comparisons that were carried out using the data received from the 29 European countries.

Alcohol and drugs

The use of alcohol and drugs by road users, especially drivers of motor vehicles, increases the risk of a road crash considerably [9]. Consequently, most countries ban the use of these psycho-active substances among drivers, or set low legal limits for blood alcohol and drug concentrations. The SPIs for alcohol and drugs should show the state of alcohol and drug use as a risk factor in a country at a certain time. They can be used by road safety authorities and politicians in assessing the needs for and the effects of countermeasures such as legislation, enforcement, education and publicity.

Theoretically, the 'ideal' SPI of the alcohol and drug related road toll would be the prevalence and concentration of impairing substances among the general road user population. In practice, however, major methodological problems are associated with this SPI, even when used within one country and when including only alcohol as a psychoactive substance. One judicial impediment is the fact that in some major European countries (i.e., Great Britain and Germany) mandatory random testing of road users by the police is prevented by law. In other countries, random breath testing for alcohol is allowed, but random testing for drugs other than alcohol is not allowed. Problems will only increase when all EU countries will have to agree on a common sampling and testing protocol and when psychoactive substances other than alcohol will have to be included. Moreover, rather large samples are required to obtain reliable results, because in most countries the prevalence of psychoactive substances in the general driver population is likely to be low in statistical terms.

When the 'ideal' SPI cannot be realized, a more feasible SPI is needed. Such an SPI could be: the number and percentage of severe and fatal injuries resulting from road accidents involving at least one active road user impaired by psychoactive substance (concentration above a predetermined impairment threshold). This SPI can be implemented step by step, starting with the blood alcohol concentration (BAC) of fatally injured drivers and gradually extending to a larger set of psychoactive substances used by all active road users involved in severe injury crashes. The successive requirements for each step would be:

- Mandatory blood testing of all fatally injured drivers, for a fixed set of psychoactive substances.
- Mandatory blood testing of all drivers involved in fatal accidents, for a fixed set of psychoactive substances (whether or not the drivers are killed or injured).
- Mandatory blood testing of all active road users involved in fatal accidents, for a fixed set of psychoactive substances.
- Extension of procedures mentioned under 1-3 to severe injury accidents, starting with testing severely injured drivers and resulting in testing all active road users involved in severe injury accidents.

Presently some countries have reached step 1 or 2 above, whereas others have no relevant data [19]. Therefore, for current evaluations, two supplementing SPIs were proposed (see Table 1), which reflect the percentage of fatalities resulting from accidents involving at least one driver impaired by alcohol or by drug, respectively. It must be noted that crash data lie at the basis of these indicators that should in general be avoided when developing SPIs. However, as explained above, an ideal indicator that would be based on random breath testing meanwhile seems unrealizable for most countries.

Country comparisons - example

The SPI for alcohol was estimated for 26 countries of a total of 29 (Fig.2), where only Ireland, Malta and Luxembourg could not provide data. Since most countries provide data for drivers above the national legal BAC limit, where the limit may vary among the countries, it was reasonable to group countries according to the legal limit and rank them within these groups. As seen from Fig. 2 the BAC limit varies from 0.0 to 0.8 g/l BAC, where the values for the alcohol SPI vary from 3.4% in the Czech Republic to 72.2% in Italy.

A basic question here is whether the variation between the countries' scores is real or due to methodological reasons. Sørensen et al [31] studied the quality of the above data in five selected countries (Czech Republic, Austria, France, Sweden, and Norway) and concluded that there was reason to believe that the data used as basis for the calculation of the alcohol SPI might be incomplete in some countries. Strict harmonization of definitions, data collection and data analysis methods is required to make the SPI results comparable.

Only seven countries could provide data for the calculation of the SPI for drugs [36]. The percentage of fatalities resulting from crashes of at least one impaired driver varied from 0.9% in Belgium to 11.8% in Spain, although the latter was likely to be overestimated. In general, the figures were not really comparable between the countries, since only Spain and Switzerland listed the drugs tested for, i.e. both medical and illegal drugs.

Speed

Speed is one of the main causes of crashes and has a direct influence on crash severity [26]. According to different estimates [26,33], speed was found to be a major contributory factor in around 10% of all crashes and in about 30% of fatal crashes. Due to the massive character of speeding and inappropriate speeds, managing drivers' speed has a high safety potential. The relation between speed and crashes is abundantly studied in the literature. In their review of speed-crash related studies, Aarts & Van Schagen [1] concluded that the safety effect of a particular change in speed depends on the type and, thus, characteristics of the road. They estimated from the studies reviewed that an average speed change of 1 km/h leads, depending on road type, to 2%-4% change in injury accidents and to 3%-8% change in fatal accidents. Different countermeasures have to be combined to reach the objective of speed reduction, including actions on speed limits, road design, drivers' education, enforcement, and in-car technologies [26].

Since traffic populations and traffic circumstances differ between road type, time of day (day vs. night), day of week (weekdays vs. weekend days), it is necessary to have different speed SPIs for different road types and different reference time periods. International comparisons of speeding performances should be carried out for roads of similar category and for which similar methods of speed data collection are used.

The speeds that were found as most relevant for comparison purposes were spot speeds measured at various locations on the road network during periods when traffic can be considered free-flowing [19]. Therefore, the speed SPIs suggested for application were the free-flow mean speed, the standard deviation, the 85th percentile speed and the percentage of drivers exceeding the speed limit (by 0 and 10 km/h), which were segregated by road type, vehicle type, period of day and period of the week (week-days and weekends).

The speed data is collected by a speed survey. Setting up the survey, the issues to be considered are: which locations are suitable for speed measurement; which road types should be considered; how to sample the set of measuring locations; which time periods are valid for speed measurements; and how to determine speeds for different types of vehicles on the basis of identified requirements for speed measurements [18]. These recommendations were tested in two pilot studies carried out in Belgium and Spain and found to be applicable when a new speed data collection system is established [29].

Country comparisons - example

Speed has systematically been monitored in many EU countries. However, the possibility of international comparison is limited, mostly due to the variability in the ways the countries conduct their surveys [36]. In addition, road classifications and speed limits vary between countries, making the comparisons more difficult. Despite the restrictions, a comparison of speeds on motorways is feasible, accounting for relative similarity of road and traffic conditions on these road types across Europe.

Fig. 3 shows the average speeds of light vehicles on motorways for the year 2007, compared with the average speeds five years earlier in 2002. The different speed limits are indicated by different colours. For Denmark and the Netherlands, only monthly indicators were available, thus the annual figures reported on Fig. 3 are simple averages of relevant monthly figures but not official indicators reported by Danish or Dutch authorities.

Unsurprisingly, the motorways with the highest speed limits show the highest average speeds. The average speed on these motorways is lower than the speed limit. On the other hand, in countries with the lowest speed limits, the average speed is (slightly) higher than the speed limit. The worst result in terms of differential between average speed and the speed limit is encountered on Denmark's 110 km/h motorways, where the average speed exceeds the speed limit by more than 5 km/h. In contrast, the average speed in the Czech Republic is impressively low in comparison with the speed limit but this indicator, similarly to the Swiss one, includes all types of vehicles and not only light vehicles.

The SPI “percentage of speed limit offenders” presented in [36] confirmed that a high proportion of drivers do not comply with the legal speed limit. The SPI values were highest in the UK and in Finland, with more than half of the light vehicles exceeding the speed limit in the UK. The lowest percentages of offenders were observed in Ireland and Switzerland despite the fact that the speed limit is lower in these countries than in France and Austria. A lower speed limit is thus not always synonymous to a higher proportion of offenders.

Protective systems

The protective systems play a vital role in protecting the most vulnerable parts of human body, i.e. belly and head, against injury and considerably increasing the likelihood of surviving in serious crashes. The protective systems considered concern two groups of road users: motor vehicle occupants and two-wheelers, and include: seat belts, child restraint systems and helmets. Nowadays, the use of seat belts is mandatory in all European countries, but the law continues to be violated by a certain proportion of traffic participants. In contrast, the legislation related to the use of safety helmets by pedal cyclists and moped riders varies considerably among countries and the rate of their presence in traffic comes mostly from users’ awareness and country culture [19].

The use of seat belts is the single most effective means of reducing fatal and non-fatal injuries in motor vehicle crashes. It reduces the death rate of car occupants by at least 40% [11]. According to [34], child restraint seats are 71% effective in reducing fatalities among children under the age of 5, but misuse and improper use is a critical problem both in the US and EU [19]. Studies on the effect of motorcycle and moped helmets were carried out mostly in the 1980s and concluded that the risk of death is more than halved if a helmet is worn [19]. The effectiveness of helmets for cyclists has been studied for decades, and they are known to reduce the risk of severe head injury by about one-third. The use of seatbelts has regularly been assessed in several European countries since 1970 (e.g. Switzerland, France, Germany) parallel to the introduction of seatbelt-related regulations.

In this domain, a direct SPI was defined as the day-time wearing rate of protective systems in traffic, according to the system's types (see Table 1). The SPIs directly measure the use of protective systems which mitigate crash consequences for the road users' health.

The SPIs are estimated by means of a national observation survey, in which the measurements should preferably be classified according to main road types, such as motorways, other rural roads and urban roads. The values for major road types should then be aggregated into one indicator (of each type) for the country. International or regional comparisons of protective systems' use rates are important tools for recognizing deficiencies, setting priorities and stimulating efforts at the political level [18].

Country comparisons – example

Fig.4 shows the daytime seat-belt wearing rates in front seats of cars and small vans, in different countries. In the case when disaggregated values for driver and front-seat passenger were available, weighting coefficients of 0.35 for front-seat passenger and 0.65 for the driver are applied, to produce a combined estimate. One can see that for Germany, France and Malta the wearing rates are highest (over 95%), while for Belgium, Czech Republic, Estonia, Spain, Hungary and Poland, the rates are lowest (below 75%). Similar figures for the other SPIs on the use of protective systems can be found in [36].

Daytime running lights

Many crashes occur because road users do not notice each other in time or do not notice each other at all. Use of daytime running lights (DRL) for cars in all light conditions is intended to reduce the number of multi-party crashes by increasing the cars' visibility and making them easier to notice [9]. The problem of visibility is especially pertinent to mopeds and motorcycles. Moreover, the use of DRL could increase the reliability of the estimation of other motorized road users' moving direction, distance and speed [19].

A study commissioned by the EC involved a meta-analysis of 41 studies of the DRL effect for cars and 16 studies of the effect for motorcycles [8]. This study showed that for cars DRL reduced the number of daytime injury crashes by 3-12% and for motorcycles by 5-10%. An EC consultation paper [5] stated that the life-saving potential of DRL to be in the order of 3 to 5% of the annual number of road fatalities in the EU. In 2006, 14 Member States had mandatory rules on the use of DRL in force, with different requirements [5]. However, the use of DRL indicators was not common in the road safety decision-making practice [19].

The DRL SPI is defined as the percentage of vehicles using daytime running lights. (It is considered as an example of indirect and measure-oriented SPI because a direct measurement of vehicle visibility is impossible). An estimate of this percentage should be based on a national observation survey of the DRL use. The total SPI value is estimated for the whole sample of vehicles that were observed in the country. Additional values are calculated for different road categories and for different vehicle types. The road categories to be considered are: motorways, rural roads, urban roads, and DRL-roads, where the term 'DRL-roads' denotes the road categories where the usage of DRL is obligatory. For example, in Hungary, DRL-roads are certain roads outside built-up areas. The vehicle types to be considered are: cars, heavy goods vehicles (including vans), motorcycles and mopeds [19].

The suggested set of DRL SPIs enables to estimate the DRL usage rates at the national level. It may serve as a background for both the purposes of countries' comparisons and along-time considerations of DRL-related issues. The background information on the DRL legislation is essential for a correct interpretation and comparison of the results. For example, comparing the countries' DRL usage rates it is reasonable to take into account whether the countries have a law/ regulation on obligatory use of DRL and if they do, for how long. Moreover, DRL usage rates cannot be interpreted practically in countries where the lights are switched on automatically. It was assumed that in the future, once the option of automatic DRL is introduced Europe-wide, the DRL SPIs would lose their importance.

Country comparisons - example

The DRL usage rates were considered for 11 countries, as presented in Table 2. In the countries where automatic DRL was already introduced a long time ago (e.g. Sweden, Norway), the DRL usage rate is close to 100%, according to expert estimates. In such countries monitoring the DRL usage rate as a behavioural SPI does not have practical implications any more. In Austria, Czech Republic, Estonia and Finland, the use of DRL is obligatory for all vehicle types, on all road types, and all year long. In Hungary, this is also the case, but only for roads outside urban areas. DRL is recommended in France, the Netherlands and Switzerland.

Table 2 shows that the DRL usage rates are highest in those countries and for those road types where the use of DRL is obligatory. Switzerland has the highest usage rate among those countries where DRL is not compulsory.

Passive vehicle safety

The passive vehicle safety SPIs relate to the level of protection offered by the vehicles which constitute the fleet in a country. Improvements in passive safety do not affect the occurrence of crashes, but help to minimise the consequences when they happen. Hakkert et al [19] distinguished two aspects of the unsafe operational conditions concerning vehicle fleet: (a) the presence of vehicles that will not protect the occupant well in a collision (lacking crashworthiness); (b) the presence of vehicles with an increased capacity to inflict injury (lacking compatibility).

With regard to the first aspect, EuroNCAP is widely used as an indicator of the crashworthiness of individual vehicles. Lie and Tingvall [22] reported that cars with a three- or four-star rating are approximately 30% safer, compared to cars with a two-star rating, and that there was a strong and consistent overall correlation between EuroNCAP scoring and risk of serious and fatal injury. Since only a share of vehicles is EuroNCAP-tested, it is also important to take vehicle age into account when assessing the crashworthiness of an entire fleet. There is ample evidence that newer cars are safer than older cars. For example, Frampton et al [15] used national casualty figures from the UK that showed an 18% decrease in fatalities in newer cars. Thus, the SPI proposed within SafetyNet to characterize the vehicle fleet crashworthiness was a combination of the average EuroNCAP score and the median age of passenger cars in the fleet.

The second aspect relates to the proportions of vehicles of different types and weights that make up the total fleet. The composition of the vehicle fleet gives an indication of the likely compatibility problems, which result from collisions between vehicles of different mass and/or geometry. These problems lead to well-recognised effects on occupant outcomes in crashes, with, typically, the occupants of smaller or lighter vehicles being more at risk from severe injuries [19]. The second vehicle SPI proposed within SafetyNet considers the composition of the vehicle fleet in each country in terms of percentages of motorised two-wheelers and heavy goods vehicles, assuming that higher shares of both types are associated with more severe accident outcomes.

Country comparisons - example

Developing the passive vehicle safety SPIs, the countries were asked to provide data containing the entire vehicle fleet database according to vehicle type, make, model and year of first registration, as it stood in 2003. For each country, a EuroNCAP score was attributed to eligible vehicles. An average figure was then calculated for each year and weighted by the number of vehicles present in the 2003 fleet from that year. An overall average EuroNCAP score was then awarded for each country and considered together with the median age of passenger cars in the fleet.

In Fig.5, the average EuroNCAP score is plotted against the median age of passenger cars in the fleet of different countries. Better safety performance would be a vehicle fleet which contains higher EuroNCAP scores and newer cars (upper right area). From the countries considered, Sweden, the UK and Belgium are the best performing countries with regards to the crashworthiness of passenger cars. Example of another vehicle SPI reflecting vehicle fleet compositions in the European countries can be found in [36].

Roads

The safety performance of the road transport system depends on the functionality of the network, homogeneity, and predictability of the road environment and the traffic involved. Besides, the road environment also has to be forgiving when an accident occurs. In order to develop suitable SPIs, quantitative relations between the road network, road design elements and road safety have to be known sufficiently well. Knowledge about these relations, however, is still lacking, although it is known that conflicts and related crashes can be prevented by choosing the right elements or facilities in the road network or individual roads. Based on these considerations, two SPIs were developed within SafetyNet: the road network SPI and the road design SPI.

The road network SPI assesses whether the 'right road' is in the 'right place'. The concept is based on the German guidelines for road categories [14]. The 'right road' is in the 'right place' in case the actual road category of a road is appropriate (from a safety point of view) given the urban centres that are connected by that road. The idea behind this concept is that the function and traffic volume of a road determine the minimal requirements that have to be met by that road in order to guarantee an acceptable level of safety, where the requirements are related to (preventing) different types of conflicts. Practically, in a country or region, the connections between selected urban centers are assessed by comparing the theoretically needed road category with the actual road category. The road network SPI is the percentage of appropriate actual road category length per theoretical road category, summarized by connections in the network considered. For more information on the calculation of this SPI see Weijermars et al [38].

The road design SPI determines the level of safety of the existing roads. This SPI is based on the EuroRAP Road Protection Score (RPS). The RPS is a measure for the protection that is provided in relation to three main accident types: run-off road, head-on impacts and severe impacts at intersections. EuroRAP designed a method to calculate the RPS for each road segment or route, expressed in one to four stars, depending on a number of road characteristics. For more information on EuroRAP RPS see Lynam et al [24]. The road design SPI proposed within SafetyNet is the distribution of the RPS scores for each road category [19].

Both road SPIs are quite complicated to estimate. Moreover, in general, data for calculating these SPIs are not readily available in most countries. To evaluate the SPI values and examine the applicability of the method, the road network SPI was estimated in a number of pilot countries, i.e. the Netherlands, Israel, Greece and Portugal [38,40]. The results showed that the road network SPI could be efficiently calculated in all countries, despite some differences in the data sources. In general, the estimated SPI scores were realistic and ranged from 81 to 94%, with the exception of Greece where the SPI was relatively lower (67%). However, there are some issues that need further research in order to further improve the SPI [40].

The road design SPI was applied to a Dutch case study [18]. From that case study it appeared to be possible to calculate the SPI if the EuroRAP RPS scores are available for each road section.

Trauma management

Trauma management refers to the system which is responsible for the medical treatment of injuries resulting from road crashes. It covers the initial medical treatment provided by Emergency Medical Services (EMS) at the scene of the crash and during the transportation to a permanent medical facility, and further medical treatment provided by permanent medical facilities (hospitals, trauma centres). There is a consensus in the professional literature that the appropriate management of road casualties following the crash is a critical determinant of both the chance of survival and, on survival, the quality of life [6,9,10]. Conversely, improper functioning of the post-crash care leads to more fatalities and severe injuries, which could be avoided.

In general, the international comparisons of the trauma management systems should be performed with caution due to a variety of definitions, legislations and systems, which are available for both the emergency and in-hospital trauma care, in different European countries. However, based on the best practice recommendations in the field of post-crash care [10], a number of features can be named which are definitely associated with better performance of the trauma management system. They are: shorter response time by EMS; higher competence level of the EMS staff; standardisation of the EMS vehicles; adequate hospital trauma care.

Based on the above considerations and accounting for the limited data available in different countries, a set of trauma management SPIs was developed [30,19]. It includes a list of indicators as presented in Table 1. The countries can be compared using selected trauma management SPIs, for instance by availability of the EMS stations, by availability and composition of the EMS medical staff, by availability and composition of the EMS transportation units, by characteristics of the EMS response time or by availability of trauma beds in permanent medical facilities [35-36]. Furthermore, a combined indicator was developed to measure a country's overall trauma management performance relative to other countries [17]. The combined indicator attributes each country to one of five levels of the trauma management system's performance such as: 'high', 'relatively high', 'medium', 'relatively low' or 'low'.

Country comparisons - example

A dataset with trauma management SPIs was created for 21 European countries [36]. Figure 6 shows, as an example, the number of emergency medical facilities per 100 km of road length and per 1000 citizens for different countries. From this figure can be seen that Germany is characterized by the highest density of the EMS stations per road length. The number of the EMS stations per population is high for Austria, Slovakia, Portugal, Finland, Norway and Estonia. Low values of both of these indicators were obtained for Greece, the Netherlands and Malta.

Country comparisons for other trauma management SPIs as well as the combined indicator values can be found in [36].

DISCUSSION

Safety performance indicators are measures that reflect the operational conditions of the road traffic system influencing the system's safety performance. Their purpose is to estimate the current safety conditions of different aspects of the road traffic system, to monitor the effect of safety interventions, and to compare the safety performance of different countries or regions.
Within the SafetyNet project, SPIs were developed for seven road safety-related areas: alcohol and drugs; speed; protective systems; daytime running lights; vehicles (passive safety); roads, and trauma management. The intention was to develop meaningful SPIs that, given the available data, could be widely applied within the EU, now and in the future. This turned out to be a complicated task, yet, was achieved with various degrees and nature of difficulty in different safety fields.

For the areas of protective systems and DRL use, reasonably good data are available in Europe and the SPIs suggested are straightforward. Concerning the usefulness of the protective systems' SPIs, a clear consensus exists among the European countries. However, as to the value of measurement of the DRL SPIs, some countries support it where others doubt that, indicating that in the future, where the majority of vehicle fleet will be equipped with automatic lights' switch-on, the issue will become irrelevant.

For the areas of speed behaviour and the use of alcohol and drugs, the development of SPIs suffered heavily from lack of data and other limitations. In the case of alcohol and drug use, legislative restrictions in some of the European countries, i.e. a lack of possibility to carry out roadside surveys, made it necessary to use crash-related data for the estimation of SPIs, that should normally be avoided when developing SPIs (as those are supposed to reflect the operational conditions of the system, prior to crash occurrences). But even then, for the SPIs based on crash data, data of sufficient quality are not readily available for some countries. As indicated by an in-depth study of Assum and Sorensen [2], there is a clear need to improve quality of the data used for the alcohol SPI. To enable meaningful across-country comparisons, the total number of drivers involved in fatal accidents, the number tested for alcohol and the number not tested, should be reported, in addition to the number of alcohol positive and negative drivers among those tested. For speed behaviour, the possibility of direct international comparisons is limited, due to variability in the ways the countries conduct their surveys as well as differences in road classifications and speed limits [19].

For passive vehicle safety, trauma management, but even more so for roads, completely new approaches had to be developed for the SPIs' estimation. For trauma management and passive vehicle safety it was possible to develop SPIs, as data were available for the majority of countries, for at least some of the SPIs. The data collection for estimating trauma management SPIs was not easy as in most European countries such data are not in use in road safety decision-making and thus, special efforts were required for the data collection, frequently including applications to medical authorities. Nevertheless, the SafetyNet project's practice demonstrated that data collection for estimating such SPIs is possible for the majority of countries.

For the area of roads, more efforts are required in the future for the estimation of comparable SPIs, where the results of the pilot studies [40] demonstrated that such a task is realizable. Moreover, recent progress with the distribution of the EuroRAP approach throughout the world (www.irap.org) strengthens the belief in the possibility of producing comparable road design SPIs in the future.

A number of European countries such as Finland, France, Sweden, Hungary, Switzerland, the Netherlands, the UK, have been carrying out systematic national behaviour surveys on selected road safety behaviours since the 1990s or even earlier. These countries have realised the importance and potential benefits of systematically monitoring road user behaviour and of creating SPIs. Repeated measurements are performed on a regular basis, which enables the assessment of traffic behaviour trends and of the impacts of countermeasures applied/ the advance of safety programmes. The most frequently covered areas in such surveys are speeds, drinking and driving, use of vehicle restraint systems. However, the available surveys were not necessarily influenced by the common rules suggested by the SafetyNet study. The authorities are usually reluctant to change and prefer to leave the comparability problems for those who attempt to carry out international comparisons. Thus, some adjustments of the surveys' frameworks and results were suggested in the SafetyNet reports [18-19].

Since the SafetyNet project was finished, further developments occurred as to SPIs' applicability. Promoting better road safety management and the Safe System approach, leading countries agreed that using safety performance indicators would reflect stronger commitment to ongoing monitoring and evaluation of safety interventions [27]. Meanwhile, the analysis of intermediate indicators for estimating the progress towards road safety targets is not a common practice yet where a consistent use of SPIs can be found in a few countries only, e.g. in Sweden [3].

In general, the European countries and international bodies came to a consensus as to the usefulness of safety performance indicators for country comparisons [4, 27, 28]. Recent publications of the Organisation for Economic Co-operation and Development, European Transport Safety Council (ETSC), and the EC include fugures with country comparisons as to the use of seat-belts in cars, helmets' use by motorcyclists, travel speeds, etc, together with legislative and safety management issues. Moreover, over the last years, ETSC led the Road Safety Performance Index (PIN) project promoting the European country comparisons in terms of safe road user behavious, road infrastructure and vehicles, beside various analyses of crash injury data [e.g. 13,21].

SPIs have been increasingly researched during the last years, with particular emphasis on methodological issues [2,20,32,37]. Further theoretical developments are required for better understanding of the relationship between SPIs as intermediate outcomes, and crashes and injuries as final outcomes of the system. Such questions were raised concerning SPIs in alcohol [2], trauma management [17] and other road safety fields. Moreover, due to the multidisciplinary character of road safety there is a rapid development of composite road safety indices [16,37,39], where SPIs are supposed to be taken into consideration in creating such a composite index.

The major bottleneck in the development and application of SPIs in Europe is the general lack of data of sufficient quality. To help the countries in setting up new data collection systems or in improving existing ones, the SPI Manual was developed [18]. This SPI Manual aims to assist countries in establishing the systems of data collection that are necessary for producing national SPIs in each of the predefined safety fields, and to make them comparable on a European level. It is recommended that the countries use this Manual as a basis for starting or improving the use of SPIs in their country. Following the project, some countries initiated establishing national observational surveys that rely on the SafetyNet rules [e.g.29]. High quality SPIs can serve as valuable tools in future knowledge- and data-driven policy-making in Europe. The SPIs concept developed in the SafetyNet can form a basis for future developments in this area.

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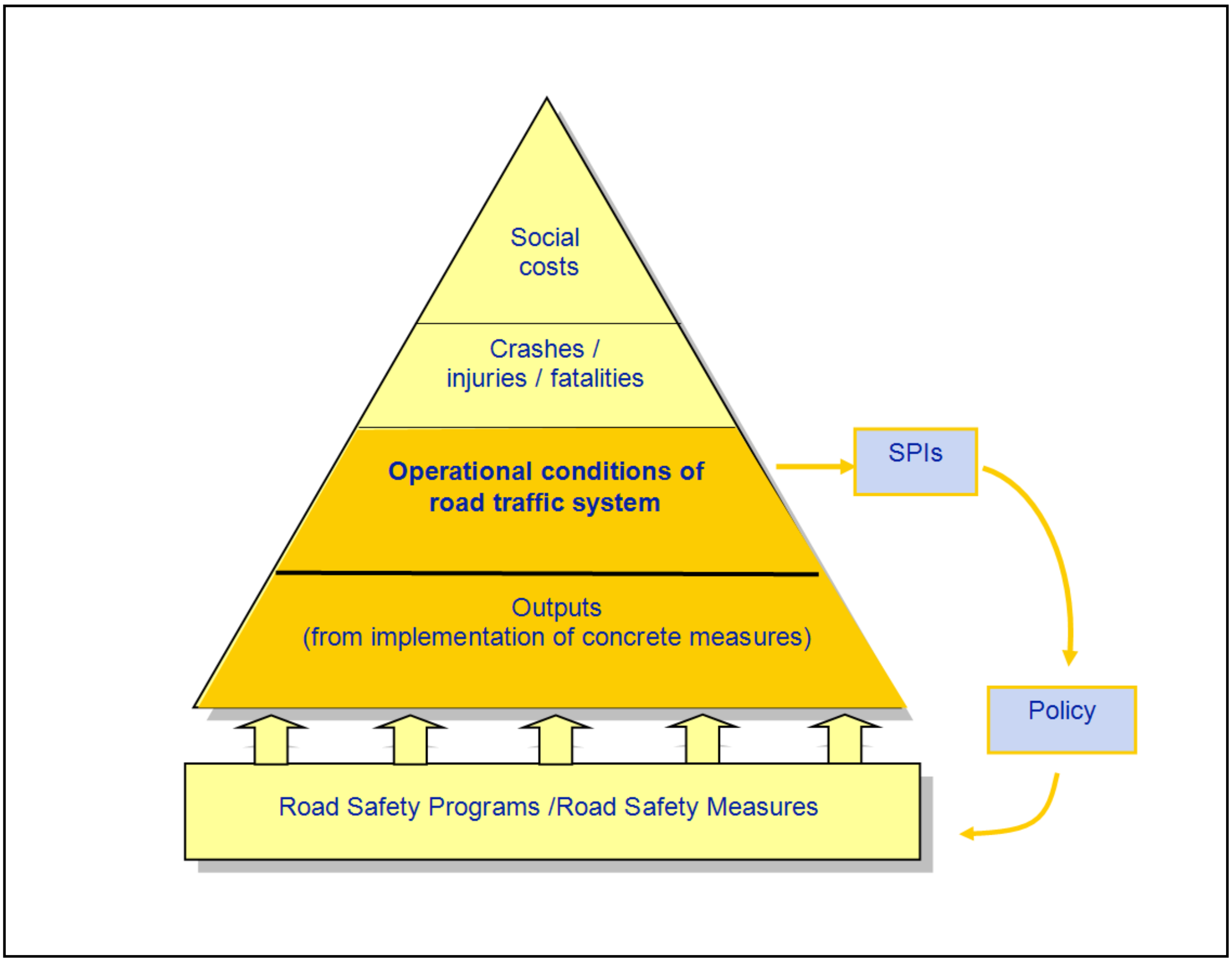
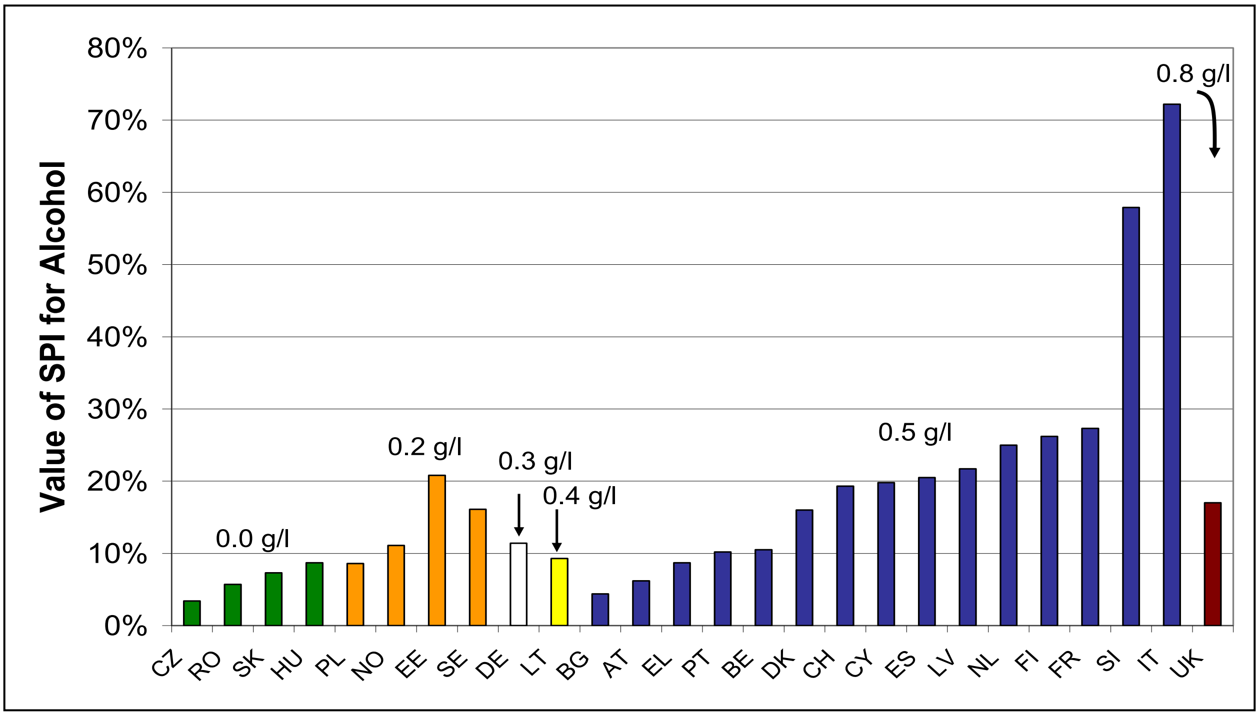
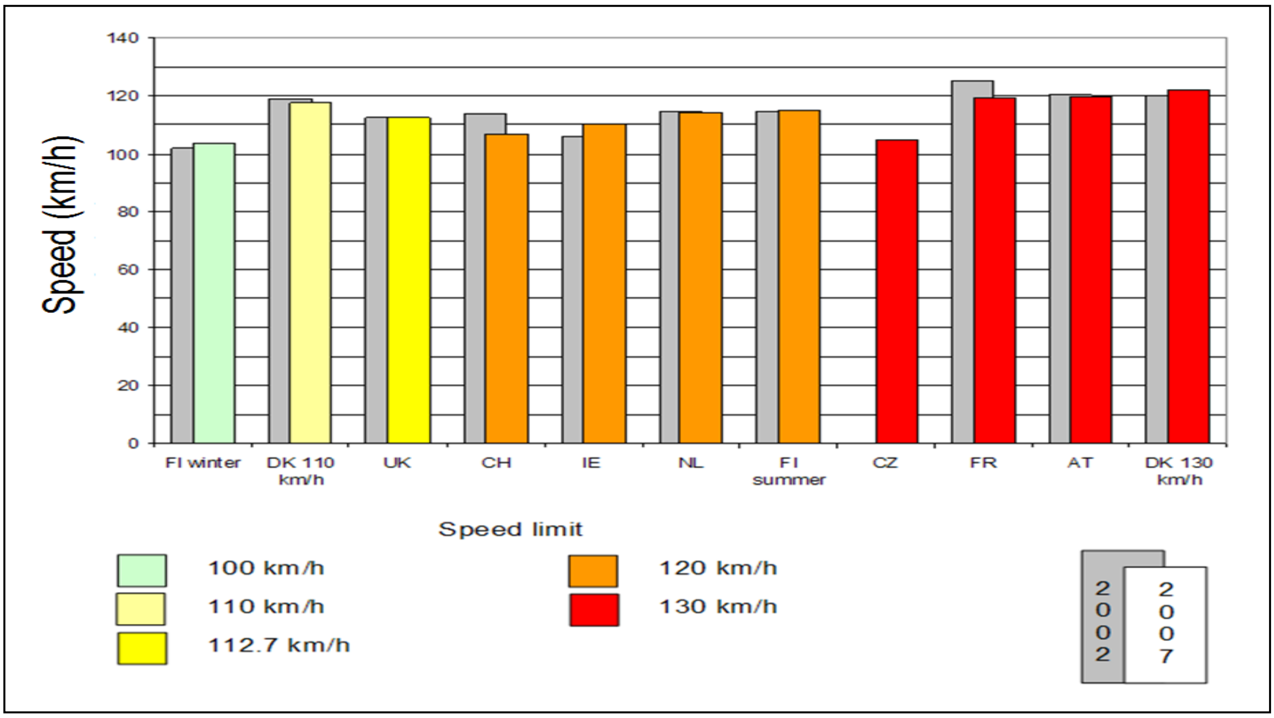


Fig. 1 Place of SPIs in safety management system. Adapted from [23] and [11]



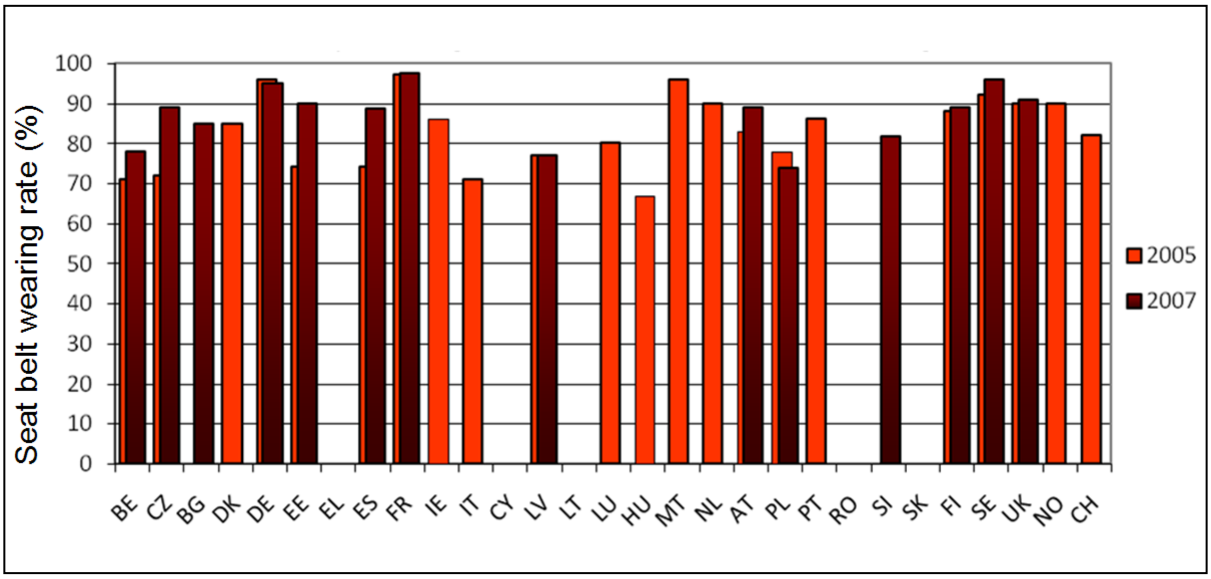
Colours indicate the same BAC legal limits.
For CZ, RO, PL, SE, LT, BG, PT and LV the figure is based on 2007 data, for BE, DE, EL, ES, FR, CY, AT, SI, SK, FI, UK and NO on 2006 data, for DK, EE, HU, NL and CH on 2005 data and for IT on 2004 data. Source: [36].

Fig. 2 Country comparison by the SPI for alcohol.



For CH, CZ, DK: all types of vehicles are considered. CZ, IE, AT, NL: figures from 2006. IE: speed limit in 2002 was 112.6 km/h (70 mph). DK: in 2002, the speed limit for all motorways was 110; since 2004 about 50% of the motorways have a new speed limit of 130 km/h. Source: [36].

Fig. 3 Average speed of light vehicles on motorways in 2007 (coloured) and 2002 (gray).



For LU: 2003; LV, MT: 2006; DK, DE, EE, IT, FR, PT, LU, CH: only driver wearing rates considered; FR: vans not included; IT, LV, MT, PL, PT does not fit fully to defined requirements. Source: [36].

Fig. 4 Daytime seat-belt wearing rate on front-seats of passenger cars and vans under 3.5 tons, in 2007 and 2005.

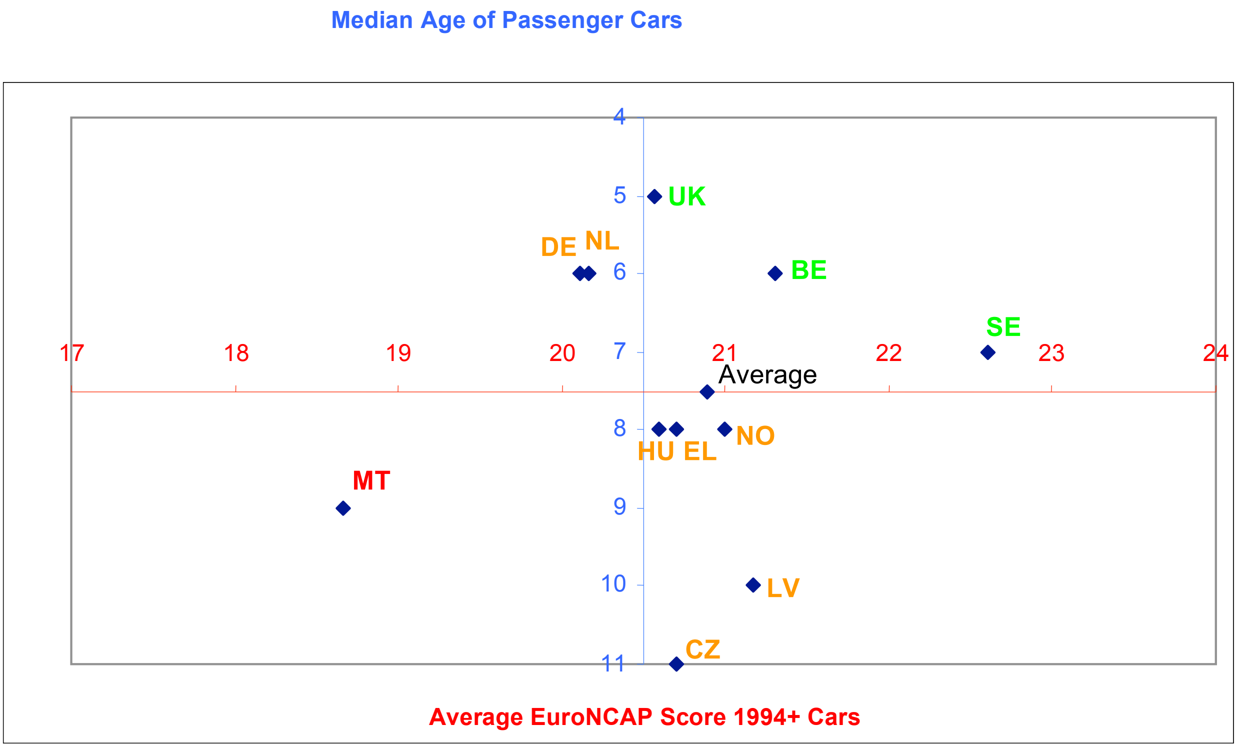


Fig. 5 Average EuroNCAP score (x-axis) and median age of passenger cars (y-axis) for different countries.

Source: [35]

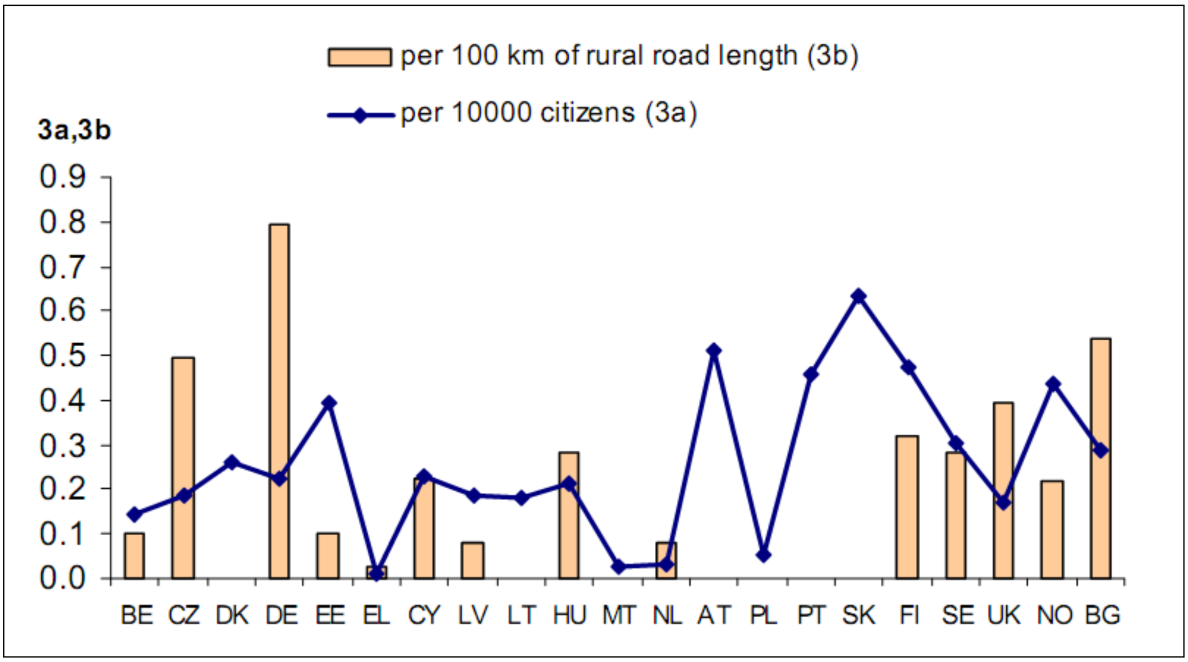


Fig. 6 Number of EMS stations per 10,000 citizens and per 100 km of rural road length.
Source: [36]

Table 1: SPIs developed for each safety area

Safety area	Developed indicators
Alcohol and drugs	Alcohol percentage of fatalities resulting from crashes involving at least one driver impaired by alcohol Drugs percentage of fatalities resulting from crashes involving at least one driver impaired by drugs other than alcohol
Speed	The mean speed, the 85th percentile speed, the percentage of speed limit offenders by road type, vehicle type, period of day (daytime, night)
Protective systems	Daytime wearing rates of seatbelts in front seats (passenger cars + vans /under 3.5 tons) in rear seats (passenger cars + vans /under 3.5 tons) by children under 12 years old (restraint systems use in passenger cars) in front seats (heavy goods vehicles + coaches /above 3.5 tons) Daytime wearing rates of safety helmets by cyclists, moped riders and motorcyclists
DRL	DRL usage rate in total, per road type, per vehicle type
Vehicles (passive safety)	The crashworthiness and median age of the passenger car fleet The vehicle fleet's composition: percentage of heavy goods vehicles and percentage of powered two-wheelers
Roads	Road network SPI percentage of appropriate actual road category length per theoretical road category Road design SPI EuroRAP Road Protection Scores per road category

Trauma management	Availability of Emergency Medical Services (EMS) stations number of EMS stations per 10,000 citizens and per 100 km length of rural public roads Availability and composition of EMS medical staff percentage of physicians and paramedics out of the total number of EMS staff number of EMS staff per 10,000 citizens Availability and composition of EMS transportation units percentage of Basic Life Support Units, Mobile Intensive Care Units and helicopters/planes out of the total number of EMS transportation units number of EMS transportation units per 10,000 citizens number of EMS transportation units per 100 km of total road length Characteristics of the EMS response time demand for EMS response time (min) percentage of EMS responses meeting the demand average response time of EMS (min) Availability of trauma beds in permanent medical facilities percentage of beds in trauma centres and trauma departments of hospitals out of the total trauma care beds total number of trauma care beds per 10,000 citizens

Table 2: DRL usage rates on different road types. Source: [36]

Country	Year	Motorways	Rural roads	Urban roads	DRL roads
Austria	2006	95%	97%	88%	93%
Czech Republic	2007	99%	99%	99%	99%
Estonia	2004	99%	100%	99%	99%
Latvia	2007	-	98%	98%	98%
France	2004	35%	24%	-	30%
Hungary	2005	95%	84%	5%	-
Switzerland	2004	51%	48%	46%	48%
Bulgaria	2007	95%	90%	90%	-
Poland	2007	100%	100%	100%	100%
Sweden	2007	100%	100%	100%	100%
Finland	2007	100%	100%	100%	100%