Deliverable D3.1: State of the art Report on Road Safety Performance Indicators

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1 Executive Summary

General

Road safety can be assessed in terms of the social costs of crashes and injuries. However, simply counting crashes or injuries is an imperfect indicator of the level of road safety. When crashes occur it is the “worst case scenario” of insecure operational conditions of road traffic. Work Package 3 of SafetyNet deals with Safety Performance Indicators (SPIs). A Safety Performance Indicator is any variable, which is used in addition to the figures of crashes or injuries to measure changes in the operational conditions of road traffic.
SPIs can give a more complete picture of the level of road safety and can detect the emergence of problems at an early stage, before these problems result in crashes. They use qualitative and quantitative information to help determine a road safety programmes’ success in achieving its objectives.

Goal

One of the main goals of SafetyNet WP3 is to develop a uniform methodology for measuring a coherent set of safety performance indicators in each of the 25 Member States and some non-EU Members. This report provides the first ideas from the WP3 team on this subject.
The SafetyNet team will move on to the other goals (offering technical assistance to some Member States that fail in producing the SPI data according to the developed uniform methodology & collecting current data on SPIs that meet the standards of the uniform methodology) at a later stage in the project.

Research areas

Work Package 3 of SafetyNet investigates SPIs in seven different road safety areas.

1. Alcohol & Drug use
2. Speeds
3. Protective systems
4. Daytime Running Lights
5. Vehicles
6. Roads
7. Trauma management

State of the art report

This report starts off with a description of the general methodology. Then, the report describes the state of the art in the seven research areas. Firstly, the theoretical backgrounds of each research area are given. Secondly, the first results from the questionnaire (that was sent to 27 countries: the 25 EU Member States, plus Switzerland and Norway) are presented. And thirdly, the first ideas on the details of the SPIs that could be used in the future are described.

Summary per task

Task 1: Alcohol & Drug use

Driving under the influence of alcohol and drugs is one of the most important factors increasing the risk of severe road crashes because impaired road users are likely to be reckless and to behave inadequately when a dangerous situation appears. Moreover, impaired road users may also be more vulnerable to physical impacts caused by collision. Better knowledge of the prevalence of alcohol and drugs among road users will contribute to the understanding of crash risk and to the need for counteraction, such as legislation, enforcement, and information. Task 1 concerns the development of Safety Performance Indicators for the use of alcohol and drugs in road traffic.

Somewhat less than half of the 27 countries indicated that they have data on alcohol prevalence among injured or killed drivers, and 4-6 countries have data on drug prevalence for such drivers. Based on these data, a SPI is proposed: the percentage of road users involved in fatal crashes and impaired by alcohol or drugs.

Data should be collected from the remaining countries to check to what extent using of the proposed SPIs in the future is possible. A detailed protocol for the SPI still has to be elaborated.

Task 2: Speeds

Driving speed is an important factor in road safety. Firstly, driving speed is directly related to crash severity. Secondly, driving speed is related to the risk of getting involved in a traffic crash. Thirdly, crash rate is not only related to absolute speed, but also to speed dispersion.

The collection of speed data is often initiated by other motives than road safety alone such as traffic management and planning. It is clear that collection of speed data can help decision makers in the field of road safety to monitor safety interventions on specific road types and to make specific comparisons to study factors relevant to safety.

From the 27 countries, 17 countries responded to the questionnaire, and from these 10 provided data to all items required. This probably indicates that information about speed data is not easily accessible at a centralized source.

Considering the desired properties of the speed SPI, we proposed a central tendency measure of the data and another considering its variability. The use of standardized average and/or median speed and absolute deviation will need further testing and validation across the set of countries, once the data is available, depending on levels of disaggregation and possible exposure variables. The issue of comparability may imply further adjustments in the suggested indicators, and the weighing procedures shall be validated.

Comparative assessment of road safety in a European countries and regions relies on a unified methodology for the measure of exposure, i.e. for the vehicle kilometres. The concept of speed SPIs has been inspired by the same philosophy and therefore shares the dependence on a valid and reliable methodology for exposure measurement.

Task 3: Protective systems

The human body is vulnerable and, during crashes, is exposed to immense forces leading to injury or death. Here, the protective systems available for all traffic participants (airbags and safety belts) play a very important role in protecting the most vulnerable parts of the human body. Availability and appropriate use of protective systems are therefore fundamental items in developing this SPI.

The rates of protective systems use vary significantly with age, sex and other socio-economical characteristics of their users. These argue for treating different road users group in order to understand the problem better and find out the general rate for the whole population. Moreover, subdividing wearing rates is important for the target group concerning information and education, and enforcement activities.

Based on current practices, a set of Safety Performance Indicators has been proposed. The indicators for task 3 are the wearing and usage rates of protective systems by road users in road traffic. As the importance of particular devices derives mostly from their safety potential at national and European level, they may vary significantly among each other. The choice of the appropriate ones should be based on sophisticated research knowledge and not only on the accessibility and measurability.

The total number of chosen SPIs might be further reconsidered, as it's quite high and requires a broad knowledge of the traffic situation and detailed survey information, which might recently not have been available for many countries.

Task 4: Daytime Running Lights

Many traffic crashes occur because road users do not notice each other in time or do not notice each other at all. This is true not only for traffic crashes in the dark but for traffic crashes in daylight as well. Vehicle visibility is therefore one of the factors which affects the number of crashes. The basic idea in developing the SPI for Daytime Running Lights (DRL) is the relation between the level of use of DRL and the size of the effect on safety (The daytime visibility of motor vehicles cannot be measured directly but the level of use of DRL can).

An indicator for DRL can thus be considered an indirect indicator for visibility. For this sub-problem an appropriate indicator was developed. The indicator is based on the relation between the level of the use of the DRL and the effect on multiparty daytime crashes (MPDA). The indicator has been identified on the basis of literature survey and the current practice.

Task 5: Vehicles

The SPI that this task is concerned with relates to the level of protection afforded by the vehicle fleet in each EU Member State. Where system failures lead to a crash, the potential of the vehicle itself to prevent (or indeed cause) injuries can determine whether the outcome is a fatality or something much less serious. The insecure operational condition could be defined as the presence within the fleet of a number of vehicles, which will not protect the occupant well

in a collision. What is needed is a measurable variable that will tell us what this number is, and what proportion of the fleet it represents in each Member State.
It was possible to find an indirect indicator for measuring passive safety. More modern European vehicle fleets that have state-of-the-art vehicle designs should theoretically result in reduced casualty levels. It is generally recognised that cars designed to meet EuroNCAP test procedures are more robust and therefore offer better protection to vehicle occupants in comparison to vehicles that were designed before the development of the EuroNCAP test programme.
Of the 27 countries, 14 have sent a complete answer. For at least 8 countries it will be possible to assign a EuroNCAP rating to the vehicle fleet in order to calculate a performance indicator for vehicles (passive safety). For at least 6 others it will be possible to calculate a simple general indicator based on either fleet mix, vehicle age or both. It is proposed that a pilot study be performed using a country whose data can be used for all three of these SPIs, and on that basis the three indicators can be compared for their accuracy and usefulness.

Task 6: Roads

Infrastructure layout and design has a strong impact on the safety performance of the road transport system. Many ongoing practises in infrastructure research apply sampling of casualty data for safety assessment. In addition, crash prevention can be improved by early assessments of safety hazards e.g. by monitoring the physical appearance of the road environment and the operational conditions of traffic. This is what Safety Performance Indicators (SPI) dedicated to roads are aiming at.
A methodology for network description and (safety related) road classification has been developed, that is assumed to be suitable for international harmonisation. As a basis, the functionality of a connection (consisting out of one or more road types) and a systematic combination of present (safety related) characteristics has been used.
At this stage of the project only a few countries are able to provide requested data on both connection types, road types and other road design characteristics. Part of this may be due to the fact that no complete systematic information on the performance of the roads is routinely available in the majority of countries. Hence, special efforts will need to be undertaken to collect these data.
Based on the present country responses it can be stated that the suggested sets of SPIs seem to be realisable and promising for comparing road networks and road design in the Member States.

Task 7: Trauma management

The better the post-crash care by emergency and medical services, the greater the chance of survival and, on survival, the quality of life. The same goes for the opposite: Improper functioning of the post-crash care system leads to more fatalities and severe injuries, which could be avoided. The term "Trauma Management" refers to the system, which is responsible for the medical treatment of injuries resulting from road crashes.
No complete systematic information on the performance of the trauma care system and on outcomes of road crash survivors is routinely available in the majority of countries. Hence, special efforts will need to be undertaken to collect

this data. The state and forms of the post crash trauma care differ among the countries. These differences should be accounted for in estimating SPIs.
Only some countries are able to provide detailed data on the performance of different steps of the post crash chain of care. The majority of countries may provide only general figures on the availability of services but not on the characteristics of their functioning. Therefore, two sets of SPIs should be recommended for the application: an initial (reduced) set, which can be filled in by the majority of countries today, and an extended set, which should be available in the future, with the perspective to provide a comprehensive picture of the performance of the trauma management system in the country.
Based on the SPIs estimation for the countries, which answered the questionnaire, we conclude that the suggested sets of SPIs seem realisable and definitely promising for comparing the trauma management systems in different countries. The primary data should be collected and the trauma management SPIs be updated on an annual/bi-annual basis.

Conclusion

This report is the first Deliverable from SafetyNet WP3. In the next months, this report will be updated with new data from the questionnaire, and the SPIs will be elaborated. This will eventually result in a common framework of SPIs: tools that can be used for monitoring road safety in Europe.

2 Introduction

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3 Methodology

Markus Lerner, BASt

3.1 Explanation of Safety Performance Indicators

Before the explanation of Safety Performance Indicators the methodological fundamentals of SPI must be defined with the aim of supplying a uniform and common methodology for different actual required SPI as well as for possible further indicators.
This should ensure the reliability and validity of SPI, increase the acceptance and application of SPI and at last get transparency for the potential users of SPI.

3.1.1 Road Safety System

The model of a road safety system shown in the ETSC-report [2] already allocated SPI on the level of intermediate outcomes. In general the model is measure-oriented and follows in its logic from the bottom upwards. As the target of SPI is to give a picture of the road safety level and not of the road safety work or the implementation stage of a specific countermeasure, the dependence on interventions lessens the potential of the model presented in the ETSC-report.
In order to reach independence from interventions and to understand the interrelations of the different levels one has to go the opposite direction and modify or better specify the model.
The model is not necessarily tied to the form of a pyramid. In general it could also be presented as a chain of blocks, but the pyramid illustrates the interdependencies of the system. The size (width) of a level indicates not the extent in means of financial resources, but the quantity of factors influencing the next higher level. Illustration as a causation chain leaves out hierarchical questions but wouldn't change the mode of operation in general.

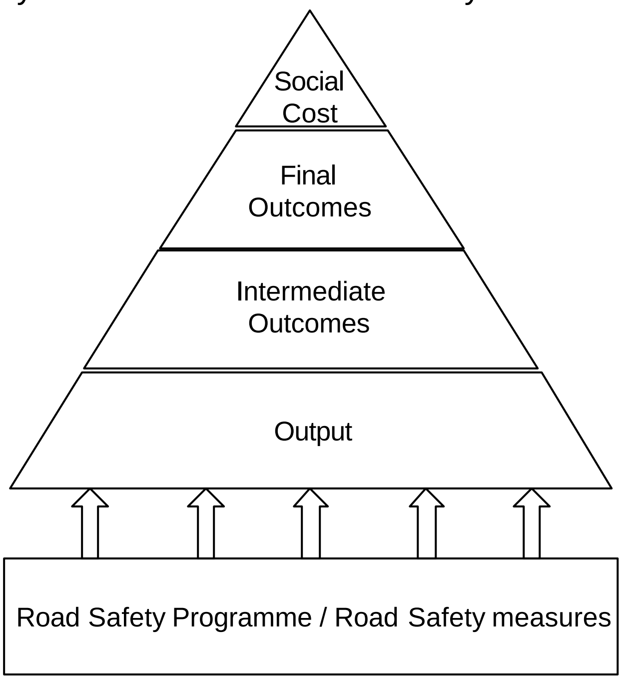

Figure 3-1: Levels in road safety

Social cost - at the top level - is the monetary outcome resulting from the final or physical outcomes at the level below (crashes/fatalities/casualties). The next deeper level is the so-called intermediate outcome. One could say crashes are the „worst case“ of insecure operational conditions of road traffic. Following this top-down logic, it is more convenient to describe intermediate outcomes as operational conditions to reach independence from interventions. Independent from any intervention, insecure operational conditions of road traffic are responsible for the occurrence of crashes and/or injuries. Insecure operational conditions of road traffic are not necessarily pre-crash related (crash prevention), they can also be crash related (injury prevention in case of a crash) or post-crash related (injury-treatment in case of injuries).

Road safety interventions aim to influence these insecure operational conditions. Therefore it is necessary to understand the process that leads to crashes in order to identify insecure operational conditions of road traffic. Only if the problem can be identified, can interventions be selected.

Following the model, the insecure operational conditions of road traffic are affected by the output (e.g. speed cameras) from a road safety programme in general or from a special road safety measure (e.g. speed enforcement). The output of a measure is the physical deliverable of the measure, whereas the outcome of the measure should be seen in improving the operational conditions (e.g. speeding), which will eventually result in crash or injury reduction. And this should ultimately reduce finally the social cost.

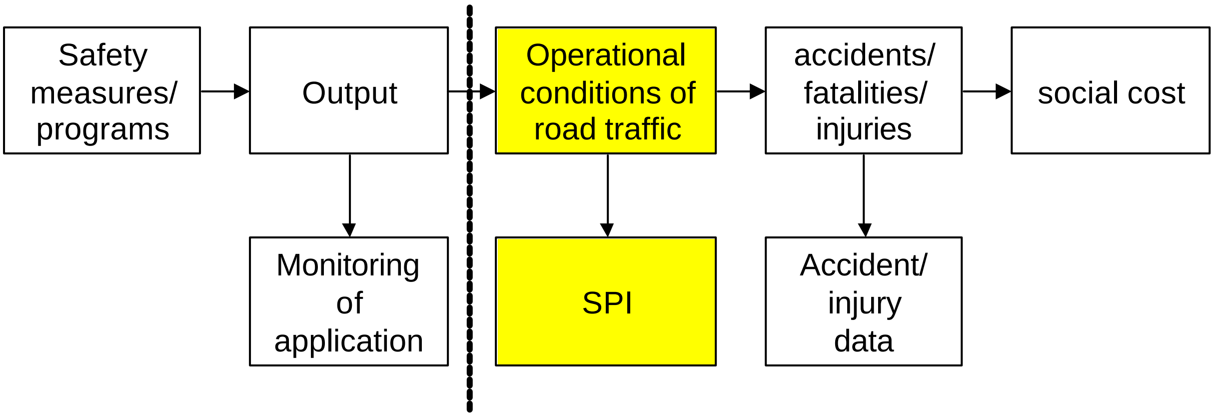

Figure 3-2: Interrelations in road safety policy

3.1.2 Problem orientation versus intervention orientation

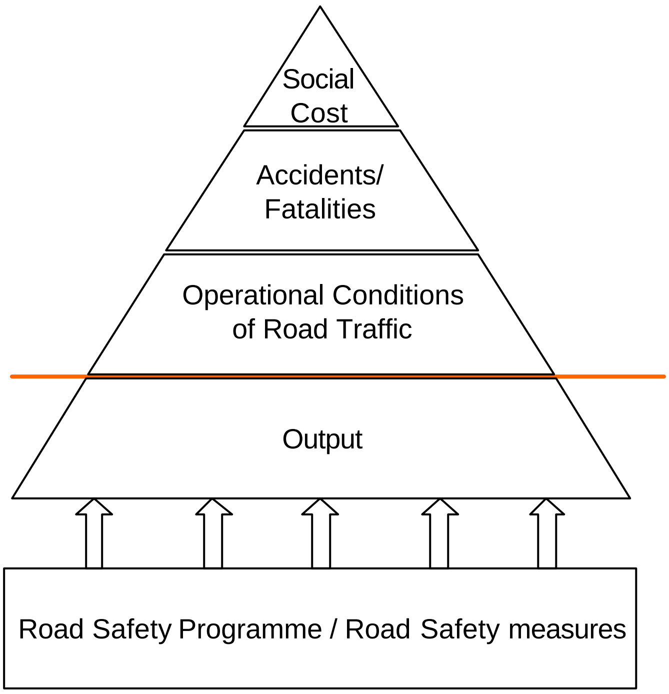

Figure 3-3: Levels in road safety

As described above, this system is divided into different areas referring to different key issues. The elements in the top (Social cost, final outcomes and operational conditions) are problem related, while the elements below (Programme/measures and output) are intervention related. Several interrelations between the different levels can be identified. The most important interrelation is located between crashes and operational conditions of road traffic on the one hand, and between operational conditions and the selected countermeasures on the other hand. This becomes obvious in the following examples:

Example 1a:
Crash analysis identified social cost due to speeding crashes. Speeding crashes are the „worst case“ of speeding behaviour. Speeding behaviour doesn‘t lead to a crash in every case. So, what‘s the problem? One could say „inappropriate speeds“. One possible intervention could be speed enforcement. The output in that case would be e.g. speed cameras, which should affect „inappropriate speeds“. If the problem definition is correct and the intervention is effective, the intervention would reduce crashes and consequently social cost.

Example 1b:
Identified is the same problem. Another possible intervention could be “Intelligent Speed Adaptation” (ISA). Depending on some details of application, the number of ISA equipped vehicles would increase more or less quick, which would also affect „inappropriate speed“.
The example shows, that one problem can be forced by different interventions. Both affect the identified insecure operational conditions of road traffic, but in different ways.

Social Cost	Social cost due to speeding crashes	
Final Outcome	Speeding crashes	
Operational Conditions	Inappropriate Speed	
Output	Speed cameras	ISA equipped vehicles
Road Safety Programme	Enforcement	ISA
	Example 1a	Example 1b

Figure 3-4: Example Speed

What does that mean for SPI:
The example of speeding crashes shows, that the indicator ideally should react on every change in the system. If this is not guaranteed, the indicator would possibly react on speed enforcement measures, but not on ISA.
To react on all possible interventions the SPI must ideally be completely independent from any road safety measure. Therefore the SPI must be exogenous and the search for an optimal indicator has to go top-down.
Independence from interventions means, the SPI must describe the scope of the identified problem instead of the scale of any intervention intended to force the problem. Speaking in the model of the road safety system this means, that the SPI must be searched above this dividing line.

The relevant interrelation therefore is the validity of the problem.
The first and the key information that is needed is an exact definition of the problem. It must be defined, which operational conditions of road traffic are insecure and leading to crashes or fatalities as the „worst case".
The second step is to put this key information into action, to convert it into a measurable variable: How can the identified problem - the insecure operational conditions - be measured?

3.1.3 Definition of SPI

Reflecting the theoretical considerations about the mode of operation of the road safety system, the following definition of SPI can be given:

Safety Performance Indicators are the measures (indicators), reflecting those operational conditions of the road traffic system, which influence the system's safety performance.
The purpose of SPI 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).*

3.1.4 Quality levels of SPI

Three quality levels of SPI can be identified:

1. Direct measurement of the identified insecure operational conditions is possible. This means that the indicator will cover the complete scope of the problem, which means the indicator will react on all possible interventions.
2. Direct measurement of the identified problem is not possible. The identified problem can be seen as a latent variable. Describing the latent variable by several indirect variables as indicators will bridge this gap. This will be the normal case and the solution would be to search for several indicators - but

also independent from interventions - describing the latent variable. Finding valid indicators to describe the latent variable would also achieve the objective.

3. Considering the expected availability of data and assessing the reasonable effort for data acquisition, in some cases it would be difficult or even impossible to do that. In this case one would have to cross the dividing line between operational conditions of road traffic and interventions, which are intended to improve the operational conditions. Doing this means to give up independence from interventions and to bridge the gap by reducing or splitting the problem.

The above-mentioned example "speeding crashes" illustrates how this could work:
If it is impossible - or better for practical reasons inadequate - to measure the problem „inappropriate speeds", it is thinkable to split the problem in several parts:
1. Inappropriate speed below the speed limit
2. Exceeding speed limits
It is a split because of the growing dependence on the interventions and it must be justified in which way the indication of only one part of the problem is suitable or not. The stronger the dependence on interventions, the more spliced the problem is.

In case the definition of the SPI is not independent from interventions one should formulate high demands on the bridge in order not to loose transparency on what is measured. The more an indicator is related to the area of interventions - means the more the problem is spliced - the more the following questions are gaining in importance:

- What should the intervention, that the SPI refers to, affect? What is the problem?
- What should be achieved? How should the problem be solved?
- How should the intervention work?
- Which part of the problem is not covered?
- Is one indicator sufficient and why or are there more needed?
- On which interventions does the indicator not react? Justify why, although this indicator is suitable?

For the elaboration and derivation of a suitable set of SPIs, which is intended to describe the development and improvement of the most important problems of road safety in Europe, it is necessary to follow a common methodology, not least to give a general methodological framework for further indicators.
Providing politicians, decision-makers, and the public with information about the level of road safety in European countries requires ensuring the reliability and validity of SPI used as well as making transparent what is measured. A common methodological framework can serve this end and thus increase the acceptance and application of SPI.

3.2 Putting into action

In the SafetyNet WP3 a set of seven SPIs has already been selected on the basis of the ETSC report 'Transport Safety Performance Indicators' (2001). Seven domains for indicators have been defined:

1. Alcohol and drug-use
2. Speeds
3. Protective systems
4. Daytime running lights (DRL)
5. Vehicles
6. Roads
7. Trauma management

On closer examination, these seven domains are related to different levels of the road safety system. While "alcohol" and "speeds" address problems of road safety, "protection systems", "DRL" and "trauma management" are addressed to countermeasures intended to prevent crashes or to lower crash consequences. The domains "roads" and "vehicles" are related to a wide area of a road safety issue, like for example "alcohol" or "speeds" are related to the area of human behaviour as cause of crashes.

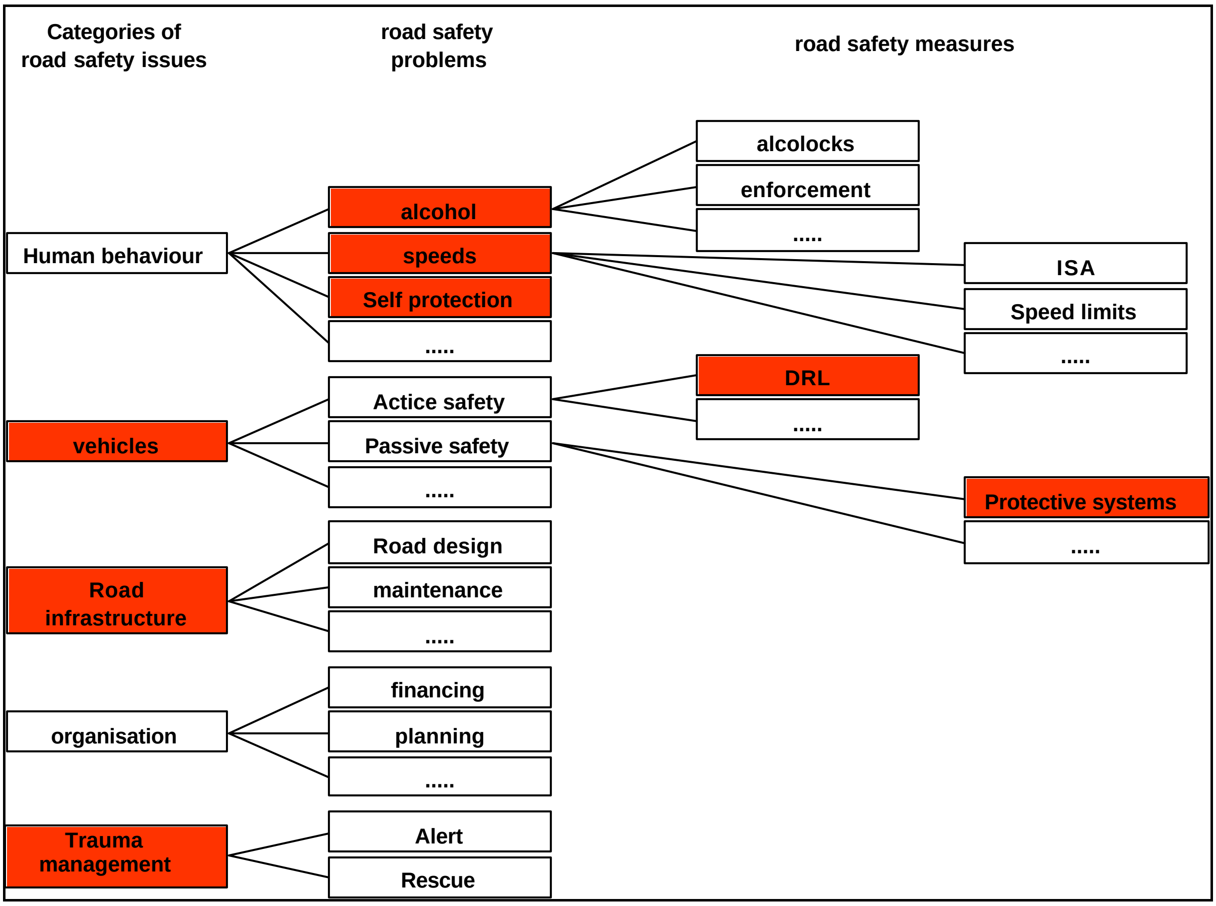

Figure 3-5: Safety Performance Indicators

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Project co-financed by the European Commission, Directorate-General Transport and Energy

Developing a coherent set of Safety Performance Indicators should start at the same level of hierarchy. Therefore it is necessary and useful to examine for every domain of SPI selected the same procedure of elaboration.
The instrument for this elaboration procedure is the step-sheet, which ensures consistency of the process and with that the use of a uniform methodology for the development of SPI. The step-sheets can be found at the respective chapters as annexes.

3.3 Aspects of interpretation of SPI

Relevant topics to take into account will be the comparability of SPI

- in time
- between countries

For specific issues and problems it could also be relevant to differentiate between e.g. different age groups, regions, road categories or road user.

Key information therefore will be the influence of several external factors and their effect and power on the development of SPI, e.g.:

- change in population structure
- change in road traffic laws
- traffic volumes
- mobility behaviour or modal split.

3.4 Literature

Leena Luukkanen (2003): Safety Management System and Transport Safety Performance Indicators in Finland.

ETSC (2001): Transport Safety Performance Indicators. ETSC Brussels 2001.

Ghazwan al-Haji (2003): ROAD SAFETY DEVELOPMENT INDEX (RSDI). 16th ICTCT workshop, 2003

National Road Safety Committee, Land Transport Safety Authority, New Zealand (2000): Road Safety Strategy 2010, A consultation document. October 2000.

4 Alcohol and drug use

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4.1 Introduction

Drivers under the influence (DUI) of alcohol and drugs have a considerably higher accident risk than drivers not under the influence. Although there is a need for more knowledge about which substances in what concentrations or doses and in combinations create the highest risks, there is no doubt that the accident risk increases with increasing blood alcohol concentration.

4.1.1 Alcohol, drugs and accident risk

Driving under the influence (DUI) of alcohol and drugs is one of the most important factors increasing the risk of severe road accidents because impaired road users are likely to be reckless and to behave inadequately when a dangerous situation appears. Moreover, impaired road users may also be more vulnerable to physical impacts caused by collision. Consequently, a large share of more severe road accidents is normally associated with drivers using alcohol and/or drugs. Mathijssen (2005) finds that "35% of serious injuries among drivers in the Tilburg police district were associated with self-administered alcohol and/or illegal drugs".

For alcohol there is a long research tradition from Borkenstein (1964) and before showing that accident risk increases with the drivers' blood alcohol concentration (BAC). Drugs are more varied than alcohol, legal and illegal, alone or in combination with alcohol or with other drugs, in medical or abuse doses etc. A recent meta-analysis of accident risks related to impairment (Vaa 2003) shows that alcoholism or abuse of alcohol has a relative risk of 2.0, i.e. twice as high accident risk as sober drivers. Medicinal drugs assumed to be used as prescribed has a relative risk of 1.49, whereas drugs assumed to be abused has a relative risk of 1.96. Mathijssen (2005, p.17) finds that "extremely high relative risks were associated with the use of morphine/heroin-only and with the combination of drugs and BAC-levels above 0.8 g/l." Moreover, he finds that "strongly increased injury risks were also associated with the combined used of several drugs, and with the combination of drugs and a BAC between 0.2 and 0.8 g/l" and "A moderately increased risk of serious road injury was associated with a BAC-level between 0.5 and 0.8 g/l. At higher BAC-levels, the relative injury risk increased more or less exponentially". Drummer et al (2004) find higher accident responsibility rates for drivers with high BAC or high cannabis concentrations or combinations of alcohol and cannabis.

Countermeasures against impaired driving, especially against the use of alcohol while driving, are quite effective in reducing road accidents. Elvik & Vaa (2004, p. 977; p. 983) find that the introduction of drink-driving, per-se laws or BAC limits reduce fatal road accidents by 26 per cent and that the enforcement of such laws reduces fatal accidents by 9 per cent.

Better knowledge of the prevalence of alcohol and drugs among road users in general as well as among road users involved in road accidents will contribute to the understanding of accident risk and to the need for counteraction, such as legislation, enforcement, and information.

4.1.2 National Responses

Nineteen countries have responded to the questionnaire (of the 27 countries that we sent the questionnaire). Table 4.1 shows the availability of data concerning alcohol and drugs in the general driver population and among injured and killed drivers:

	Alcohol (number of countries where information is available)	**Drugs** (number of countries where information is available)
General drivers	11	3
Injured drivers	13	4
Killed drivers	14	6

Table 4-1: Availability of data on alcohol and drugs among general, injured and killed drivers. Number of countries.

The table indicates that we should concentrate on alcohol as a start. Data for alcohol are available for the whole year for 9 countries and for part of the year for 2 countries. Eight countries have a legal limit of 0.5 (BAC, Blood Alcohol Content) and three countries have a limit of 0.2 and one country has a limit of 0.8. Eight countries have more detailed data than above/below the legal limit, which means that comparison should be possible, even if other factors such as road types vary between countries.

Several countries have obviously misunderstood some of the questions. Most of the misunderstandings seem to be due to language problems or to the construction of the questionnaire.

Judging the quality of the data from the questionnaire is difficult. Examples of data would be needed to judge the quality and to assess the possibility of merging. Merging is, however, likely to be time-consuming and require a lot of reorganisation of data.

4.1.3 Resulting Difficulties

The main difficulty is the number of countries that have not responded to the questionnaire. Of the 27 countries included in the study 14 have data on alcohol for killed drivers and 13 for injured drivers. For drugs 6 countries have data on killed drivers and 4 countries for injured drivers. 11 of 29 countries have data on alcohol prevalence in the general driver population and only 3 have data on drug prevalence.

4.2 Building up Indicators

It is possible to find several direct indicators for alcohol and drug use. The most relevant indicators would be (cf. the diagram on p.24)

> *the percentage of the general road user population impaired by alcohol and/or drugs*

and

> *the proportion of injuries and fatalities resulting from accidents involving at least one impaired active road user.*

Defining SPIs for alcohol and drugs is not difficult, but the lack of data is the problem. The lack of data cannot be solved by indirect indicators or dividing the problem.

Collecting data on alcohol and drug use in the general road user population is costly and difficult. Moreover, demanding breath or blood specimens for drugs from the general road user population without suspicion is not allowed in most countries. In some countries random breath testing for alcohol of motor vehicle drivers is carried out, but in other countries, like Germany and the UK, even random breath testing of motor vehicle drivers is not allowed. Voluntary testing is possible, but may be invalid, because the prevalence of drugs and alcohol may be lower than the non response rate. Consequently, the prevalence of alcohol and drugs among the active road users involved in on-the-spot fatal accidents was chosen as the most valid and practical indicator. Only on-the-spot fatal accidents were chosen, because the definition of fatal accidents varies between countries, from victims dead on the spot to victims dead within 30 days after the accident. Moreover, collecting blood specimens for drug analyses if the victims die several days after the accident, does not make sense, and the only possible way would be to demand specimens from all severe personal-injury accidents.

4.3 Questionnaire

Even if alcohol and drugs may seem a limited and simple problem for which to create SPIs, detailed information on the data required is necessary. Consequently, the questions had to be asked in detail, and this is why this part of the questionnaire became long. In the first questionnaire only questions of availability of data were asked rather than asking for the data themselves.
The questionnaire did not ask for data about impairment of pedestrians and cyclists involved in fatal crashes, nor for drivers involved, but not injured or killed. Consequently, the survey does not show whether such data exist.

4.4 Searching for Appropriate Indicators

Indicators can be constructed for alcohol prevalence for killed and injured drivers for about half the countries. Drug prevalence data for killed and injured drivers exist in 6 and 4 countries respectively. There is a question, however, whether alcohol data for killed and injured drivers are representative or only for drivers suspected for drinking and driving. In the latter case the prevalence will be overestimated.

Even if prevalence data are collected by police or health authorities, the data collection plan should be made in collaboration between researchers and authorities to ensure representativeness of the results.

It is in principle impossible to say whether countries which have not answered, have data or not, but it is most likely that these countries do not have data. If so, quite a lot of countries would have to establish new data collection routines. Establishing such routines in reasonably short time, will require great interest and pressure from top national authorities.

A schematic representation of the possible and chosen SPIs can be found in section 4.8.2.

4.5 Further Proceedings

Based on the idea of what data would be present, and what legislation would allow in the EU countries, the following realistically applicable SPI for alcohol and drug used is proposed (cf. the diagram on p.24):

> *The percentage of on-the-spot fatalities resulting from crashes involving at least one impaired active road user, with substance concentrations above predetermined impairment threshold, for a standard set of psychoactive substances.*

Active road users are all road user categories except passengers (so: drivers, riders or pedestrians). For practical reasons only crashes where a person is dead on the spot can be included. Impairment should be measured by blood samples taken from all active road users involved in such crashes. These blood samples should be analysed for alcohol, amphetamines, benzodiazapines, cannabis, cocaine, and opiates. Results should be published as the percentage of motor vehicle drivers, cyclists and pedestrians involved in fatal (on the spot) crashes impaired by the above substances, i.e. alcohol alone, BAC>0.5 per mil, one or more of the above drugs and alcohol and drugs in combination. Deeper analyses should be possible on drivers of different kinds of motor vehicles, and on concentrations and combinations of the substances.

The discussion about the optimal SPI for alcohol and drug used continued only after the questionnaire was submitted to the country authorities. Consequently, a new, but much shorter questionnaire than the first one will have to be sent to all countries, asking for the data required.

4.6 Conclusions

Somewhat less than half of the 27 countries indicated that they have data on alcohol prevalence among injured or killed drivers, and 4-6 countries have data on drug prevalence for such drivers. However, a different SPI was chosen than decided on by the time the questionnaire was made. Therefore, after the submission of the first questionnaire, a new questionnaire should be sent to all 27 countries to collect data. After the data collection, an assessment of the data quality should be made to check to what extent the construction of the proposed SPIs is possible. A detailed protocol has to be elaborated to ensure comparability of methods of analysis.

4.7 Annexes

4.7.1 Step-sheet

0	Level 0	Describe:
	Key information: Exact definition of the problem; which operational conditions of road traffic are insecure and leading to crashes or fatalities as the „worst case“	Drivers under the influence (DUI) of alcohol and drugs have considerably higher accident risk than drivers who are not under the influence. Although there is a need for more knowledge about which substances in what concentrations or doses and in combinations create the highest risks, there is no doubt that the accident risk increases with increasing blood alcohol concentration (BAC) and concentration of some drugs in motor vehicle drivers. This fact is shown by the much higher prevalence of alcohol among killed drivers than among the general driver population.

1	Level 1	
a	Direct measurement possible?	**Yes** (Go to 1b)
b	How can the identified problem - the insecure operational conditions - be measured?	The ideal SPIs would the prevalence of alcohol and drugs in different concentrations and combinations for all road users except passengers – road users in general as well as among the injured and killed road users. Random roadside surveys of the general driver population are the best way to measure DUI. It can also be measured by self-reporting in opinion polls, but this method is much less reliable. Prevalence of alcohol and drugs among killed and injured road users is another important

		indicator. Ideally, the prevalence both among the general road user population and among accident-involved road users should be known, as the two together will show the increased crash risk. To make the SPIs as simple as possible, only road users involved in on-the-spot fatal accidents will be included. Blood samples should be taken from all active road users involved in on-the-spot fatal road accidents. The blood samples should be analysed to show the prevalence of relevant drugs in each road user category.
		⇩
		a) Query of availability. Some countries have annual data on some of the relevant drugs for drivers. Other countries have some data and other countries have no data at all. To what extent these data are available, is shown in chapter 4.8.3 of this report. However, a new questionnaire asking for alcohol and drug prevalence for active road users involved in on-the-spot fatal road accidents will have to be submitted to all 27 countries.

2	**Level 2**	
a	Are there suitable indirect indicators to describe the latent variable?	**No**

3	**Level 3**	
a	Can the problem (level 0) be divided into sub-problems to be handled?	**Yes** (Go to 3b) The problem may be divided into rough categories of concentrations of alcohol, prescribed doses of prescription drugs, abuse of prescription drugs, and the use of illicit drugs. However, the division into sub-problems does not solve the problem of missing data.
b	The following questions have to be answered to explain the extend of the SPI referring to the problem (level 0):	
	To which interventions is the indicator related?	This SPI is mainly related to legislation and enforcement, but also to information and education activities.
	What should the intervention affect?	The prevalence of alcohol and drugs among road users involved in fatal crashes
	What should be achieved? How should the problem be	Lower prevalence – preferably zero for some substances and consequently fewer accidents

	solved?	with impaired road users. Strict legislation and enforcement combined with information campaigns. Prevalence of alcohol could also be reduced by installing alcolocks in all motor vehicles.
	How should the intervention work?	Adequate legislation, increased enforcement and information.
	Which part of the problem is not covered?	Some drivers are likely to disregard any rule no matter what the risk of getting caught is. These drivers are extremely difficult to avoid, but technology may contribute. An ignition interlock that can only be activated by a valid driver's licence could reduce recidivsm of drivers who have lost their licence.
	To which interventions does the indicator not react? Justify why this indicator can still be used.	Although there are a lot of possible interventions to which the indicator will not react, the indicators will react to sufficient, effective interventions such as increased enforcement.
	Is one indicator sufficient and why, or do we need more?	More - prevalence of alcohol and certain drugs in at least three road user categories, drivers of motor vehicles, cyclists and pedestrians involved in fatal crashes.
		⇩
		a) Query of availability. b) If it is predictable, that the data performing this indicator wouldn't be available, go to 4

4	Level 4	
a		Direct measurements possible on level 1.

4.7.2 Diagram

(See next page)

DUI (Driving Under the Influence)

Problem: alcohol and other psychoactive substances (illegal and medicinal drugs) induce increased crash risk

SPI

Derived SPIs

Proportion of material damage, injuries and fatalities resulting from accidents involving at least one impaired active road user

Active road user = driver, rider or pedestrian

Proportion of injuries and fatalities resulting from accidents involving at least one impaired active road user

Proportion of fatalities resulting from accidents involving at least one impaired active road user

Proportion of active road users impaired by alcohol and/or other psychoactive substances involved in fatal accidents

Proportion of impaired active road users involved in on-the-spot fatal accidents

Proportion of active road users involved in on-the-spot fatal accidents, with substance concentrations above predetermined impairment threshold, for a standard set of psychoactive substances

Proportion of on-the-spot fatalities resulting from accidents involving at least one impaired active road user

Proportion of on-the-spot fatalities resulting from crashes involving at least one impaired active road user, with substance concentrations above predetermined impairment threshold, for a standard set of psychoactive substances

Proportion of active road users impaired by alcohol and/or other psychoactive substance, by degree of impairment

Proportion of car drivers impaired by alcohol and/or other psychoactive substance, by degree of impairment

Proportion of car drivers impaired by alcohol and/or other psychoactive substance, by degree of impairment, in selected periods and /or in selected regions

If the general driving population is tested, the **degree of impairment** should be taken into account, since the crash risk increases with increased impairment.

Formula

A basic assumption here is that the ratio of on-the-spot fatalities and all fatalities is the same irrespective of impairment. In other words, the total amount of fatalities related to impairment (f_{imptot}) can be calculated by taking the on-the-spot fatalities related to impairment and by multiplying it with the above mentioned ratio:

$$f_{imptot} = f_{impc} \times \frac{f_{tot}}{f_c}$$

Although *SPI1a* only uses the on-the-spot fatalities, the above implies that it is equal to the ratio of the *total* amount a fatalities related to impairment and the *total* amount of fatalities irrespective of impairment.

$$SPI\,1a = \frac{f_{impc}}{f_c}$$ **(preferred)**

Alternatively,

$$SPI1b = f_{impc} \times \frac{f_{tot}}{f_c} \times \frac{1}{vkm}$$ **or**

$$SPI1c = f_{impc} \times \frac{f_{tot}}{f_c} \times \frac{1}{p}$$

SPI1a, SPI1b, SPI1c
Preferred (*SPI1a*) and two alternative Safety Performance Indicators (*SPI1b and SPI1c*)

f_{impc}
Number of on-the-spot fatalities resulting from accidents involving at least one impaired active road user, with substance concentrations above predetermined impairment threshold, for a standard set of psychoactive substances

f_c
Number of on-the-spot fatalities

f_{tot}
Total number of fatalities

vkm
Vehicle kilometres travelled (per 100 million km)

p

Primary Data

At all fatal crashes, assessment of:

- Psychoactive substance use by all active road users involved

General Data

- Impairment thresholds (per substance and for substances in combination)*
- Exposition measure:
  - Vehicle kilometres travelled, or
  - Total population
- Total number of on-the-spot fatalities
- Total number of fatalities

* substances to be included: (short term) alcohol; (long term) benzodiazepines, cannabis, cocaine, (met)amphetamines, opiates

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4.7.3 Usability of Safety Performance Indicators (SPI) of task 1

Country	Is the SPI realisable for this country? (yes/no/partly)	For what period (e.g. annually) can the SPI be determined?	Comments/Restrictions
Belgium	Partly		Alcohol for killed drivers
Cyprus	Partly		Alcohol for killed and injured drivers
Czech Republic	Partly		Alcohol for killed and injured drivers
Denmark	Partly		Alcohol for killed and injured drivers
Germany	Partly		Alcohol and drugs for killed and injured drivers
Greece	Partly		Alcohol for killed and injured drivers
Spain	Partly		Alcohol for killed drivers
Estonia	Yes		Alcohol and drugs for killed and injured drivers
France	Partly		Alcohol for killed and injured drivers
Hungary	Partly		Alcohol for killed drivers
Ireland			No answer
Italy			No answer
Latvia	Partly		Alcohol for killed and injured drivers
Lithuania			No answer
Luxembourg			No answer
Malta	No		
Netherlands			No answer The task 1 group knows that certain relevant data exist in the Netherlands
Austria	Partly		Alcohol for killed and injured drivers
Poland	Partly		Alcohol for killed and injured drivers
Portugal	Partly		Alcohol and drugs for injured drivers. Only drugs for killed drivers (Mistake in answer?)
Slovakia			No answer
Slovenia			No answer
Finland			No answer
Sweden	Partly		Alcohol for killed drivers
United Kingdom	Partly		Alcohol and drugs for killed drivers, only alcohol for injured drivers
Norway	Partly		Alcohol and drugs for killed and injured drivers
Switzerland	Partly		Alcohol and drugs for killed and injured drivers

4.8 References

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5 Speeds

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5.1 Introduction

This chapter addresses the question which SPIs in the area of speed should be selected and which issues play a role in comparing and validating these SPIs. The chapter is arranged as follows. In the introduction (5.1) we describe general theoretical, methodological, and practical matters with regard to speed measurement. Section 5.2 focuses on the choice of appropriate SPIs in the area of speed. The results of a European survey on speed measurement in Europe are presented in section 5.3. In section 5.4 we discuss possible difficulties in obtaining valid SPIs and ways to proceed. Finally section 5.5 closes with general conclusions and recommendations.

This first section presents a general orientation on the use of speed data for generating Safety Performance Indicators. In the next paragraph we first describe a stepwise process for arriving at SPIs (5.1.1). The knowledge about the relation between speed and crashes is described in section 5.1.2. Next we generally describe how speed data are often used for policies (5.1.3). Possible standards for quality of speed data are mentioned in section 5.1.4. Existing systems of speed measurement in Europe are described in section 5.1.5.

5.1.1 Stepwise process for arriving at Speed SPIs

The process to arrive at reliable and valid Safety Performance Indicators has a number of steps:

1. To derive from the research literature the main indicators of safety performance
2. To select a group of roads that are indicative of mean speed and speed development for all roads of that type in the country
3. To select a way of reducing speed data from that group of roads to one or two indicators that may be compared in a standardized way with parameters from roads in other countries
4. To select a group of comparable roads in other countries
5. To identify possible traffic and road circumstances that may differ between countries and that may affect the speed-crash rate relation (even when comparable roads are being chosen), enabling decisions as to place different countries in different comparison blocks.
6. To validate the Safety Performance Indicators by modelling speed-crash relation for different groups of countries.

5.1.2 Knowledge from the literature

Recently Aarts and Van Schagen (2005) reviewed the literature on the relation between speed and crash frequency. Based on this review this section discusses the relation between speed and crashes.

Driving speed is an important factor in road safety. Firstly, driving speed (actually: impact speed) is directly related to crash *severity*. This relation is based on the kinetic energy that is released during a collision. The amount of kinetic energy depends on the masses of the colliding objects and the square of their (relative) velocity.

Secondly, driving speed is related to the *risk* of getting involved in a traffic crash. Theoretically, the relation between speed and crash rate is much more complex than the relation between speed and crash severity, because there are many potentially interacting physical and psychological factors. First of all, higher speeds leave drivers less time to react to changes in their environment than lower speeds. Second, stopping distances are larger at high driving speeds than at low driving speeds and manoeuvrability is reduced.

As Aarts and Van Schagen (2005) point out, the speed-crash rate relation is further complicated by the fact that crash rate is not only related to absolute speed, but also to speed dispersion. If vehicles in the same lane travel at different speeds, the probability of an encounter is larger than if they drive at similar speeds (e.g. Hauer, 1971; see also Elvik et al., 2004).

The majority of the speed-crash studies looked at absolute speed, either at individual vehicle level or at road section level. Respectively, they found evidence for an exponential function and a power function between speed and crash rate. Other studies looked at speed variance and found evidence that this is also an important factor in determining crash rate. Recent evidence for the effects of speed variance was only found at road section level. At individual vehicle level, the evidence is, as yet, inconclusive. A number of recent studies explored the interaction between the speed-crash rate relation and road and traffic characteristics. According to Aarts and Van Schagen (2005), the results show very consistently that crash rate increases faster with an increase in speed on minor roads than on major roads. At a more detailed level, lane width, junction density, and traffic flow were found to affect the relation between speed and crash rate.

According to the Aarts and Van Schagen review some recent studies demonstrate that on roads designed for higher speed (e.g. (semi-)rural roads and motorways), crash rate rises less sharp with an increase in speed than on roads designed for lower speeds (e.g. urban roads). Aarts and Van Schagen interpret this finding to be a result of to the amount of traffic interaction and traffic composition on these types of road. Roads that are designed for high speed are mostly characterized by wider lanes, fewer junctions, and sometimes even physically separated driving lanes to reduce encounters with obstacles

and other traffic. Aarts and Van Schagen also cite empirical evidence that these factors indeed affect the relation between speed and crash rate (e.g. Baruya, 1998). Baruya found that not only wide lanes and low junction density, but also low traffic flows greatly reduce the increase of crash rate with increasing speed. Thus it is clear that external factors such as road and traffic characteristics influence the relation between speed and crash rate. The possible effect of other factors, such as the effect of weather, obstacle density along roads, traffic composition, and 24-hour fluctuations in traffic flow, has not yet been quantified by good empirical results. These issues may be examined in future research.
Related to road characteristics is the design speed. Design speed discrepancies have been found to be important for speed and crash rate. Garber and Gadiraju (1989), for example, found that roads with a design speed of approximately 10 km/h higher or lower than the speed limit had the lowest crash rates. Another design speed-related issue that may be relevant for the relation between speed and crash rate is the concept of longitudinal design consistency.

5.1.3 The use of speed data for policy purposes

The collection of speed data is often initiated by other motives than road safety alone such as traffic management and planning. In practice, monitoring vehicle volumes and speeds are used in traffic demand and road maintenance forecasts. It is clear that collection of speed data can help decision makers in the field of road safety to monitor safety interventions on specific road types and to make specific comparisons to study factors relevant to safety.

Decision makers in the field of traffic safety can make use of speed data in several ways, e.g. to name a number of important analyses and comparisons:

1. monitor the extent of speeding on several roads in order to identify roads with high proportion of offenders and roads with extreme offenders;
2. monitor the development of speeding over time in order to identify hours per day, months in a year, or seasons in a year that shows disproportionably high numbers of offenders;
3. monitor the proportion of heavy goods vehicles over time in order to study the possible connection to road safety;
4. monitor the development of speeding over time in relation to the actual speeds enforced by the police (enforcement margins) and activities on or near the measured road type;
5. monitor the development of speed distribution over time and identify hours per day, months per year, and seasons in a year that shows a deviant distribution with possible negative effects on road safety;
6. monitor the relation between traffic intensity and traffic speeds.

It is clear that before speed data can be used to support policy decisions, they should be representative, reliable, valid, and precise enough. Therefore, there should be clarity as to how this quality can be produced and maintained. In this respect it is helpful to consider the whole process of production of speed data and to set up standards or recommendations for the execution of specific steps in this process.

5.1.4 Standards for speed data

Use and analysis of speed data for EU policy requires speed data that satisfy certain minimal quality standards. In essence, EU speed data should be reliable, valid, precise and commensurable to such an extent that they can be used for specific purposes of policy development and decision-making.

In order to understand which quality standards are relevant, it is useful to view collection, analysis, and use of speed data as an integrated production process with subsequent links to/chain of subsequent links. In each of these links, care should be taken to safeguard quality and to tailor the production process to the specific needs/requirements of the policy makers/decision makers.

Table 5.1 provides a summary of the steps in the production process, main questions/decisions and specific issues that guarantee or affect data quality.

Steps in speed data collection and analysis	Main questions to be answered, decisions to be made	Issues involved
1. Measurement design and implementation	How can we design and implement a measurement system that will guarantee data that offer reliable and valid indication of speeds of different types of vehicles?	- reliability - validity - sampling techniques - practical considerations
2. Data collection and initial processing	How can the procedure of data collection be optimized to ensure fast, reliable and error-free data processing?	- quality standards for the delivery original data (in agreement with contractor) - choice of software - choice of original measurement parameters - initial error check
3. Error control	How can we detect and remove errors by setting up quality standards in agreement with contractor and by special error-detection software?	- systematic check on unacceptable errors - error correction decisions/procedures - required precision - workable size of data
4. Data reduction	How can we reduce the "bulk" of data to a database tailored for analysis purposes?	- commensurability issues - interpolation techniques - choice of aggregation levels - choice of statistics
5. Possibilities data-analysis and description for policy use/decision-making	How can the outcomes of statistical analysis inform and support short term and long term policy decisions?	- safety - traffic/mobility management - environment
6. Possibilities for in-depth scientific studies	How can in-depth studies increase our understanding of the relations between speed, speed dispersion and crash risk for different road types?	- relation between speeds and crashes - interaction of speed with other variables & crash severity

Table 5-1: Steps in the process of speed data collection, main questions, decisions and issues to guarantee or affect data quality.

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5.1.5 Existing systems for speed data

In many EU countries speed data are recorded by (visible or invisible) measurement loops attached to a data recorder that classifies data according to a pre-specified format. For example, the so-called Golden River Marksman M660 is a data recorder that is being used in many EU countries (UTMC, 2000). In practice, the data recorders are read out and set up again every 4-6 weeks by a person.

A new development is that data recorders are able to send data minute by minute to a large database by GRPS wireless communication technology. For example, in the Netherlands 18 measurement loops in the province of Zuid-Holland send their data every minute by wireless technology to a central database under control of TEC Software and several clients - like the Dutch motorists association ANWB and the road authority of Zuid-Holland – make use of these data for different purposes (e.g. daily traffic management; long term evaluation of policies). Interestingly, besides the regular speed and intensity data, gap distance between cars data can also be delivered by this large, minute-by-minute growing database.

In essence, speed-monitoring systems can be classified into four categories:

- flexible speed measurement using radar as part of regular police speed checks
- flexible speed measurement with radar according to some scientific, sampling design
- permanent speed measurement through measurement loops – often secured into the road surface
- a combination of permanent and flexible monitoring systems

Table 5.2 describes some advantages and disadvantages of these systems.

Criteria	*Flexible speed measurement*	*Permanent speed measurement designs*
Costs	Relatively high since the equipment has to be transported, set-up, read out, etc. by human labour	In the long term (over several years) less than flexible systems
Reliability	Special care has to be taken that equipment is set up according to strict regulations	In general the measurement will be reliable although some equipment malfunction or wrongly specified set-up instructions may cause some (often easily detected) errors.
Representa-tiveness	Limited to particular days, times, dependent upon sampling design	Since measurement is (nearly) continuous, the only limitation to representativeness is the choice of the particular

Table 5-2: Advantages and disadvantages of flexible and fixed speed measurement systems

5.1.6 Possible indicators

Table 5.3 shows specific statistical measures that may be derived from speed measurements.

General categories	Specific indicators
Measures of central tendency	Arithmetic mean
	Median
	Mode
Measures of dispersion	Standard deviation
	Inter-quartile distance
	Skewness
	Kurtosis
Percentile measures	e.g. V90
	e.g. V85
Other safety relevant measures	Proportion of heavy goods vehicles
	Gap distance between cars (expressed in seconds)

Table 5-3: Overview of statistical estimators

These statistical measures provide general statistical descriptions of traffic stream and traffic speeds on a particular road segment. It is often the comparison of these indicators over time, between similar road types and the relation between different indicators (e.g. percentage of heavy goods vehicles and speeds) that is interesting for policy makers and policy decision-making.

5.2 Choosing appropriate indicators

5.2.1 Introduction

As we have seen (section 5.1.2.), the relation between speed and safety is embedded in a complex network of other variables that affect driving behaviour on the road system. Speeding behaviour is determined by several causes and recording of these factors should be an integral part of the further development of the two basic indicators. In this paragraph we will discuss several methodological matters that are involved in the choice and the use of appropriate SPIs in the area of speed. In subsequent sections we will address:

- Comparability of indicators (section 5.2.2)
- Distribution-free indicators (section 5.2.3)
- Aggregation level and representativeness (section 5.2.4.)
- Possibilities for validation of SPIs

Even if the relation between speeding and safety may be observed at the uppermost aggregate level of the national road network, several studies (cf. Aarts & Van Schagen 2005) show that the relations are observed more profitably when disaggregating by road and traffic characteristics.

As to the traffic characteristics, the main concern is to avoid bias in the data caused by congestion periods. Inclusion of data recorded during these periods can obviously and substantially lower summarizing statistics calculated on the data. In this respect, we recommend to clean out congestion data when constructing SPIs in the area of speed-related safety.

As to the road environment, it was chosen to use the SafetyNet Road Classification as a basis (task 6 - chapter 9). This classification has the advantage of offering a general framework for all road Safety Performance Indicators developed within WP3. However, in order to keep the data collection more or less manageable, a reduction of subcategories in main categories seemed necessary. Therefore, five groups of main road categories were used as displayed in Table 5-4.

	Road category type			
	Main	Abbrev-iation	Subcategory	Characteristics
Rural areas	1	AAA	Motorways	through roads with a flow function, dual carriageway, 2x2 or more lane configuration, obstacle free zone wide or safety barrier, intersections grade-separated
	2	AA	Dual carriageway	2x1 lane configuration, obstacle-free zone or safety barrier
		A	Single carriageway	1x4 or 1x2 lane configuration, obstacle-free zone or safety barrier
	3	BB	Rural distributor 1	dual carriageway, 2x2 or 2x1 lane configuration
		B	Rural distributor 2	single carriageway 1x2 lane configuration
		C	Rural access road	single carriageway, 1x2 and 1x1 lane configuration)
Urban areas	4	DD	Urban distributor road 1	distributor road, dual carriageway, 2x2 or 2x1 lane configuration)
		D	Urban distributor road 2	distributor, single carriageway, 1x4 or 1x2 lane configuration
	5	E	Urban access road	access road, single carriageway, 1x2 or 1x1 lane configuration).

Table 5-4: Basic road categories

5.2.2 The basic Speed SPIs

Starting point of the reflection is safety, which is operationalized as a crash rate, i.e. events that follow exposure. In the domain of road safety, events commonly used are the number of serious crashes, the number of fatalities, or the number of severe injuries and/or the number of slightly injured people. An exposure measure that has been widely used, is the number of vehicle kilometres. This data is, however, not always available. Any reflection on an SPI for speed should take this operationalization of crash rate into account.

An SPI for speed cannot, though, be used as an instrument to measure developments in the overall road safety and should only be targeted at the crash rate related to speeding.

The extensive literature review of Aarts and Van Schagen (2005) shows that two aspects of speeding behaviour have an influence on the general road safety and on speeding related risk :

- the average speed on a road and
- the variability in speeds.

The decrease in reaction times that accompanies high speeds implies higher risk on the one hand, and difference in speed or conflicting speeds will on the other hand be more likely to induce collisions.

As these aspects have separate effects and fulfil different roles in the crash generating process, it is necessary to develop at least two types of speeding SPIs: a measure of location, i.e. a typical value that can describe the speed data, and a measure related to the speed data dispersion.

5.2.3 Comparability

An important objective of the SPIs is to enable valid comparisons within and between countries. Within countries, the use of road categories should be carefully prepared, ensuring that the necessary comparability of each national road system and the proposed one are properly taken into account. There is indeed no one-to-one relation between maximum speed limits and road category. For comparisons it is essential to use roads with the same speed limits when constructing the indicator for a specific road category. Otherwise, aggregation will mask important differences and adjustment procedures for further comparison will be unpleasantly complicated.
Once the indicators are obtained for each road category for which speed data are available, one may proceed towards comparison between categories. Comparison of the characteristic speed indicator, can be obtained by dividing the characteristic speed by a function of the maximum speed limit. In absence of empirically validated functions, a plain identity function is proposed. That is, a road category for which e.g. the maximum speed limit is 70 km/h and for which the mean speed is 72.5 km/h, will result in an SPI value of 72.5/70.

For comparisons of the dispersion indicator, it is important to obtain a relative measure of variability. Differences of 10 km/h are indeed much more easily obtained on roads with maximum speed limit 130 km/h than on 40 km/h roads. In order to control for this relation between average level and variability about this average level, it is standard statistical practice to divide the absolute measure of dispersion by the observed measure of characteristic speed.

The indicators obtained by these standardization procedures enable both comparisons within and between countries as the same reasoning applies for both scenarios. The next question to be answered is whether simple arithmetic means and standard deviations may be applied as basic indicators.

5.2.4 Distribution-free indicators

Speed distributions are under-investigated in road safety research. An analysis on Belgian data shows that especially for roads with low maximum speed limits (30 km/h, 50 km/h) the distribution may be heavily skewed to the right. As a consequence the arithmetic mean will inevitably be a bad estimator for the bulk of the data. In this context, a robust measure, like the median is a natural replacement as a measure of normal distribution (characteristic speed). This measure has the additional advantage that it automatically accommodates for outlying observations.
For the measure of dispersion, the statistical literature puts forward the median absolute deviation as a replacement for the standard deviation. It is defined as the median of the absolute differences of each observation and the observed median and has many desirable properties from a theoretical viewpoint.
From a practical viewpoint, the robustness of both of these measures will contribute in preventing random fluctuations (related e.g. to different measurement strategies in the different SafetyNet countries) to be interpreted as real differences in speeding behaviour.

5.2.5 Disaggregation and representativeness

An important issue in designing speed SPIs concerns the question at which aggregation level – national, regional, separate roads - the speed-safety relation is best observed and the question how one can aggregate data bottom-up in a way that preserves representativeness of each respective aggregation level.
The first question can be answered when one keeps in mind the intimate relation between road and traffic environment on the one hand and speeding behaviour on the other. The more similar these characteristics will be (i.e. the more one investigates relations on lower aggregation levels), the more neatly will one be able to perform analyses "all other circumstances being equal".
The second question is essentially a question concerning the best weighting procedure to be used when one would like to combine several measures on one aggregation level to a single measure for the particular level under investigation. It is helpful to consider (by way of analogy) the implicit weighting procedure in the assessment of road safety risk in general. Let r_{nation} be the national risk, let *a* be the total number of crashes and let *w* be the total number of vehicle kilometres driven in the country under study. Let regional totals (for a generic region *i*) be noted a_i for crashes and w_i for vehicle kilometres. The regional risk can then obviously be written $r_i = \frac{a_i}{w_i}$ and the national risk can be rewritten as $r_{nation} = \frac{\sum_i a_i}{\sum_i w_i}$. It follows immediately that one can obtain the national risk from

the regional risks by applying $r_{nation} = \frac{\sum_i (w_i \cdot r_i)}{\sum_i w_i}$. In this formula it becomes clear that regional risks count for as much as the vehicle kilometres driven in the particular region, i.e. regional risks are representative for w_i vehicle kilometres.

The same reasoning applies to speed SPIs. When measures on a lower level of aggregation should result in a single higher-level measure, SPIs should be weighted by driven vehicle kilometres. Let SPI_i stand for a speed indicator at a lower level of aggregation, for example, an indicator for one road of a particular road type *T*. When we want a single indicator value for this road type *T*, it makes sense to let the indicator count for as much driven vehicle kilometres as the road (or its measurement site) represents in traffic activity. In a more formal manner,

$SPI_T = \frac{\sum_i (w_i \cdot SPI_i)}{\sum_i w_i}$. From a road safety viewpoint one may thus conclude that this weighting procedure imposes itself. Weighting procedures using other risk exposure measures may be equally valid, but vehicle-kilometers is conceptually closest to notion of `population at risk'.

5.2.6 Validation of SPIs

The study of the relation between safety (crash frequencies) and speeding has been extensively studied in the literature (cf. Aarts and Van Schagen, 2005). One British study, Baruya (1998), is of particular interest to this task as it investigated speed-crash relations taking into account various road and traffic characteristics. The study, however, only takes into account rural single carriageway roads in three European countries (United Kingdom, Sweden, and The Netherlands). The variables included in the named research design are :

- Crash frequency (*A*)
- 24 hour flow (*fl*)
- mean speed ($\bar{v}$)
- variance of speed
- standard deviation of speed
- coefficient of variation of speed
- proportion of flow exceeding the speed limit ($o_{v\lim}$)
- speed limit ($v_{\lim}$)
- number of junctions per road section (*j*)
- length of the road section in km (*l*)
- width of the road lanes in meters (*w*)
- bend indicator (on a scale from 0 to 3)
- gradient (on a scale 0 to 2)

The final model relating all these variables to the crash frequency (as a measure of safety), is (Baruya 1998) :

$$A = 5.663\, fl^{0.748} l^{0.847} \exp\left(0.038 j - 0.056 w + 0.023 v_{lim}\right) \exp\left(0.023 v_{lim}\right) \bar{v}^{-2.492} o_{v\lim}^{0.114}$$

Functional relations of this nature may be of valuable help to validate the use of speed indicators in a comparative perspective. If one can model a similar relation in a satisfactory manner for a group of countries, there is indeed strong evidence that one can use the developed speed SPIs for comparative purposes.

The relation obtained by Baruya (1998), however, is a complex one. It will in this respect be helpful in the validation phase (when actual data on SafetyNet countries will be used) to work towards simplifications or re-parameterizations of this model making use of common transformation strategies.

Another aspect of the Baruya model that may be improved concerns the number of parameters included in the model. Several other studies identified supplementary variables to be controlled for when studying the dependence of road safety on speed indicators. Garber and Gadiraju (1989) studied in more detail the effect of the design speed of roads. Design speed in itself is inevitably a construct that may take into account variables already accounted for as e.g. lane width. Nevertheless it makes sense to include this factor and to determine its effect empirically during model building. Other variables which are less investigated in this context but do appear in speed research are the obstacle density across road sections, the traffic composition (% of heavy goods vehicles, presence of vulnerable road users), and weather conditions.
A last improvement on the Baruya approach will be the development of models in each of the four large SafetyNet road categories.

As the indicators are based on direct observation of speeding behaviour, they are sensitive to any factor that may influence speeding. The analysis by road type, however, for which use is made of the SafetyNet road classification is too general to guarantee that the indicator controls for the road environment as a whole. The use of robust indicators, however, enables us to focus only on the main messages contained in the speed data. Secondly, the parallel collection of traffic and road characteristics makes it possible to empirically validate the road Safety Performance Indicators for speed within each road category.

Therefore, the indicators used cannot but offer a summary of the speed distribution on a particular road type in a specific country, cf. 5.1 Introduction. In a further stage of the project, it may be preferable to collect raw data and to aggregate speed measurements in a more empirically justified and data-driven manner.

5.3 Survey results

A questionnaire survey was sent to representatives of 27 countries (all 25 EU members, plus Norway and Switzerland) to study the way countries perform speed measurements. This paragraph presents the aim, response, and main results of this survey.

5.3.1 Aim of the survey

The aim of the questionnaire survey was to identify the availability, quality, and use of speed safety data in different European countries. The questionnaire asked for four different road types (motorways, A level roads, rural roads, and urban roads) questions about the following subjects:
- availability of speed data (question 1.1)
- set-up of measurements over different roads and road sections (1.5, 1.6)
- contents of the data (1.4)
- quality assurances of the data (1.7, 1.8, 2.6, 2.10)
- selection of roads for speed measurement (1.7)
- speed limit system (1.10, 1.11)
- type of and functioning of measurement equipment (2.1, 2.2, 2.3, 2.4, 2.5)
- periods and times of measurement (2.7, 2.8, 2.9 and 2.10)
- types of analysis (3.1, 3.2, 3.3 3.4, 3.5, 3.6)
- types of speed and speed variability indicators (4.1 and 4.2)

The SPI survey aimed to gather speed data for four road categories (motorways, A-level roads, rural roads and urban roads)
Table 5-5 summarizes the main contents of the questionnaire.

Theme	Questions
Content of data	Data availability on different roads
Quality assurances of data	1.8. From which type of organization did you receive data or report on speeding? 2.6. Is there any check on possible errors or mistakes in the data before they are analysed or published?
Selection of roads for speed measurement	1.6. Does data concern measurements on different roads? 1.7 Why were these roads selected for measurements? 2.10 Were these measurements based on scientific sampling procedures?
Speed limit system	1.10 In your country, do you have one or more speed limits per road category? 1.11 Please specify these speed limits
Type and functioning of measurement equipment	2.1. What kind of instruments are used for data gathering? 2.2. What are the official names of the instruments?
Periods and times of measurement	2.7 In what period of the year do measurements take place? 2.8 In what part of the week do measurements take place 2.9 In what part of the day do measurements take place?
Types of analysis	3.1. Is the data split out for different days of the week 3.2. Is the data split out for different periods of the year 3.3. Is the data split out for rush hours versus normal hours? 3.4. Is the data splits out for days versus nights? 3.5. is the data split out for cars versus heavy goods vehicles 3.6. is the data split out for different road types?
Types of indicators	4.1. Which indicators (average speed per road, average speed weighted,

Theme	Questions
	median speed per road, median speed weighted) are recorded in the reports? 4.2. Which indicators (percentage over offenders measured at .. or .. or .. over the limit) are recorded in the reports

Table 5-5: Contents of the speed SPI survey

5.3.2 National responses

Around mid November 2004 a questionnaire was sent out. The present section is based on the response until March 2005. Table 5-6 provides a summary of the responses and availability of data.

<table>
<tr><th colspan="5">Progress and quality of response speed indicators questions per 11 March 2005</th></tr>
<tr><th>1
Any response?</th><th>2
Availability of speed data?</th><th>3
Completeness of survey response?</th><th>4
Extra data file delivered?</th><th>5
Speed data per individual road section?</th></tr>
<tr><td>No: 10
IE, IT, LT, LU, NL, PL, SI, SK, FI, CH</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="6">Yes: 17

AT, BE, CY, CZ, DK, ES, FR, DE, EL, HU, LV, MT, NO, PT, SE, UK</td><td>No: 3
EL, LV, MT</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="5">Yes: 14 AT, BE, CY, CZ, DK, ES, FR, DE, HU, NO, PT, SE, UK, EE</td><td rowspan="2">Not complete at all: 4 BE, CY, DE, ES</td><td>No: 4 BE, CY, DE, ES</td><td>-</td></tr>
<tr><td>Yes -</td><td>-</td></tr>
<tr><td rowspan="3">Almost complete: 10 AT, CZ, DK, EE, FR, HU, NO, PT, SE, UK</td><td>No: 5 EE, FR, HU, SE, UK</td><td>-</td></tr>
<tr><td rowspan="2">Yes: 5 AT, CZ, DK, NO, PT</td><td>No: 3 AT, NO, PT</td></tr>
<tr><td>Yes: 2 CZ, DK</td></tr>
</table>

Table 5-6: Response rate to the speed SPI survey, and availability of data

Of the 27 countries approached to deliver responses, 17 actually responded and 10 produced a survey response that was fairly complete. Five countries also delivered an extra data file containing a sample of the speed data.

5.3.3 National conditions: quality of data

On the basis of the survey the potential quality of available data can be estimated from a number of criteria:

1. Does data have official status as official figures?
2. Is data regularly assessed?
3. Have roads for measurement at least partly been randomly selected?
4. Were any error checks made on the data before analysis and reporting?
5. Were roads chosen according to scientific sampling procedures?
6. Were measurements done without obtrusive police presence?

If the answer to these questions was yes the data were scored with a plus. Table 5-7 presents the results of this ranking.

Countries	Status of data	Regular assessment + once a year ++ more than once a year	Selection criteria roads	Error check	Scientific sampling	Measure-ments without visible police presence
AT		+		+		
BE		+	+	+		+
CY				+		
CZ		+		+		+
DK	+	++		+		+
EE*	+					
FR		++	+	+		
HU*	+					
NO		++	+	+		+
PT				+		+
ES						
SE	+		+	+	+	+
UK	+	+	+	+		+
When data did have national official status, when data were assessed at least once a year, when roads were randomly selected, when an error check was done and when sampling method was scientific, the relevant topics questions were scored with + or ++. * No data on motorways						

Table 5-7 Assessment of the Speed Data

As we can see only Sweden, United Kingdom, Norway, and Denmark score positive on most criteria. Estonia and Hungary score plus on only one criterion.

5.3.4 National conditions: set-up of measurement system

Table 5-8 presents per road type the number of roads on which measurement occur, the types of traffic measured, equipment used, measurement period and whether some form of scientific sampling has occurred.

Road type	Number of roads	Types of traffic measured	Equipment	Measurement period	Scientific sampling
Motor-ways	AT: 8; DK:10 FR: 35, PT:5 UK: 27	CZ: all traffic together AT, BE, FR, NO, PT, SE UK: cars vs heavy goods vehicles	BE, FR: radar DK, SE: loops NO: radar + loops UK: piezo strips and Loops CZ Lasergun	AT, CY, CZ, DK, FR, NO, UK: whole year SE: May-Sept PT: Part year BE: one week	BE, PT: stratified sample SE: independent probability samples
A level	DK:5, EE: 8 FR: 65 HU:1, PT:11 UK: 33	CZ, HU: all traffic together BE, DK, EE, FR, NO, PT, SE, UK: cars vs. heavy goods DK, ES, NO, SE, UK: all options available	BE, FR: radar CZ: lasergun DK, SW: loops UK: piezo strips+inductive loop	CY, CZ, DK, EE, FR, HU, NO, UK: Whole year SE, PT: part of the year BE: one week a year	BE, PT: stratified sample SE: independent probability samples
Rural	DK 7, EE 15 FR 50, HU 3, PT: 5	CZ, HU: all traffic together BE, FR, PT: cars vs heavy goods vehicles SE: all options	BE, FR: radar DK, SE: loops NO:radar+loops SE: loops+ tubes PT portable de-vice CZ: lasergun	CY,CZ,DK,EE,FR,HU,NO,UK: whole year SE, PT: part of year BE: one week per year	BE, PT: stratified sample SE: independent probability samples
Urban	DK 21, EE 4 FR 90, HU 3 PT 11, UK 36	CZ, HU, EE: all traffic BE, DK, FR, NO, PT: cars vs. heavy vehicles	BE, FR: radar DK, SE: loops NO: radar+ loops CZ laser gun	AT, CY, CZ, DK, EE, FR, HU, NO, UK: whole year	BE, PT: stratified sample SE: independent probability samples

Table 5-8: Number of measurement points, types of traffic measured, equipment, measurement period and use of scientific sampling per road type per country

From table 5.8 we conclude the following:

- The set-up of the measurement system is the same for most road types.
- France and United Kingdom have the most measurement spots per road type.
- A few countries such as Sweden, Portugal and Belgium only have speed data for part of the year.
- Only a few countries seem to have used an explicit scientific sampling method for selection of measurement sites.

Table 5-9 presents the indicators for mean speed, speed dispersion and speed offending which countries currently use.

	Indicators		
Road type	Average speed	Speed variability	Speed Offenders
Motorways	CZ, DK, FR: average speed per road AT, UK: average speeds all roads together unweighted NO, PT: all mentioned options	AT: SD + V85 CZ: V85, PT: V85	AT, FR, SE, UK: % over limit
A level	EE, NO, PT: all mentioned indicators	DK, EE, PT: 10 km over limit	DK, EE, PT: 10 km over limit EE, DK: 20 km over limit DK, PT 30 km over limit
Rural	CZ, DK, FR average speed per road DK: all roads together EE, NO, PT all mentioned indicators	EE, HU, PT: SD per road NO: all indicators	DK, EE, FR, PT % 10 km/h over limit DK, PT: 30 km over limit
Urban	AT, DK, CZ, HU, NO, PT: Average speed per separate road NO, PT: all indicators	A, CZ, PT: V85 AT, HU, NO, PT: S.D. separate roads NO: all indicators	AT, FR, SE, UK: % over limit DK, FR, PT: % 10 km over limit

Table 5-9: Speed indicators in current use per road type per country

The average speed per road and the standard deviation of the speed per road are commonly used indicators. Some countries also have the average unweighted speed of several roads

5.4 Future work: difficulties and ways to proceed

Of the 27 countries approached by the EC ICC to deliver data, only 17 responded to the questionnaire on speed data. However, only 10 countries provided data to all items required, and this represents a low response rate. Considering a set of criteria (Table 5-3), countries with higher quality of speed data could be identified: Norway, United Kingdom, Sweden, and Denmark. On the other hand, the worse cases using this scale were found to be Hungary and Estonia.

Other countries that provided no response such as Germany and the Netherlands are expected to have fairly good and extensive speed data. This data would be very useful if it can be delivered in the second phase.

Innovative methods of collecting and delivering speed data to build the speed SPIs will be envisaged soon by the European Commission, making use of Institutional Data Protocols and new technology applications able to transfer quickly the necessary data.

The survey showed that the most commonly used indicators are average speed and its standard deviation per road type, as well as % of offenders above the speed limit (Table 4.5), the latter related to the main purposes of data collection.

Critical issues are on how to assess and assure a common quality of the speed data in the set of countries.

Considering the desired properties of the SPIs, a set of speed SPIs was able to be derived. This considered a central tendency measure of the data and its variability. The necessary standardization procedures, average and median speed and the measure of speed variability such as (median) absolute deviation will need further testing and validation across countries, considering the available speed data, levels of disaggregation, and further exposure variables.
The issue of comparability may imply further adjustments in the suggested indicators, as similar reference conditions shall be achieved.

Comparative assessment of road safety in a European framework relies on a unified methodology for the measure of exposure, i.e. for the vehicle kilometres. The concept of speed SPIs has been inspired by the same philosophy and therefore shares the dependence on a valid and reliable methodology for exposure measurement.
Based on the limited findings of our survey a limited number of European countries have data that satisfy several quality standards. The data of some countries such as the Netherlands and Germany is owned and supervised by regional or state authorities, which makes it difficult to get unified national data.
One problem is that in some countries speed data is owned by different authorities. For these countries, deliberation with several authorities is necessary in order to collect any data.

The SafetyNet classification of road types alone is in itself not enough for choosing similar roads in all different European countries since it does not take into account important road and environment characteristics that may affect the speed-crash rate relation and that differ between European countries. Important characteristics such as the maintenance of the road, the type of traffic on the road (percentage heavy vehicles), and the immediate environment of the road (pedestrians, children) are not measured by this classification.

Although the "theoretically best" Safety Performance Indicators can be singled out, it would be too optimistic to expect that these safety indicators will yield intelligible results for a general cross-sectional European comparison. From research we know that the speed-crash rate relation varies with different characteristics of roads and traffic (e.g. Aarts and van Schagen, 2005). We also know that these differences are not fully captured by the SafetyNet-road classification, since this is only a classification of road characteristics, but not of other traffic related variables such as road environment and traffic conditions.

Moreover, the SafetyNet-classification is an ideal-type classification that assumes that roads have been clearly categorized into one type with separate functions (through, distributor, access). Some European countries have roads with mixed functions (e.g. both distributor and access function) that would be hard to classify according to the pure distinctions in the SafetyNet-classification.

In modelling the relation between speed and crashes Baruya (1998) has shown that for single carriageway rural roads the speed risk relation for Portugal is different from United Kingdom, Sweden.

The indicators proposed, median speed and median absolute deviation of speed are not difficult at all to calculate and are similar, in this respect, to indicators already in use in several countries that were approached by SafetyNet. The main problem concerns common quality standards and measurement strategies without which comparability of the indicators can be seriously undermined.

It will therefore be a matter of major interest in the next phase of the SafetyNet project to define explicitly and in high detail what minimal requirements should be met for single-spot measurements.

A second issue that needs clarification is the selection itself of measurement spots. The diversity in current practice calls for precise guidelines in order to maximally reduce possible selection bias. Some countries select sites using principles of sampling design, whereas other countries gather data from a set of fixed measurement sites. Other countries' speed data emanate from arbitrary enforcement campaigns for which representativeness can no way be guaranteed.

A third and last point of importance to obtain valid indicators is the definition of a common exposure measurement methodology. Only a common framework for the measurement of vehicle kilometres will assure correct aggregation procedures.

5.5 Conclusions and future work

Speed is one of the important dimensions in the operation of the road system. On the other hand, speed plays a major role in road safety. A recent review by SWOV suggests that the likelihood of having higher crash rates and crash severity increases if speed is higher and/or where speed differences are larger, if all other relevant elements remain unaltered.

The questionnaire survey sent mid November 2004 to the EU ICC aimed to collect speed information in all Member States in order to help us developing the state of the art to derive the most appropriate speed SPIs. However, only 17 countries responded, and from these only 10 provided data to all items required. This represented a much lower response rate than expected.

This probably indicates that information about speed data is not easily accessible at a centralized source. It is known for two countries, Germany and Netherlands, that speed data is owned and managed by state or regional authorities. We expect that innovative methods of collecting and delivering data shall be envisaged soon by the European Commission experts involved, making use of Institutional data protocols and new technology applications that will make possible to transfer quickly the necessary data.

By considering a set of criteria (Table 5-3), we have identified four countries with a higher quality of speed data: Norway, United Kingdom, Sweden, and Denmark. Other countries that provided no response yet such as Germany and the Netherlands are known to have fairly good and extensive speed data, so it would help the project if this data could be delivered. In these particular countries the speed data is available at state or regional level.
Two countries were able to be identified as the worst cases in terms of data quality and other required items' format: Hungary and Estonia.

The most commonly used indicators seem to be average speed and its standard deviation per road type, as well as the percentage of offenders above a certain speed limit (Table 5-5). Nevertheless, the levels of aggregation and weighing procedures differ across various countries, and this fact requires further attention.

Considering the desired properties of the speed SPI, we proposed a central tendency measure of the data and another considering its variability. The use of standardized average and/or median speed and absolute deviation will need further testing and validation across the set of countries, once the data is available, depending on levels of disaggregation and possible exposure variables.

The issue of comparability may imply further adjustments in the suggested indicators, and the weighing procedures shall be validated.

Comparative assessment of road safety in a European countries and regions relies on a unified methodology for the measure of exposure, i.e. for the vehicle kilometres. The concept of speed SPIs has been inspired by the same philosophy and therefore shares the dependence on a valid and reliable methodology for exposure measurement.

We make the following recommendations for a six-year process to arrive at a first set of SPIs in a limited number of countries and a standard procedure for further SPIs:

1. set up initial requirements for single spot-speed measurements (2005-2006)
2. set up initial requirements for the selection of single spot-speed measurement sites (2005-2006)
3. define a standardisation and re-calculation procedure for different national measures of exposure (2006-2007)
4. define the total dataset which is relevant for SPIs (2006-2007)
5. with the knowledge of 1-4 contact national and regional authorities of different countries to seek out project partners that potentially have good quality data over a longer time period (2008)
6. consult with those authorities who are interested in participating in an European Road Safety Observatory (2008) and discuss the specific

conditions under which they agree to deliver data and information in a more or less standardized way
7. collect SPIs, and additional data about traffic conditions (traffic volume), crashes at a central computing agency/website ((2009-2010)
8. check data for errors and inconsistencies (2010)
9. validate SPIs by modelling (2010-2011)
10. set up new requirements and guidelines for data and involve more countries and regions (2012)

5.6 References

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5.7 Annexes

5.7.1 Step-sheet

0	**Level 0**	Describe:
	Key information: Exact definition of the problem; which operational conditions of road traffic are insecure and leading to crashes or fatalities as the „worst case“	- High average speed increases crash rate (considering separate road types) - High variability in speed increases crash rate (considering separate road types)

1	**Level 1**	
a	Direct measurement possible?	Yes: Go to 1b /No: Go to 2
b	How can the identified problem - the insecure operational conditions - be measured?	The insecure operational conditions can be measured by direct observation of the speed of vehicles
		⇩

a) Query of availability. b) If it is predictable, that the data performing this indicator wouldn't be available, go to 2

2	**Level 2**	
a	Are there suitable indirect indicators to describe the latent variable?	Yes: Go to 2b /No: Go to 3 There is no need for indirect indicators as there is no latent variable present.

3	**Level 3**	
a	Can the problem (level 0) be divided into sub-problems to get handled?	Yes: Go to 3b /No: Go to 4
b	The following questions have to be answered to explain the extent of the SPI referring to the problem (level 0):	
	To which interventions the indicator is related?	The indicator is related to setting maximum speed limits on road segments.
	What should the intervention affect?	The intervention should affect speeding behaviour, i.e. lower the average speed driven on the particular road segment.
	What should be achieved? How should the problem be solved?	A lower average speed should be achieved.
	How should the intervention work?	Knowledge of the speed limit and of the sanction on transgressing the limit should induce behavioural change.
	Which part of the problem is not covered?	The definition of minimum speeds is very uncommon and unpractical. As a consequence, interventions targeted at reducing the variability of speed are not at all easily identified.
	To which interventions does the indicator not react? Justify why this indicator can still be used.	-
	Is one indicator sufficient and why, or do we need more?	There is a need of at least an indicator of average speed and an indicator of spread of speed
		⇩
		a) Query of availability. b) If it is predictable, that the data performing this indicator wouldn't be available, go to 4

4	**Level 4**	
a	No suitable SPI is available to indicate the problem (level 0) or the sub-problems (level 3)	Any measurement on a lower level can (only) indicate the application stage of a road safety measure.

5.7.2 Diagram

(see next page)

Speeds

Problem: inappropriate speeds induces increased injury risk

SPI

Measure of inappropriateness of driven speeds
For all vehicle types, for appropriate road classes

Normalized characteristic speed (characteristic measures are e.g. average, median, etc.)
For all vehicle types, for appropriate road classes
'Appropriate' means: for road classes based on detailed road characteristics

Normalized speed dispersion (distribution measures are e.g. median absolute or standard deviation)
For all vehicle types, for appropriate road classes
'Appropriate' means: for road classes based on detailed road

Derived SPI's

Speed median, normalized by speed limit
For all vehicle types, for appropriate road classes

Speed median absolute deviation, normalized by median
For all vehicle types, for appropriate road classes

Speed median, normalized by speed limit
For all vehicle types, for SafetyNet road classes (AAA, AA, A; BB, B, C; DD, D, E)

Speed median absolute deviation, normalized by median
For all vehicle types, SafetyNet road classes (AAA, AA, A; BB, B, C; DD, D, E)

Speed median, normalized by speed limit
For all vehicle types, for aggregated SafetyNet road classes:
ARC1 Aggregated road class 1: AAA
ARC2 Aggregated road class 2: AA and A combined
ARC3 Aggregated road class 3: BB, B, and C combined
ARC4 Aggregated road class 4: DD, D, and E combined

Speed median absolute deviation, normalized by median
For all vehicle types, for aggregated SafetyNet road classes:
ARC1 Aggregated road class 1: AAA
ARC2 Aggregated road class 2: AA and A combined
ARC3 Aggregated road class 3: BB, B, and C combined
ARC4 Aggregated road class 4: DD, D, and E combined

Formula

Note that the formula for *SPI1* assumes that one speed limit holds per aggregated road class

1. Speed median, normalized by speed limit:

$$SPI1 = \frac{\tilde{m}(\bar{s})}{L_{ARC\_X}}$$

2. Speed median absolute deviation, normalized by median:

$$SPI2 = \frac{\tilde{m}(\bar{y})}{\tilde{m}(\bar{s})}$$

with

$$\bar{y} = (|s_1 - \tilde{m}(\bar{s})|, \ldots, |s_N - \tilde{m}(\bar{s})|)$$

$\bar{s}$

The set of observed speeds for the concerned road class. In other words: $\bar{s} = (s_1, \ldots, s_N)$, where s_i is the ith observed speed and N is the total number of observed speeds.

$\tilde{m}(\bar{s})$

median (50th percentile) of the set of observed speeds $\bar{s}$.

50th percentile
The 50th percentile is that speed value in the set of observed values that corresponds to a cumulative frequency of 50%.

_X
Number of the aggregated road class

L_{ARC_X}
Speed limit of the aggregated road class

$\bar{y}$

The set of absolute differences between each of the observed speeds s_i in the road class and the median of all observed speeds, $\tilde{m}(\bar{s})$.

$\tilde{m}(\bar{y})$

median (50th percentile) of the value set $\bar{y}$.

Primary Data

- A set of observed speeds for each of the chosen aggregated road classes
- Speed limit for each of the aggregated road classes

General Data

Transport
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6 Protective Systems

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6.1 Introduction

6.1.1 The problem

The human body is vulnerable and, during crashes, is exposed to immense forces leading to injury or death. Passive safety of the vehicle itself, as an external form of occupants' protection in case of crash, cannot nowadays fully protect vehicle occupants against injuries. Here, the protective systems available for all traffic participants play an irreplaceable role in protecting the most vulnerable parts of human body, i.e. belly and head. They have a significant influence on the injury involvement and severity rates. Availability and appropriate use of protective systems are therefore fundamental items in developing this SPI.

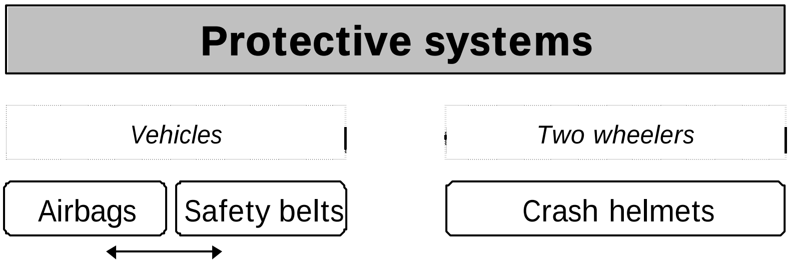

Figure 6-1: Protective systems

Protective systems in vehicles (airbags and safety belts) work primarily by restraining their occupants in the event of a crash. Their efficiency is strongly dependent on the speed that the vehicle with restrained occupants is travelling at and the type of the collision. Safety restraints are most effective in rollover crashes and frontal collisions occurring at low speed. As the speed is related to the road environment, the urban areas, with generally lower speed limits, enhance their efficiency. The risk the particular car occupants run is not equal as the passengers in rear seats are usually farther from impact zones of the vehicle. As the wearing rates vary for different road types, they have to be assessed separately for different road types.

In the event of a crash, helmets for two-wheelers protect the most vulnerable part of their body, the head, by absorbing a part of the kinetic energy. Their safety effect is limited and strongly depends on the speed at which the crash occurs; therefore also in the case of two-wheelers, the wearing rates have to be assessed together with the road types. This conclusion, however, doesn't apply for cyclists, whose speed is naturally limited.

Some other additional equipment of vehicles, which is elsewhere considered as protective system, e.g. headrest, was not included because of its insignificant safety effect and/or its extensive use.

The rates of protective systems use vary significantly with age, sex and other socio-economical characteristics of their users. These argue for treating different road users group in order to understand the problem better and find out the general rate for the whole population. Moreover, subdividing wearing rates is important for the target group concerning information and education, and enforcement activities.

According to ETSC [ETSC, 2005], the average seat belts wearing rate for EU15 countries is around 68% for front seats occupants and 37% for rear seats occupants. The wearing rates in the 10 recently accessed EU countries are expected to be little lower, with a greater difference for rear seats occupants. More precise data for 25 EU Member States is not available yet. With regard to their safety potential, all possible measures have to be taken to assure their wider use with a target of at least 95%.

Building-up the SPIs is based on the fundamental problem treatment as describe above, i.e. separately for airbags, safety belts and safety helmets. Although the detailed knowledge on wearing rates is important from many points of view, identification of the overall rates describing the national road safety condition is preferred, i.e. the rates for children, frontal and rear occupants in all road environments will be analysed. Similarly for two-wheelers, the overall wearing rates for particular riders might be analysed in different ways.

6.1.2 Estimated safety effects of protective systems

When searching for the set of optimal SPIs, we focus, first of all, on the safety effect and life saving effect of particular devices at national level.
Under safety effect (effectiveness) of a protective system, we understand the proportion of lives that would be saved if the system were used. Particular protective devices have different effectiveness; moreover there is some interaction between them: The safety effect of safety belt itself is lower than the safety effect of simultaneous use of belts and airbag.

Seat belts
The use of seat belts is the single most effective means of reducing fatal and non-fatal injuries in motor vehicle crashes. According to TRL research, it reduces the death of car occupants by at least 40% [Grime, 1979]. More recent estimates of TRB based on FARS data reconfirm the agency's earlier estimates of fatality reduction by manual 3-point belts: 45% in cars and 60% in light trucks [Kahane, 2000]. One of the most sophisticated studies in the field, published by Evans in 1986 estimates the effectiveness of safety belts in preventing fatalities to drivers and right front passengers by applying the double pair comparison method to 1974 or later model year cars coded in the FARS as 43±3%. NHTS

uses for its "Lives saved calculations" the effectiveness of 48% for occupants older than 4 years. The considered effectiveness of the three point belts in conjunction with airbags is 54% for occupants over 12 years.

Note: Only lap/shoulder belts are considered here, as the old lap belts have been gradually being replaced and their occurrence is rather marginal in cars. However, the situation is different in case of heavy vehicles and coaches. The effectiveness varies significantly for both types according to TRB, which carried out a study targeting rear seat passengers in cars, for whom the lap belts might be still in use. Back seat lap belts are 32% effective in reducing fatalities and lap/shoulder belts are 44% effective in reducing fatalities when compared to unrestrained rear seat occupants in passenger cars [Morgan, 1999].

Child restrains

According to the TRB report, child safety seats are 71% effective in reducing fatalities in children under the age of 5, but misuse is a critical problem [TRB-TRIS, 2000].

Airbags

The effectiveness of the airbags in traffic crashes depends on a simultaneous use of seat belts. According to NHTSA, the effectiveness of frontal airbags alone is around 13% (i.e. 13% of those drivers killed in the car without frontal airbag would have been saved if their vehicle would have been equipped with it). The effectiveness of frontal airbag used together with lap-shoulder belt is much higher and reaches 50%. (In an 'optimal' type of crash, i.e. in frontal collision, the safety effect might be up to 61%.)

Motorcycle helmets

There are few studies on the effect of motorcycle and moped helmets, and they are not very recent. Hurt et al. (1981) surveyed over 900 injured motorcyclists, of which 60% were non-helmet wearers and 40% wore a helmet. The analysis of injuries at the critical to fatal threshold showed that they were 3.5% above this threshold for the wearers but 8.2% above this threshold for the non-wearers. It can be concluded from this that the risk of death is more than halved if a helmet is worn. In his conclusions Hurt states that "helmeted riders and passengers showed significantly lower head and neck injury for all types of injury at all levels of severity". Otte, Jessl & Suren (1984) studied 272 motorcyclists injured in road crashes around the Hanover area. Non-helmeted riders accounted for 72.5% of the total injuries and yet this group was outnumbered (by how many is not stated) by the helmet wearers. Overall (including figures from a previous study) Otte et al claim that 70% of non-helmeted riders suffer head injuries whereas only 45% of helmeted riders sustain head injuries. Recent research in the EU is hardly possible due tot the fact that helmet wearing rate is almost 100%. In various States in the USA there has been much research into the effect of the helmet use law repeal. However, this type of study evaluates the effect of the repeal of helmet use laws on the motorcycle fatality rate (De Wolf, 1986). It does not evaluate the effectiveness of motorcycle safety helmets because there is no direct comparison between helmeted and unhelmeted riders. This is largely true of all such studies and, for that reason, they are not discussed here except to say that in almost all cases of law repeal the incidence of head injury, fatal and otherwise, increased.

Bicycle helmets

In a widely quoted article by Thompson et al. (1989), who carried out a case-control study in hospitals in Seattle, it was concluded that cyclists who do not wear a helmet have a 6.6 times greater probability of sustaining a head injury and are 8.3 times more likely to suffer brain injury than cyclists who do wear a helmet. According to this data, a reduction by a factor of eight in the annual number of cyclist victims with brain injury could be achieved if all cyclists wore a helmet. In Denmark, Bernhoft et al. (1993) estimated from an in-depth analysis of 88 fatal crashes involving cyclists, that in one third of the crashes involving children, adults, and elderly cyclists, the cause of death was exclusively head injuries (for children in particular), or involved serious head injuries. These authors concluded that in some of these crashes, the usage of a bicycle helmet might probably have reduced the severity of the injury, and thus avoided a fatality. Royles (1994) reviewed a number of studies addressing the issue of how many bicycle related deaths and head injuries could be prevented if cyclists wore helmets. In Sweden, Lind and Wollin (1986; in Royles, 1994) carried out a questionnaire survey, and concluded that more than 70% of the crash victims for whom the head was recorded, as the main site of injury would have benefited from the use of a helmet. Olkkonen (1993) investigated the injury severity of bicycle crash victims in three Finnish provinces from 1982-1988, and estimated that almost 50% of the 200 fatal injuries could have been prevented if a helmet had been worn.

Note: Ideally we might want to assess the collision type as well, as the effectiveness of a particular device might be influenced much by. However, in most of the crashes, a protective system increases the protection of the user against the injury as it helps to reduce the forces to which the body of the road user is exposed.

Estimation of lives saved by protective systems in EU15

Based on recent CARE data for 2002, the rough estimation of the lives saved in EU15 can be made using the NHTSA methodology (Glassbrenner, 2003). The lives saved are here estimated as follows: If x people die using a safety device that has an effectiveness *e* (i.e. that reduces fatalities in settings in which people would otherwise die by *e*x100%), then one can infer that a total of *x*/(1-*e*) used the device in a setting in which they would otherwise die (the potential fatalities), *e*x/(1-*e*) of which were saved by the device.

In 2002, the road traffic toll was following: 17.846 car passengers, 5.131 motorized two-wheelers and 1.456 cyclists in EU15. From the questionnaire, the estimated use rates in crashes were 60% for seat belts, 80% for motorcyclists and moped riders and 10% for cyclists. The estimated effectiveness of protective systems was 50% for car occupants, 40% for motorcyclists and moped riders and 50% for cyclists.

Type	Effectiveness	Fatalities	No PS used	Potential fatalities	Lives saved
Passenger cars+vans	50	26000	11000	22000	11000
HGV+bus	50	2200	1900	3800	1900
Pedal cyclists	50	2200	1600	3200	1600
Moped	50	2700	650	1300	650
Motorcycle	40	5000	500	850	350
SUM					**15500**

Table 6-1: Rough estimate of lives saved by protective systems each year in EU25

Accident data used in table 6-1 are rough estimates of 30-days fatalities registered in 2002 in EU25 MSs (Care,Irtad). The computation behind uses many simplifications, as it doesn't consider the effect of airbags and use only rough estimates of both systems' effectiveness and their real use in crash and therefore has only illustrative character [5]. The more precise evaluation based on real EU25 data should be however possible in the near future, allowing to foresee the safety effect in the future as well. Additional lives are saved each year by airbags in passenger cars; those are however not figured out in this computation.

6.1.3 Types of protective systems

Within "Protective systems" we distinguish three items:

1. Airbags
2. Seat belts and child restraints
3. Helmets for two-wheelers

Ad 1) *As an airbag, we understand a passive (idle) restraint system that automatically deploys during a crash to act as a cushion for the occupant. It creates a broad surface on which the forces of the crash spread, to reduce head and chest injury.*
In order to create an appropriate SPI, airbags can be divided in front airbags (driver and passenger) and side airbags. For the measurements concerning front airbags we can divide a direct and indirect way. The direct way is to ask for the presence rate. However, we assume that there are no statistics of countries of the presence of airbags. If we receive the confirmation by means of the questionnaires, the indirect way is the solution. It means to gather the age distribution of the car fleet. (This data are collected in the frame of task 5 dealing with passive safety of vehicles.) After some years the whole car fleet will be equipped with airbags; then this measurement will not be relevant.
For side airbags the indirect way is to gather information about the proportion of sold new cars equipped with side airbags.

Ad 2) *Under the term seat belts, we understand a standard three-point lap-shoulder belt system regularly installed in passenger cars and light vans. Under*

the term child restraints, a crash tested device that is especially designed to provide infant/child protection is meant.
The presence of seat belts does not seem more relevant due to the fact that only in cars older than 1989 no belts are fitted on the rear seats only. (However, in some countries, especially the accessing countries, the proportion of these vehicles in the whole fleet is still relevant.) This means that the measurements concern only the wearing rates (use rates). In all EU countries there is the rule: if a seat belt is present, the use is obligatory.

Ad 3) *Under the term helmet, we understand a crash/safety helmet designed for two-wheelers, whether motorized or non-motorized.*
In creating a relevant SPI, the two steps are necessary: to find out whether their use is obligatory and whether particular wearing rates differ by type of road user (cyclist, mopedists, and motorcyclist).

In general
Misuse of seat belts and helmets are also relevant issues. Especially concerning child seats (the child and/or the seat is fixed too loose) and helmets (not using the chin strap; the strap is too loose; helmet damage; etc.) It was decided is to skip this issue due to expected problems gathering the data.

6.1.4 National General Conditions

To fully understand possible national differences and to anticipate possible misunderstandings when treating the problems, the legislation on the use and presence of protective systems have to be mentioned here:

Ad 1: The presence of airbags in the vehicles has not yet been treated by European (national) legislation. The responsibility therefore lays on the manufacturer and customers who decide whether the car will be equipped with airbag(s), or not.

Ad 2: Already in 1984, the European Parliament made the compulsory use of safety belts on all roads, whether rural or urban, a priority measure. In its Resolution of 18 February 1986, it further stressed the need to make the wearing of safety belts compulsory for all passengers, including children, except in public service vehicles. Subsequently, all cars up to 3.5 tons manufactured after this year must be equipped with safety belts.
Related EU legislation currently in force (Directive 91/671/EEC) requires that all occupants of cars and light vans use seat belts. That Directive does not specify the type of child-restraint system that would be appropriate and allows for the carriage of children without being restrained by an appropriate child restraint where such a restraint is unavailable, i.e. it leaves scope for Member States to allow children of 3 years and older to be restrained by an adult seat belt. It also permits Member States to exempt children younger than 3 years of age from wearing child restraints if they are seated in the rear and if child restraints are not available in the car.

A new Directive (2003/20/3) coming to the force in May 2006 will extend the obligatory use of seat belts to all motor vehicles occupants, including trucks and coaches. It will also revoke all exception applicable nowadays for children under 12 travelling in cars. The only new exemption, applicable for children restraints use, will concerns children under 3 years old travelling in coaches, who will be exempted from obligatory wearing of seat belts.

Ad 3: Unlike for seat belts, there is no EU directive pertaining the use of safety helmets currently in force. The legislation may therefore vary among particular Member States However it's well known that there is a general duty feeling among motorcyclists to wear a helmet.

In general, particular Member States have bigger or smaller interest in collecting data on the use of protective systems. Some countries need this data to evaluate the effectiveness of their enforcement actions; some others carry out serious research on their effectiveness and contribution in lowering the severity of the crashes. In few countries, the data is not a subject of interest at all.
As the interests of particular countries in having information on the use of protective systems vary, the used methodology may vary much and consequently influence the reliability of data. In order to guarantee the comparability of the data and the way in which the data is collected, the data has to be understood. This means measurements include variables as time, location, sample size, regularity, and others.

6.1.5 Resulting Difficulties

The expected difficulties are related to the part of EU restraints systems legislation, which allows for national treatment, i.e. for child restraints and bicycle and mopedists' helmets. Here, national legislations often define different age groups for the usage of these types of protective systems. It is well known that there exist sub-categories for child restraints systems, some related to the age of the child, some to their weight. Regarding safety helmets, young traffic participants might be addressed differently by the legislation as their risk is higher and their wearing rates may vary significantly with the age. To conclude, although there is a need to address traffic participants in all age groups, it might be difficult to address particular age groups.
The national methodologies used for the collection of the data on SPI may differ much among each other, what can lead to data incompatibility and unreliability. Here, the quality of the data in respect to policy making and research depends on the their provider. Generally, Police reported wearing rates assessed during enforcement actions are much higher than in reality. Self-reported wearing rates are generally higher as well, but the situation would clearly vary among countries.

Some other expected difficulties to be met when building different SPIs on protective systems:

Ad 1: It's probable that national governments don't possess the information on their presence in the vehicles. As the presence of the air bags is not related to the concrete model, or indeed series of vehicles, it's likely almost impossible to get a national overview on the percentages.

Ad 2: The presence of safety belts in vehicles might be assessed differently, and total numbers for all users by sex, age, and other characteristics might be missing. The same applies for different road environments, where the overall national rate might be missing. Here, the ways to assess missing rates will have to be investigated.

Ad 3: The data for cyclists might be missing and incomplete for many countries, the wearing rates for motorized two-wheelers might not be reliable as there are countries declaring 100% wearing rate.

6.2 Building up Indicators

6.2.1 Direct indicators

It was possible to find a direct indicator, as it was already identified in few studies and beside that, there is a current praxis in new EU countries, which historically have some experience with the use of this SPI. Under the direct indicator, we understand

The day-time wearing (usage) rate of protective systems in traffic.

This SPI directly measures the use of protective systems, which contribute to the reduction of crash consequences severity. The SPI is sensitive on human behaviour, which apply for awareness and enforcement.

6.2.2 Indirect indicators

It is also possible to find indirect indicators, from which the direct indicators can be derived. They are well described in literature and moreover regularly used in many European countries.

The first indirect indicator relates to:

The use of protective systems recorded in accidents by the Police. (1)

The second indirect indicator concerns:

The presence of the systems, or their availability in general. (2)

1. The police records are an important source of accident related data for the development of SPIs protective systems as it is the only one indicator available in many countries. However, there is a lot of difficulties related to the use of accident data. Their reliability vary much as the legislative background differs,

so that the reporting might be influenced by external factors. For example, insurance companies can be interested in the problem etc., so we cannot rely on the self-reporting, or police-reporting data. Like that, only wearing (usage) rates among road fatalities are of interest. They are not biased as in the serious accident the use of a protective system at the moment of a crash is easily recognisable by a policeman.

Regarding seat belts wearing rates, it should be generally possible to develop a model describing the relationship between the day-time wearing rates and fatalities wearing rates in accidents, based on the data from the countries, in which the both figures are available. In the U.S., the NHTSA uses since many years a model, which allows to predict the use of seat belts among potential fatalities from known day-time wearing rates. The most recent version of this model is UPF(x) = 0.47249 x2 + 0.43751 x, where x denotes belt use in the front seat during daytime and UPF(x) denotes the belt use among potential fatalities when daytime front seat use is x. (Wang and Blincoe, 2003)

2. The presence, or the availability of a protective systems among population is a very rough indirect indicator, as it does not have a clear relationship with the wearing rates in traffic. Further it loses its importance with time, as the availability is almost reaching 100% in most of the cases. (E.g. presence of seat belts in passenger car.)

6.2.3 Constructing indicators by dividing the problem into sub-problems

A literature review has been done on the current knowledge on the safety effect of particular protective systems. Both direct and indirect indicators have been treated together according the type: i.e. Seat belts, Airbags and Helmets. For each particular problem, the availability and the potential of direct and indirect indicators has been investigated. For seat belts, the presence and the use was addressed separately.

As the construction of the seat belts may vary, implying different safety effects, all the differences in their quality should be assessed in theory. Examples to be mentioned are: the shoulder-height seat-belts adjusters which allow a comfortable fit for occupants of varying height, seat-belt retractors which lock the belt automatically in a crash or severe deceleration, or pre-tensioners minimising the amount of slack belt and consequently reducing the risk of a front-seat occupant hitting the steering wheel or dashboard. However, it doesn't seem to be necessary to address all these particular variations, since they don't influence the final safety effect as much as the use of a seat belt of any quality. As the wearing rates depend on many external variables, the scope of the questionnaire did concentrate on: Vehicle types, Age groups, Road types, Gender of occupants, and Seating position.

Regarding Vehicle types, ideally all vehicle types would be addressed, including further subdivision for cars (such as taxi, police, etc.). However, this is not possible in the frame of this project. It was therefore decided to focus on the vehicle types representing the majority and having the highest possible safety capability, i.e. cars.

Regarding type of roads, all roads types existing in Europe were distinguished by using the IRTAD definitions and SafetyNet definition as well. As the methodology predestines the quality and interpretability of the data, the way the wearing data is assessed was of a great interest assuming the fourth basic data sources: Insurance companies, Statistical offices, Police, Others. The regularity of the surveys is assessed as well.

We thought that categorizing motor vehicles, specifically mini-buses, vans, heavy vehicles could be done by collecting data of safety belt wearing rates. It was decided not to collect them because of the problems in splitting them into mentioned categories. Categorizing children into the sub-groups according to their age in order to cover the users using the same type of protective systems.

6.3 Questionnaire

In order to obtain as much information as possible, but at the same time keep the questionnaire short, the questions posed were formulated in such a way allowing simple one, or two word answers to most of the questions. The only exception was the part regarding the methodologies used to gather data on wearing rates, as it was desired here to learn many particularities.
Basically, the questionnaire was divided into the four parts. Two of them dealt with safety belts, one with airbags, and one with helmets. For each part, the set of question was formulated in such a way that the respondent not possessing data could skip the next questions.

The following figure illustrates the reasoning behind the questionnaire for protective systems. Where it was appropriate to ask for the legislative background, the question on current law in the country was positioned at the beginning. Furthermore, the respondents were generally asked if in their country the data on wearing rates existed. If yes, they were advanced to the more detailed questions assessing the scale of data collection and methodology used.

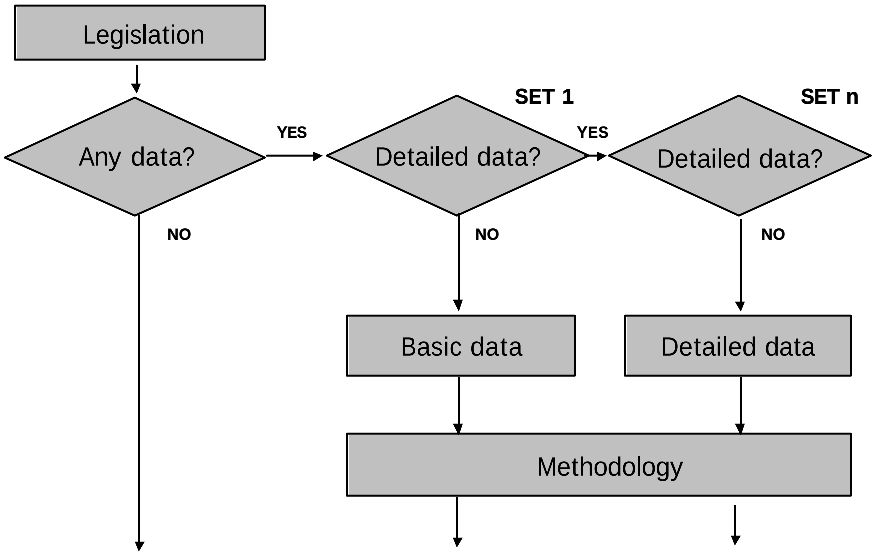

Figure 6-2: scheme used for questionnaire

As the aim was to gain as much data on wearing rates for different road users, road types, and gender as possible, some questions were prepared in the form of tables allowing the same question for several variables. When investigating the helmet wearing rates of cyclists and children restraints system use, the space has been left for defining the specific age, or weight categories and specification of the appropriate protective system type.

6.4 National Responses

The lessons learnt by analysing the responses of particular countries are not very surprising: there are big variations existing in terms of quality and availability of data needed to realize suggested SPIs on protective systems. In certain countries, no information is available; however some of them have recently started with its collection.

National respondents have, for the most part, well understood the questions asked and answered in a correct way. The first part of the questionnaire, dealing with the presence of seat belts in vehicles, caused them some difficulties, as some of them understood this question as a request for wearing rates. Some others perhaps left the question unanswered. However, the lesson learnt from their responses regarding this part is clear enough (there is no data on airbag presence in the vehicle fleet in the EU).

From the responses concerning the wearing rates, the old information was forwarded in some cases, moreover some respondents probably haven't understood the importance of data source choice for their reliability as they provided with the rates coming from police observation, or mailing questionnaires responses, despite the regular research observations having already been established in their country. Here, another general problem must

be mentioned: some of the experts filling in their national questionnaires obviously did not have access to the research databases or failed to use this sort of data. The problems might lay in the independency of some research institutes and resulting difficulties of the state administration to obtain their data.
As obvious from the national responses, the countries interested in data collection on using protective systems are often looking at the same indicators, while using IRTAD definitions for road types, using distinctions for different occupants' seats and vehicle types as well. It allows for comparing and merging data among countries. Nevertheless, the quality of the comparison is influenced by the fact that the year for which the expert sent the relative data/most recent data is not always the same, i.e. there is data from 2004, 2003 and 2002.
In few cases, the quality of data received was influenced by the way the questionnaire was constructed at some places: a choice 'zero', or 'none' was missing in the roll-down menu and the respondent had no other choice than to answer in the wrong way.

6.5 Searching for Appropriate Indicators

The indicators for task 3 are the wearing and usage rates of protective systems by road users in road traffic. As the importance of particular devices derives mostly from their safety potential at national and European level, they may vary significantly among each other. The choice of the appropriate ones should be based on sophisticated research knowledge and not only on the accessibility and measurability. In general, the detailed knowledge on the use of protective systems covering all device types, road types, and users would be considered as a best base for a series of SPIs. The indicators in this row can be called as “ideal indicators” and should be ranged in respect to their safety efficiency. However, one must think about the realizable indicators, for which most of the countries possess appropriate information.

The process of identifying the appropriate SPI is illustrated in section 6.9.2 of this report. The schemes presented there show how the indicator might be aggregated from the particular indicators. However, this might be not desired, as the overall or aggregated indicators might aggravate their quality and usefulness. Appropriate indicators are therefore chosen with regard to the former research findings and current practices.

Set I: Seat belts

SPI A – Frontal seats – passenger cars + vans /under 3.5 tons/
SPI B – Rear seats – passenger cars + vans /under 3.5 tons/
SPI C – Children under 12 years old - restraint systems use in passenger cars
SPI D – Frontal seats – HGV + coaches /above 3.5 tons/
SPI E – Coaches – passengers

Set II: Safety helmets

SPI F – Cyclists
SPI G – Mopedists
SPI H – Motorcyclists

Comments:

1. There is no sense in measuring driver and frontal passenger seat belt wearing rates separately. Results from the Questionnaire: General wearing rates in 11 countries 83.8% (driver seat) against 82.8% (frontal passenger seat). In crashes, however, 75.7 against 67.4%. [SPI A]
2. Wearing rates for different road types and sex should be aggregated since the disaggregated rates are more important for in-depth analysis studies and probably not available in all MS. (e.g. Not all road types are present in some countries.)
3. The values given should be representative for the total road network; therefore one hopes that the countries calculate them from their aggregated data. The formula was provided and can be found in Annex 6.9.2.
4. Assessing vans separately is not reasonable, as they are in the same vehicle category as cars and it should be left voluntarily to countries to collect this type of data [SPI A].
5. One should consider wearing rates for coaches, despite the fact that it's data is hardly assessable and is probably not an important indicator [SPI E].
6. Seat belts wearing by front passengers in heavy vehicles and coaches might be addressed through a common SPI [SPI D].
7. Assessing helmet wearing rate among motorcycles SPI H should be understood as an indicator for the near future only, as it has already reached almost 100% in few countries (Norway, Germany).

6.6 Further Proceedings

The effectiveness of the particular retention system and its contribution in saving human lives on European roads for a particular country might be considered and explicitly calculated. This will require some data, which is being collected in WP1. The effect of the systems at the European level can further serve as a ranking for the proposed SPIs, which might imply for a revision in terms of ranking and finding the ideal indicators for the EU. In order to rank the countries, the data from certain countries will be updated in order have comparable information for the same time frame. The review of survey methodologies used in different countries can be drafted and the best practices identified. In the Phase II of SafetyNet, the guidelines for data collection in WP3, task 3 will be drafted and proposed as an example methodology for those countries, which at present fall short in data collection.

6.7 Conclusions

Based on current practices and raised from the need to monitor and evaluate the contribution of protective systems use in the 27 countries, a set of Safety Performance Indicators has been proposed. Unlike for other SPIs, which have been developed under the SafetyNet WP3 scheme, the identification of the appropriate indicators was more or less a convenient matter, requiring the consideration on the area treated by the indicator in view of its potential safety contribution and effect. The final number of chosen SPIs might be further reconsidered, as it's quite high and requires a broad knowledge of the traffic situation and detailed survey information, which might recently not have been available for many countries.

6.8 References

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6.9 Annexes

6.9.1 Step-sheet

0	**Level 0**	Describe:
	Key information: Exact definition of the problem; which operational conditions of road traffic are unsafe and leading to crashes or fatalities as the "worst case"?	The human body is vulnerable and during the crash is exposed to the immense forces leading to injury or death. The availability, road users awareness and enforcement resulting to the use of protective systems, which might reduce the severity of the injury occurring during the crash is crucial for lowering system's outcomes (injury severity).

1	**Level 1**	
a	Direct measurement possible?	Yes
b	How can the identified problem - the unsafe operational conditions - be measured?	➢ Seat belts and helmets: wearing rates ➢ Airbags presence
		⇩
		a) Query of wearing rates for seat belts and helmets. b) In advance query of the presence of air bags. If necessary indirect measurement is possible See 2.

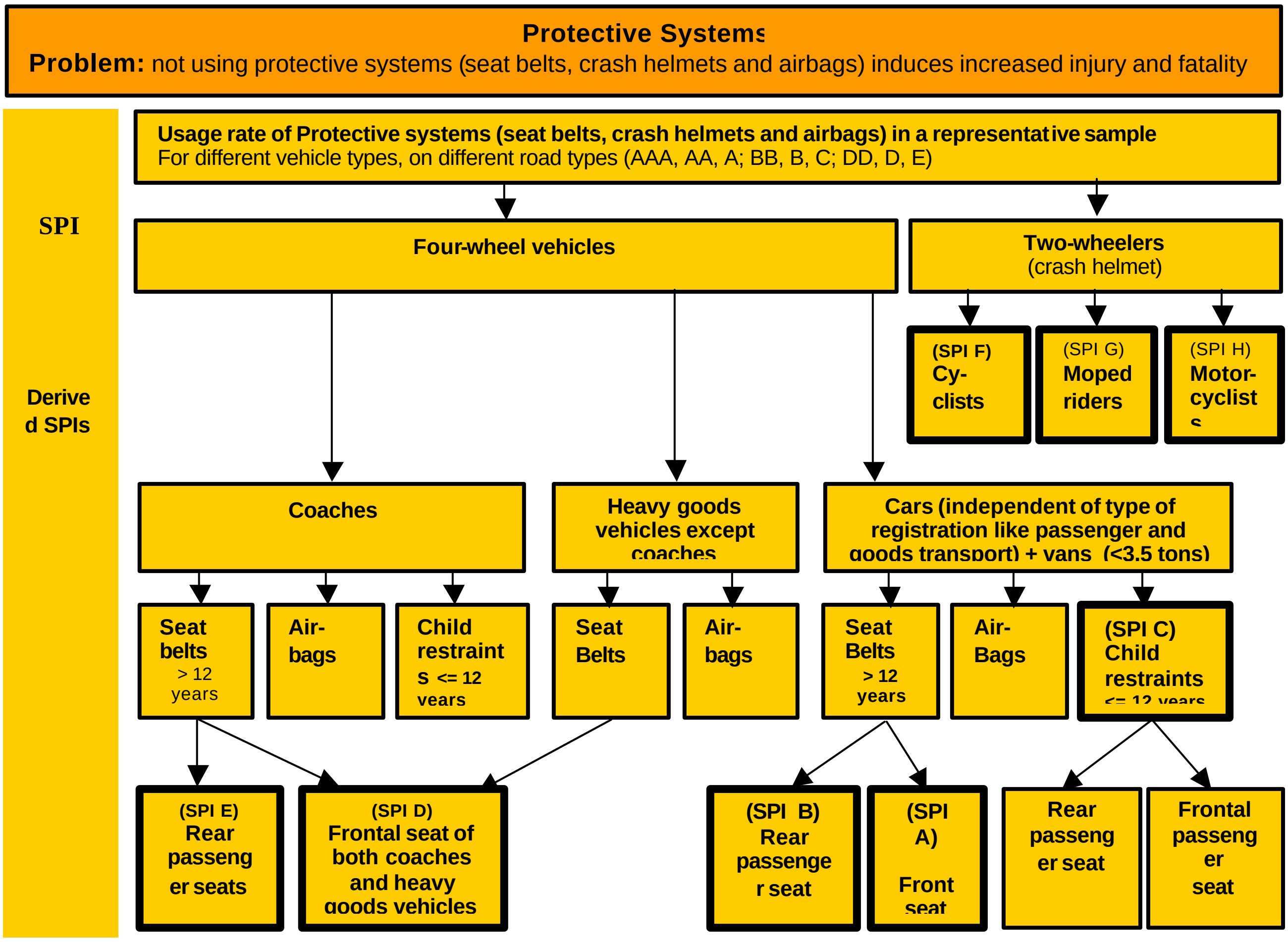
2	**Level 2**	
a	Are there suitable indirect indicators to describe the latent variable?	Yes
b	Which indirect indicators are suitable to describe the latent variable and how?	Seat belts and helmets: Police records. In minor cases insurance companies records and medical services records on wearing rates. Frontal airbags: the age of the car fleet Side airbags: the proportion of sold new cars equipped with side airbags.
		⇩
		Seat belts and helmets: Specific research Airbags: query

3	**Level 3**	**not applicable**

4	**Level 4**	**not applicable**

6.9.2 Diagram

(see next page)



Formula

X
Either A, AA, B, C, D, E, F, or G
i
road type
N
Total number of road types assessed
WR_i
Wearing rate of the protective system under consideration for road type *i*
TS_i
On road type *i*, the share in traffic, i.e., the percentage of kilometres travelled on road type *i* by the vehicle type under consideration

For each SPI indicated (SPI A through SPI G), the value is calculated by taking the weighted sum of the wearing rate of the protective system under consideration, for all road types studied, in a representative sample:

$$SPI\_X = \sum_{i=1}^{N} WR_i \times TS_i \qquad \sum_{i=1}^{N} TS_i = 1$$

where:

WR_i is the 'wearing rate', the number of persons using the protective system divided by the total amount of users of the particular vehicle type, observed in a representative sample during an independent roadside survey
and
TS_i is the 'traffic share' for road type *i*, i.e., the amount of kilometres travelled on road type *i* by the vehicle type under consideration, divided by the total amount of kilometres travelled by the vehicle type under consideration for all road types assessed

A
Seat belt; frontal seats; over 12 years old; passenger cars and vans
AA
Seat belt; rear seats; over 12 years old; passenger cars and vans
B
Child restraint, frontal and rear seat; under 12 years old; passenger cars and vans
C
Seat belt; frontal seat; over 12 years old; coaches and heavy goods vehicles
D
Seat belt; rear seat; over 12 years old; coaches and heavy goods vehicles
E
Crash helmet; cyclists
F
Crash helmet; moped riders
G
Crash helmet; motorcyclists

Primary Data

- Number of persons wearing the particular protective system studied, for each road type studied, for each vehicle type under consideration
- Total number of persons that were in the position to wear the particular protective system studied, for each road type studied, for each vehicle type under consideration

General Data

- Number of kilometres travelled by coaches, heavy goods vehicles, cars, vans, bicycle, moped and motorcycle for each road type assessed

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6.9.3 Usability of Safety Performance Indicators (SPI) of task 3

Country	Is the SPI realisable for this country? (yes/no/partly)	For what period (e.g. annually) can the SPI be determined?	Comments/Restrictions
Belgium	Yes	Annually	
Cyprus	No		
Czech Republic	Yes	Annually	
Denmark	Yes	2 x per year	
Germany	Yes	2 x per year	
Greece	No		
Spain			No answer
Estonia	Yes	Annually	
France	Yes	3 x per year	
Hungary	Yes	Annually	
Ireland			No answer
Italy			No answer
Latvia	No		
Lithuania			No answer
Luxembourg			No answer
Malta	Yes	Irregularly	
Netherlands			No answer
Austria	Yes	Annually	
Poland			No answer
Portugal	No		
Slovakia	Yes	Irregularly	
Slovenia			No answer
Finland			No answer
Sweden	Yes	Annually	
United Kingdom	Yes	2 x per year	
Norway			No answer
Switzerland	Yes	Annually	

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Project co-financed by the European Commission, Directorate-General Transport and Energy

7 Daytime Running Lights

Péter Holló, KTI; Victoria Gitelman, TECHNION; Chris Schoon, SWOV; Maarten Amelink, SWOV.

7.1 Introduction

Many traffic crashes occur because road users do not notice each other in time or do not notice each other at all. This is true not only for traffic crashes in the dark but for traffic crashes in daylight as well. Vehicle visibility is therefore one of the factors which affects the number of crashes (Attwood 1981, Rumar 1980, Helmers 1988, Elvik and Vaa 2004).

The eye reacts to contrasts and changes in contrast in the field of vision. When light conditions are particularly difficult, such as at dusk, in rain, or in fog, it becomes difficult to see all traffic elements (Elvik and Vaa 2004).

Use of daytime running lights (DRL) for cars in all light conditions is intended to reduce the number of multi-party accidents by increasing the cars' visibility and making them easier noticed (Elvik and Vaa, 2004).

Elvik and Vaa (2004) summarized the results of about 20 studies, which evaluated the effects on accidents of DRL on cars. The studies were carried out in different countries such as USA, Canada, Sweden, Norway, Denmark, Israel, Austria, Hungary, and considered two types of effects: the effect on the accident rate for each car of using DRL and the effect on the total number of accidents in a country where the DRL use is mandatory. The researchers found out that the DRL use reduces the number of multi-party accidents by around 10-15%.

The problem of visibility is especially pertinent to mopeds and motorcycles. Poor visibility was indicated as a contributing factor to many accidents involving these vehicle types. The DRL use is accepted to be one of the ways for increasing moped and motorcycle visibility (Elvik and Vaa 2004). 12 studies, from the USA, Australia, Great Britain and Malaysia, considered the effects on accidents of using DRL on mopeds and motorcycles. Summing up their findings, it was stated (Elvik and Vaa 2004) that mopeds and motorcycles using DRL have an accident rate which is 10% lower than for those not using DRL. However, this estimate is considered as uncertain, because the confidence interval of the summary value was very wide making the result statistically insignificant.

The basic idea in developing the SPI for Daytime Running Lights (DRL) is the stated relationship between the level of DRL use and the effect on safety. Besides, the daytime visibility of motor vehicles cannot be measured directly but the level of use of DRL can.

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7.1.1 National General Conditions

At the time of writing, responses are available from 17 counties such as:
Belgium, Czech Republic, Denmark, Germany, Estonia, Greece, Spain, France, Cyprus, Latvia, Hungary, Malta, Austria, Portugal, Sweden, United Kingdom, Norway.

Annual data is available in 3 countries (Czech Republic, Estonia, Hungary), monthly data are available in one country (France).

Surprisingly, regular survey is only obligatory in one country (LV) and is recommended in another one (Estonia), in all other countries, including 9 countries having a DRL law, is not even recommended. At this moment only for four countries are DRL usage rates are available (the Czech Republic, Estonia, France, Hungary). Only the Czech Republic provided rates according to vehicle types.

7.1.2 Resulting Difficulties

There are great differences in the legislation of the surveyed countries. The DRL obligation, if it exists, is valid only for certain periods of the year, vehicle categories, road categories; this can create difficulties in the comparison of the data. Usage rates cannot be interpreted practically in countries where the lights are switched on automatically. Relatively long time-series are available in Hungary only (from the year of the DRL-introduction: 1993).
Foreign vehicles are taken or not taken into account in two countries (FR, LV), and in 5 countries, respectively.

7.2 Constructing Indicators

It is not possible to find a direct indicator for visibility because the daytime visibility of motor vehicles cannot be measured directly. Visibility has many aspects (lighting, colour, size). This study deals with DRL only.

An indicator for DRL can thus be considered an indirect indicator for visibility. For this sub-problem an appropriate indicator was developed. The indicator is based on the relation between the level of the use of the DRL and the effect on multiparty daytime crashes (MPDA).

The indicator has been identified on the basis of literature survey and the current practice. It is appropriate to measure the percentage of the drivers who follow the rules (use the lights in an appropriate way).

7.3 Questionnaire

The earlier research results (e.g. Commandeur 2003) and our own (e.g. Hungarian) experience in connection with the data collection for the DRL use surveys were accounted for in the development of the DRL questionnaire.

The questionnaire was built in a way, which enables to obtain information on all the issues, which are relevant to the DRL use in a country. The main components of the questionnaire are:

1. Legislative background (whether the DRL use is obligatory in the country and for which vehicle types; as well as the issues of automatic switch on and the sanctions for non-use).
2. Surveying circumstances of the DRL usage rate (the frequency and the structure of the survey; sampling rules and available results).
3. Evaluation details (how the DRL survey data are processed; whether the DRL use rates available for separate road types and vehicle categories).
4. Means for increasing the DRL use (whether information and/ or enforcement campaigns or special road signs are applied to stimulate the DRL use).

7.4 National Responses

At the time of writing this report, responses are available from 17 counties: Belgium, Czech Republic, Denmark, Germany, Estonia, Greece, Spain, France, Cyprus, Latvia, Hungary, Malta, Austria, Portugal, Sweden, United Kingdom, Norway.

A law concerning the use of DRL exists in **12 countries** out of 17(marked with*)

Options	BE*	CZ*	DK*	DE*	EE*	EL	ES*	FR*	CY	LV*	HU*	MT	AT	PT*	SE*	UK	NO*	Total
Yes	1	1	1	1	1		1	1		1	1			1	1		1	**12**
No						1			1			1	1			1		**5**

Table 7-1: Existence of legislation on DRL in European countries.

Four countries delivered data on DRL usage rates (CZ,EE,FR,HU). Only CZ also provided rates according to vehicle types. Each country has its specific legislation for types of vehicles and type of area.

	CZ	**EE**	**FR**	**HU**
motorway	100	99.31	35	97.3
rural	77	99.57	24	92.2
urban	86	98.96		6.7
DRLroads	88	99.28	30	94.7
year	2004	?	2004	?

Table 7-2: DRL usage rate in four European countries

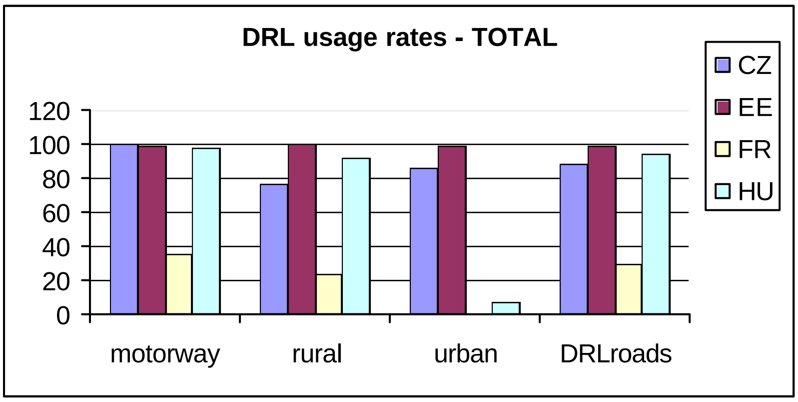


Figure 7-3: DRL usage rate in four European countries

7.5 Searching for Appropriate Indicators

It is impossible to elaborate a direct indicator on daytime visibility of motor vehicles. (A discussion on the issue is also given in section 7.7.1.) However, it is possible to apply an indirect SPI in the form of:

The percentage of vehicles using daytime running lights.

The general indicator is estimated for the whole sample of vehicles, which is available for a country. If the data permit a similar value will also be calculated for different road types and for different vehicle types. The details of the suggested SPIs are presented in the scheme in section 7.7.2.

The road types considered in the scheme (for which SPIs are planned to be estimated) are: motorways, rural roads, urban roads, DRL-roads. The term "DRL roads" implies the road categories where the usage of DRL is obligatory. For example, in Hungary, DRL roads are the ones, which are outside built-up areas.

The vehicle types considered in the scheme (for which SPIs are planned to be estimated) are: cars, heavy goods vehicles, motorcycles. Mopeds are currently not included because this vehicle type is treated in all countries together with motorcycles. From the point of view of DRL, motorcycles and mopeds are the same two-wheeled motorised vehicles. Therefore, the right name of this category would be: motorcycles and mopeds, or two-wheeled motorised vehicles. In a later phase of the work a possibility of introduction of a separate category for mopeds will be considered.

The legislation on DRL is also included into the SPI scheme because it is of a basic importance from the SPI point of view. For example, DRL usage rates cannot be interpreted practically in countries where the lights are switched on automatically. These data are not necessary for the estimation of the SPI, but for the right interpretation and comparison of the results.

Due to the same reason: a need for reasonable comparisons among the countries, general data on the country are also included in the scheme.

A more specific calculation of the SPIs is not necessary because the SPI set selected is relatively straightforward. However, the quality of the data should be further assessed to make the SPI calculation more reliable.

As demonstrated in Section 7.4, it is possible to calculate the indicators with the received data.

7.6 Further Proceedings

Presently, the responses are available from 17 countries. The table in Section 7.7.3 shows which countries replied to the questionnaire, for which countries the above defined SPIs can be calculated (i.e. 'realisable'), and for which periods the data are available.

7.7 Annexes

7.7.1 Step-sheet

0	**Level 0**	Describe:
	Key information: Exact definition of the problem; which operational conditions of road traffic are insecure and leading to crashes or fatalities as the „worst case"?	Unsatisfactory conspicuity of motor vehicles. Many crash injuries result from road users failing to see each other. Particular problems are elderly pedestrians failing to see motor vehicles in residential areas, car users failing to see two-wheel motorized vehicle users. Further problem is the unreliable estimation of the moving direction and speed of other motorized road users

1	**Level 1**	
a	Direct measurement possible?	Yes: Go to 1b /**No**: Go to 2

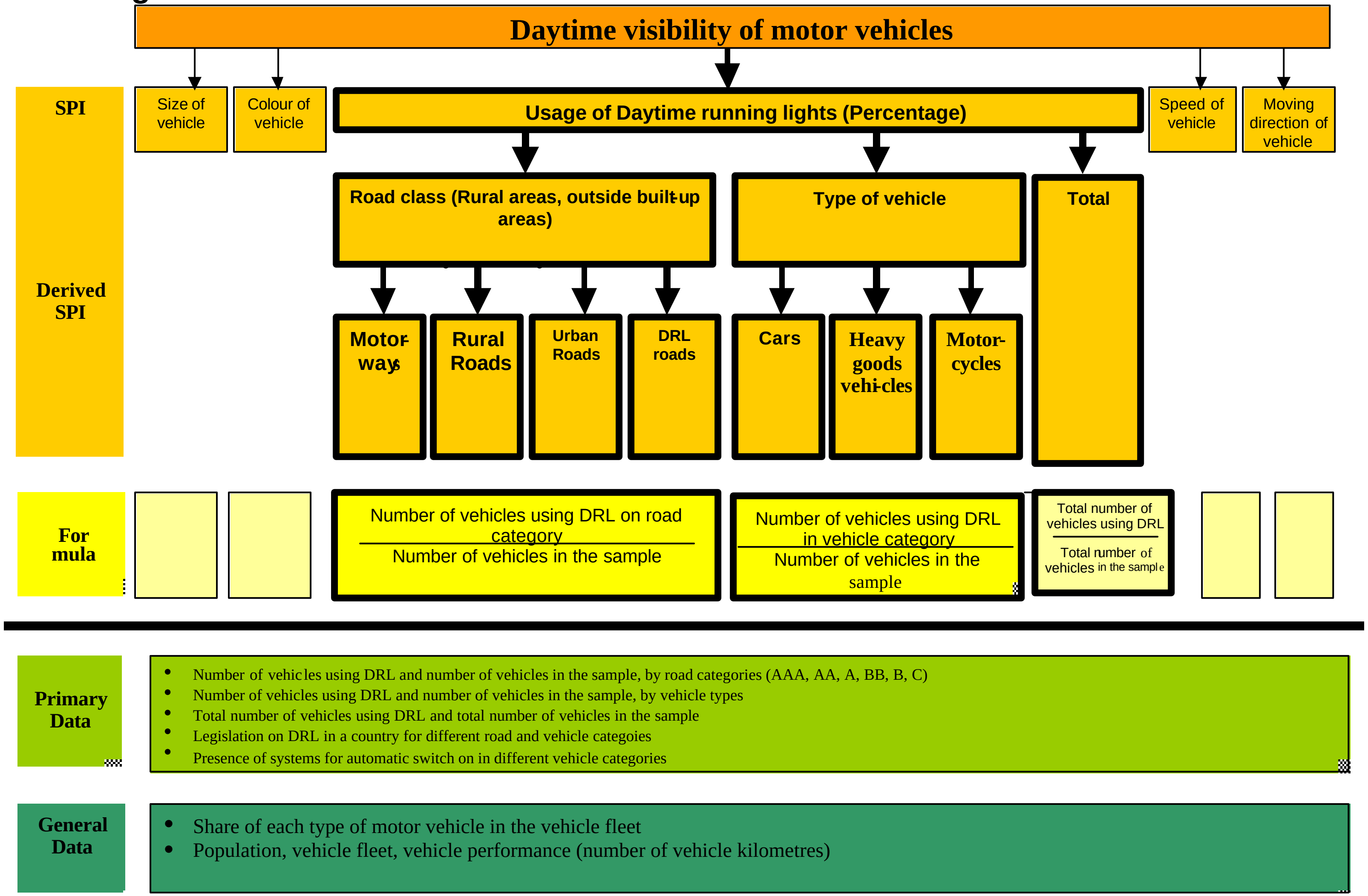
2	**Level 2**	
a	Are there suitable indirect indicators to describe the latent variable?	Yes: Go to 2b /**No**: Go to 3

3	**Level 3**	
a	Can the problem (level 0) be divided into sub-problems to get handled?	**Yes**: Go to 3b /No: Go to 4
b	The following questions have to be answered to explain the extent of the SPI referring to	

	the problem (level 0):	
	To which interventions the indicator is related?	To the usage of DRL
	What should the intervention affect?	The daytime conspicuity of motor vehicles and the reliability of the estimation of moving direction and speed of other motorized road users
	What should be achieved? How should the problem be solved?	Better daytime conspicuity of motor vehicles with daytime usage of headlights/daytime running lamps, easier and more reliable estimation of moving direction and speed.
	How should the intervention work?	It should improve the daytime conspicuity of motor vehicles and help the reliable direction and speed estimation.
	Which part of the problem is not covered?	
	To which interventions does the indicator not react? Justify why this indicator can still be used.	Other measures aimed at improving the detection of road users. It is easy to measure and it is proved that there is a close relation between this SPI and the number of multiparty daytime crashes.
	Is one indicator sufficient and why, or do we need more?	One indicator (rate of DRL users) is enough according to different road and vehicle categories
		⇩
		a) Query of availability. b) If it is predictable, that the data performing this indicator wouldn't be available, go to 4

4	**Level 4**	
a	No suitable SPI is available to indicate the problem (level 0) or the sub-problems (level 3)	Any measurement on a lower level can (only) indicate the application stage of a road safety measure.

7.7.2 Diagram


Daytime visibility of motor vehicles
SPI
Size of vehicle
Colour of vehicle
Usage of Daytime running lights (Percentage)
Speed of vehicle
Moving direction of vehicle
Derived SPI
Road class (Rural areas, outside built-up areas)
Type of vehicle
Total
Motor-ways
Rural Roads
Urban Roads
DRL roads
Cars
Heavy goods vehi-cles
Motor-cycles
For mula
Number of vehicles using DRL on road category
Number of vehicles in the sample
Number of vehicles using DRL in vehicle category
Number of vehicles in the sample
Total number of vehicles using DRL
Total number of vehicles in the sample
Primary Data
Number of vehicles using DRL and number of vehicles in the sample, by road categories (AAA, AA, A, BB, B, C)
Number of vehicles using DRL and number of vehicles in the sample, by vehicle types
Total number of vehicles using DRL and total number of vehicles in the sample
Legislation on DRL in a country for different road and vehicle categoies
Presence of systems for automatic switch on in different vehicle categories
General Data
Share of each type of motor vehicle in the vehicle fleet
Population, vehicle fleet, vehicle performance (number of vehicle kilometres)

7.7.3 Usability of Safety Performance Indicators (SPI) of task 4

(SPI is realisable, if the usage rates of DRL are measured and can be delivered at the moment)

Country	Is the SPI realisable for this country? (yes/no/partly)	For what period (e.g. annually) can the SPI be determined?	Comments/Restrictions
Belgium	No		
Cyprus	No		
Czech Republic	Yes	annually	
Denmark	No		
Germany	No		
Greece	No		
Spain	No		
Estonia	Yes	annually	
France	Yes	monthly	
Hungary	Yes	annually	
Ireland			no answer
Italy			no answer
Latvia	No		
Lithuania			no answer
Luxembourg			no answer
Malta	No		
Netherlands			no answer
Austria	No		
Poland			no answer
Portugal	No		
Slovakia			no answer
Slovenia			no answer
Finland			no answer
Sweden	No		
United Kingdom	No		
Norway	No		
Switzerland			no answer

Transport
Project co-financed by the European Commission, Directorate-General Transport and Energy

8 Vehicles

Andrew Morris, VSRC; Lucy Rackliff, VSRC; Mouloud Haddak, INRETS

8.1 Introduction

The SPI that this task is concerned with relates to the level of protection afforded by the vehicle fleet in each EU Member State. Where system failures lead to a crash, the potential of the vehicle itself to prevent (or indeed cause) injuries can determine whether the outcome is a fatality or something much less serious. In this case, the fatality not the crash is the "worst case", since unlike an SPI such as speeding, passive safety measures do not influence the occurrence of crashes. The insecure operational condition could therefore be defined as the presence within the fleet of a number of vehicles that will not protect the occupant well in a collision. What is needed is a measurable variable that will tell us what this number is, and what proportion of the fleet it represents in each Member State.

8.1.1 National General Conditions

The most widely used measure of the level of passive safety currently available in the EC is the EuroNCAP star rating. Crash testing is seen as one reliable method of assessing the relative level of protection a vehicle offers its occupants in certain common crash types (mainly Frontal and Side impacts). In 2000, the EC estimated that the EuroNCAP had become the most common cost effective vehicle safety action available to the EU. It commented that it had brought forward the benefits of new crash-testing legislation by 5 years and had raised industry best practice even higher. (http//:www.EuroNCAP.com). The EuroNCAP test procedures are based on those developed by the European Enhanced Vehicle-safety Committee (EEVC) for legislation, except the front impact speed is increased by 8 km/h so as to cover crash severity leading to most deaths and serious injuries. The pole test is based on standards developed in the US. Cars designed to do well in the EuroNCAP tests should offer improved protection in a wide variety of road crashes. The actual tests involve a front impact test at 64 km/h into an offset deformable barrier, a side impact test at 50 km/h, a side impact pole test at 29 km/h, and tests with pedestrian head and leg forms at 40 km/h. The injury risk is assessed using a number of sources including data from the dummy's instruments, examination of the high-speed film, and examination of the car by crash investigation experts. As there is no instrumentation to measure injury risk in certain areas, adjustments are also made to take account of other potential dangers, including those to different sized occupants. The EuroNCAP assessment protocol is then applied to arrive at the rating for each body region.
The EuroNCAP test programme provides information about a vehicle's comparative safety rating in its class available to the car buyers. It also acts as an incentive for manufacturers to improve the safety of their cars. This provides

a significant benefit in terms of injury reduction for both car occupants and vulnerable road users.
EuroNCAP has been responsible for a dramatic change to overall car safety. This is readily seen in how quickly manufacturers improve their safety equipment and the steps they take to do well in the tests. Real world injury studies carried out by SNRA (Swedish National Roads Administration) and SARAC (Safety Advisory Rating Committee) demonstrate a reduction in injury risk for every EuroNCAP star received.

There are several approaches that have been considered in this task. However the simplest and most cost-effective involves evaluation of fleet data. Three approaches could be taken:

1. Analysis by EuroNCAP score
2. Analysis by year of first registration
3. Analysis of fleet mix.

All of these methods require Member State fleet data in some level of detail, but the availability of these data is relatively unknown. It is not until the responses are returned by the National Experts that the availability can be established. Where the availability of good quality data permits an SPI based on test scores can be constructed. For other countries it may be necessary to construct only simple general indicators. In these cases it is proposed to compare the indicators in order to identify any differences in their performance.
This SPI will attempt to assess the national fleet as at 2003 or 2004 however, it is recognised that in some cases, individual Member States will need to go back further than this date in order to provide the necessary.

8.1.2 Resulting Difficulties

The main difficulty that is anticipated concerns the comparability of data between Member States. There is little consistency between Member States in terms of the safety-equipment with which individual makes/models are fitted. For example an XYZ Ford Fusion may have ESP/ECU as standard in one Member State but not in another that makes comparisons very difficult. In the case of optional equipment it is very difficult to determine which vehicles have been equipped and which have not.
The quality and availability of data is also expected to vary widely between countries. For example, some Member States record vehicles by year of first registration, some by year of production; some distinguish between makes and models, some do not. The extent of the problem associated with this issue will not be known until analysis of the data begins in earnest. Other potential difficulties include:

- How to categorize vehicles whose year of production does not correspond to year tested by EuroNCAP
- How to identify the level of equipment in models where features are optional extras in one country, but standard in another
- How to deal with makes which have very limited NCAP tests (for example, Jaguar)

It is possible that only a small percentage of some fleets will contain vehicles that have been subjected to the test-programme.
Furthermore, the EuroNCAP rating applies only to a certain percentage of vehicles that are variants of a particular make/model. However, the data supplied by the Member States should be specific enough to allow discrimination according to which vehicles have been subjected to the test-programme.
There are also limitations with the approaches that are proposed since analysis of the date that are provided will not pinpoint differences in risk of injury to various sectors of the population in each Member State. For example, there are known differences injury risk according occupant age and sex. Furthermore the EuroNCAP test procedures only involve single-point testing for frontal and side impacts that require one test-speed and one impact condition for each scenario. It is well known that real-life crashes are much more diverse in nature in terms of collision speed and, direction of crash-force, object struck etc., and it would be impossible for the EuroNCAP programme to cater for all of the possible combinations of scenarios.
Such factors can only be examined in detail through in-depth crash studies. However, such studies are only currently being conducted in a handful of the 25 EU Member States. Even these studies have different operational characteristics in terms of methodological approach.

8.2 Constructing Indicators

A direct indicator of vehicle safety performance of the national fleet in each Member State could not be attained, and so inferences have to be made. This is because it is not possible to measure directly the capacity of the vehicle to protect in every type of crash (frontal, sideswipe, etc), or for every type of occupant (rear passenger, front passenger; child, elderly). However, performance in crashworthiness tests such as EuroNCAP is the best information we have from which to draw inferences.

It was possible to find an indirect indicator. More modern European vehicle fleets that have state-of-the-art vehicle designs should theoretically result in reduced casualty levels. It is generally recognised that cars designed to meet EuroNCAP test procedures are more robust and therefore offer better protection to vehicle occupants in comparison to vehicles that were designed before the development of the EuroNCAP test programme. Hobbs (1996) says of EuroNCAP: “There is good evidence that manufacturers respond…… and that this is reflected in road accident casualties”.
An indication of the proportion of vehicles in the fleet that have been tested according to EuroNCAP in each individual Member States should therefore give an indication of the safety rating of the fleet.
In theory, the national vehicle fleets that have the greatest proportion of high star ratings according to EuroNCAP should be the safest in the EU.
The data supplied only relates to passenger vehicles; the situation for other vehicle types cannot be measured by this method.

In each Member State, it is acknowledged that a large percentage of the vehicle fleet will not have been subjected to EuroNCAP test procedures. Other indicators (such as vehicle age) could be considered as an alternative

The resulting data that will be provided in response to the questionnaires will be very general and some assumptions will need to be made together with some data manipulations. The indicators will not be described in formulas – a simple indicator will involve the following:

The proportion of the vehicle fleet rated as;
1 star
2 star
3 star
4 star
5 star
No stars (i.e. before the introduction of EuroNCAP).

A simple system will be developed to take into account these proportions and it is possible that a weighting procedure will be used to give a rating of the overall vehicle fleet.

Other indicators that will be examined include analysis of (1) overall age of the vehicle (by studying year of first registration) and (2) analysis of the overall fleet mix.

1. Overall Age of the Fleet

   The overall age of the fleet should give a general indication of the safety of the fleet. This is because it is generally recognised that newer vehicles offer more protection in the event of a crash than older vehicles for two main reasons;

   (a) Newer vehicles are much more likely to be equipped with state-of-the-art safety technology and are likely to be designed from a structural point of view to be more 'crashworthy' in the event of a crash. This implies that in modern vehicles, crash-energy is managed more efficiently by the vehicle structures thereby reducing the risk of energy-transfer and hence injury potential to the occupant.

   (b) Older vehicles are more prone to rust and therefore do not generally perform as well in the event of a crash since the crash-energy is 'managed' much less efficiently by the vehicle with greater associated risk of injury.

2. Vehicle Mix

   The vehicle fleet mix should give an indication of the safety of a fleet since there are issues of vehicle-to-vehicle compatibility that have a well-recognised effect on occupant outcomes in crashes. For example, there may be greater numbers of car-to-truck/bus crashes in Member States that have a higher proportion of truck/buses in the fleet. It may follow that the fleet in such Member States are more prone to serious injury outcomes.

8.3 Questionnaire

The questionnaire that has been developed used a very simple question to obtain the necessary data that will eventually lead to the development of the SPI for Vehicle Safety. Respondents were simply asked to provide a spreadsheet detailing the total vehicle fleet by age, make, and model.

8.4 National Responses

The two main problems encountered by the national experts in providing the data to build this indicator were the size of the data file required and the fact that the data collected nationally in some countries is not detailed enough. A summary is provided below of the responses received.

status	Full response	Full response may be possible	Some data sent	Data unavailable	No response
Number	8	2	4	2	11

Total = 27 (EU 25 + Norway and Switzerland)

In the cases where a full response may be possible, data has been requested by the national expert, but not received yet (Greece), and in the case of the United Kingdom a more precisely defined request must be submitted by SafetyNet.
In the case of the 4 countries that sent some data; data by make and model was not available for the Czech Republic, Denmark and Norway. These countries all sent a breakdown of numbers of vehicles by year of registration or year of production only. In the case of Malta, a change in data collection meant that the data could not be supplied for the year requested. A sample of data has been sent.
Austria and Switzerland stated that the data could not be provided as requested. It will be necessary to discuss with the relevant experts what data is available, and how it could be used to measure the level of protection afforded by the national fleet in those countries.
It is encouraging that 8 countries sent a full response to this section, despite the fact that a considerable amount of detailed information was requested.

8.5 Searching for Appropriate Indicators

For at least 8 countries it will be possible to assign a EuroNCAP rating to the vehicle fleet in order to calculate a performance indicator for vehicles (passive safety). For at least 6 others it will be possible to calculate a simple general indicator based on either fleet mix, vehicle age or both. It is proposed that a pilot study be performed using a country whose data can be used for all three of these SPIs (for example Cyprus), and on that basis the three indicators can be compared for their accuracy and usefulness. It is not anticipated that a further questionnaire will be necessary, though modifications to the data may be necessary in order to make the best use of the (sometimes limited) data that is available.

8.6 Further Proceedings

The first data set will be used as a pilot to test the indicator for reliability. The assumptions might be modified and the indicators might be composed again e.g. by giving different weights to indicators. Furthermore the comparability across countries will be tested.
The data are currently being analysed and the first results are not yet available. These will be supplied as an addendum to this Report.

(Ghazwan al-Haji: 16th ICTCT workshop, Road Safety Development Index (RSDI), 2003)

8.7 Conclusions

Providing an indication of the safety of a fleet is not an easy process and the results as determined by the methodology presented in this report should not be taken to give a definitive indicator of the overall safety of a fleet. It is necessary to consider the interdependency of other SPIs, though a supplementary methodology may be required to achieve this. For example, the SPI of vehicles (passive safety) with which this task is concerned is clearly closely related to elements of the SPI for protective systems (seatbelts, airbags, and their use by occupants). Also there are inter-dependencies between different countries; a country which has land borders with poor scoring countries may find the accuracy of the SPI is affected by this. It is possible that transformation rules may have to be calculated to take account of this. There are also possible relations to be explored with other SafetyNet Work Packages, for example Work Package 2 (Risk Exposure Data). This could asses the different outcomes that result from having a very safe fleet which is driven extensively, compared to having a less safe fleet which is far less heavily used.

The main point to consider is that the Passive Safety of Vehicles SPI is considered as an indicator only, and not as a rigorously determined statement of fact.

8.8 Annexes

8.8.1 Step-sheet

0	**Level 0**	Describe:
	Key information: Depending on their age, size and design, different vehicles will perform differently in the	In the case of this performance indicator, the insecure operational condition is not necessarily the factor that leads to the crash, but rather one that leads to a preventable injury. So in a country

	event of a crash.	where a higher proportion of the fleet is made up of cars with a good level of protection, serious and fatal crashes will form a smaller proportion of the total.

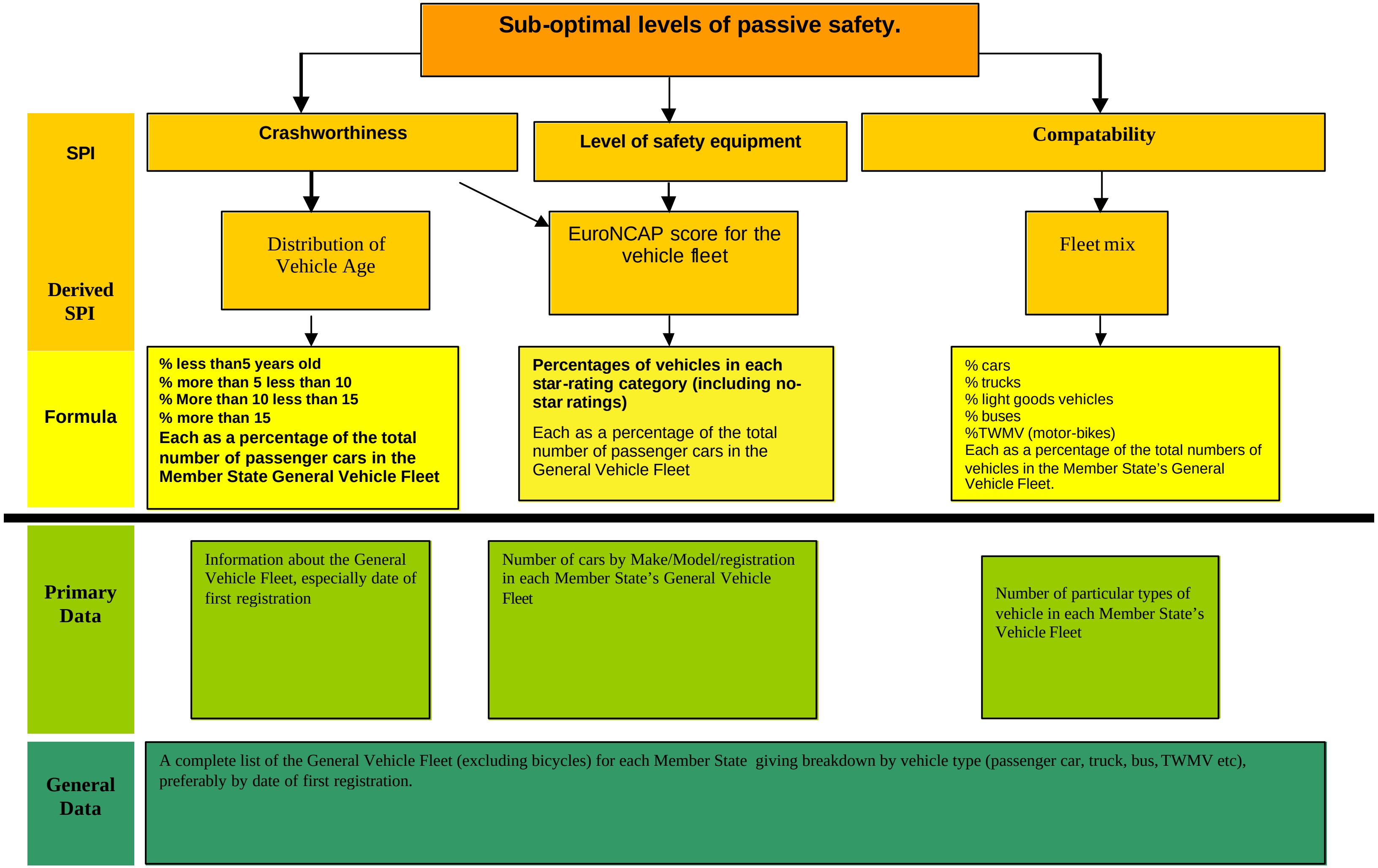
1	**Level 1**	
a	Direct measurement possible?	No

2	**Level 2**	
a	Are there suitable indirect indicators to describe the latent variable?	Yes
b	Which indirect indicators are suitable to describe the latent variable and how?	It is not possible to directly measure the level of protection offered by the fleet. However, the results of EuroNCAP testing provide an indication of how certain cars will perform. Also, in general more modern cars are likely to perform better than older ones and larger vehicles will perform better than smaller. By looking at the fleet in terms of the proportion of vehicles that have been tested (and the scores), the age of the fleet, and the mix of vehicles, it should be possible to derive a score for protection/passive safety.
		⇩
	Query of availability:	At the very least it is anticipated that countries should be able to provide vehicle registrations by vehicle type and by year of first registration. Some will also be able to provide registrations by make, model, and vehicle type. b) If it is predictable, that the data performing this indicator wouldn't be available, go to 3

3	**Level 3**	
a	Can the problem (level 0) be divided into sub-problems to get handled?	Yes
b	The following questions have to be answered to explain the extend of the SPI referring to the problem (level 0):	
	To which interventions the indicator is related?	Legislation relating to design and maintenance standards. Consumer information and protection with respect to vehicle purchase. Policy regarding use of protective systems (e.g. fitting of seat belts) Taxation policy, affecting the relative price of

		second hand/new cars.
	What should the intervention affect?	Intervention should affect use/misuse of passive safety systems, the type of equipment people prioritize when they purchase a vehicle, and the general composition of the fleet.
	What should be achieved? How should the problem be solved?	Encouragement of governments, manufacturers and consumers to place a high emphasis on the ability of vehicles to protect occupants in a collision.
	How should the intervention work?	Reduction of the number of poorly maintained, older and less sophisticated vehicles in the fleet.
	Which part of the problem is not covered?	Incompatibility (for example, large vehicles colliding with very small ones), non-domestic traffic
	To which interventions does the indicator not react? Justify why this indicator can still be used.	Any changes in technology or policy that do not coincide directly with make/model/year tested by EuroNCAP. While there may be cases where EuroNCAP lags behind changes, it is a good general indicator of the protection offered by vehicles. As such, while there may be specific cases where it is not an ideal indicator, it will provide a good picture of the general situation.
	Is one indicator sufficient and why, or do we need more?	More than one indicator may be necessary to take account of the compatibility of vehicles. Regardless of the general level of protection offered by the car fleet, fatalities could be affected by the presence in the fleet of much larger or smaller vehicles (for example goods vehicles, motorcycles). Also it may be advisable to look at the proportion of foreign traffic in a Member State. Where foreign flows are significantly high, this could affect overall passive safety performance which would not be reflected in domestic vehicle registrations.
		⇩
		a) Query of availability. b) If it is predictable, that the data performing this indicator wouldn't be available, go to 4

8.8.2 Diagram


Sub-optimal levels of passive safety.
SPI
Crashworthiness
Level of safety equipment
Compatability
Derived SPI
Distribution of Vehicle Age
EuroNCAP score for the vehicle fleet
Fleet mix
Formula
% less than5 years old
% more than 5 less than 10
% More than 10 less than 15
% more than 15
Each as a percentage of the total number of passenger cars in the Member State General Vehicle Fleet
Percentages of vehicles in each star-rating category (including no-star ratings)
Each as a percentage of the total number of passenger cars in the General Vehicle Fleet
% cars
% trucks
% light goods vehicles
% buses
%TWMV (motor-bikes)
Each as a percentage of the total numbers of vehicles in the Member State's General Vehicle Fleet.
Primary Data
Information about the General Vehicle Fleet, especially date of first registration
Number of cars by Make/Model/registration in each Member State's General Vehicle Fleet
Number of particular types of vehicle in each Member State's Vehicle Fleet
General Data
A complete list of the General Vehicle Fleet (excluding bicycles) for each Member State giving breakdown by vehicle type (passenger car, truck, bus, TWMV etc), preferably by date of first registration.

8.8.3 Usability of Safety Performance Indicators (SPI) of task 5

Country	Is the SPI realisable for this country? (yes/no/partly)	For what period (e.g. annually) can the SPI be determined?	Comments/Restrictions
Belgium	Yes		
Czech republic	Partly		Alternative data sent
Denmark	Partly		Alternative data sent
Germany	Yes		
Estonia	Yes		
Greece			Expert awaiting data
Spain	Yes		
France			Data not sent yet
Ireland			No data sent yet
Italy			No data sent yet
Cyprus	Yes		
Latvia	Yes		
Lithuania			No data sent yet
Luxembourg			No data sent yet
Hungary			No data sent yet
Malta	Partly		Alternative data sent
Netherlands			No data sent yet
Austria	Maybe		Discussion needed
Poland			No data sent yet
Portugal	Yes		
Slovenia			No data sent yet
Slovakia			No data sent yet
Finland			No data sent yet
Sweden	Yes		
United Kingdom	Maybe		Discussion needed
Norway	Partly		Alternative data sent
Switzerland	No		Data not available

9 Roads

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9.1 Introduction

Infrastructure layout and design has a strong impact on the safety performance of the road transport system. Many ongoing practises in infrastructure research apply sampling of casualty data for safety assessment (a posteriori). In addition, crash prevention can be improved by early (a priori) assessments of safety hazards e.g. by monitoring the physical appearance of the road environment and the operational conditions of traffic. This is what Safety Performance Indicators (SPI) dedicated to roads are aiming at. This chapter describes considerations for the development and definition of SPIs in the roads domain, as a deliverable of task 6 within SafetyNet WP 3.

The safety performance of the road transport system is the result of the (right) combination of the functionality, homogeneity, and predictability of the network, the road environment, and the traffic involved. Relevant questions that arise are: is the right road placed at the right place in the network from a functional point of view? Does the physical appearance and characteristics of a road comply with its functionality? And as a consequence, is traffic safety sufficiently guaranteed? To answer these questions, the safety problem has to be organized in at least two levels: the road network and individual road design. In order to develop or find suitable SPIs, quantitative relations between road network, road design elements, road characteristics and road safety have to be known sufficiently well. However, knowledge 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 elements and facilities, SPIs will be proposed. The development of SPIs is a creative process that needs to be continued. This document describes the state-of-the-art of the process at this stage and is input to ongoing work.

In this first section, background information on safety features of road network and road design is described. The second section presents a literature review of a selection of relevant studies and some closely related projects. It is meant to define scientific starting points and to identify links to current initiatives, in order to facilitate the selection and development process of SPIs. Section 9.3 gives a concise overview of crash statistics concerning countries of the partners in this task. It is used to identify crash types and road types that can be related best to infrastructure characteristics. In section 9.4 general definitions of SPIs are given and possible SPIs for road design and network are determined. At the end of this section a hierarchical overview of the proposed SPIs is presented. The set of identified SPIs is input to the questionnaire that is described in section 9.5. This questionnaire has been sent to the national experts to be filled in. Section

9.6 shows the first national responses. Section 9.7 draws conclusions on the development of SPIs related to road design and road networks.

In the next phase of the project, the feasibility of the proposed SPIs will be assessed in more detail by a closer examination of the country responses on the questionnaire. This will result in a description of the requirements of SPIs and practises for implementation.

9.1.1 Road network

A road network fulfils three functions:

- Flow function: facilitate road users to go from origin to destination;
- Area distribution function: to enter and leave an area;
- Access function: facilitate road users to reach an individual dwelling, shop, or company.

Roads and streets, generally speaking, fulfil simultaneously more than one function. This phenomenon contributes (greatly) to making roads less safe. That is why, in a sustainably safe road network, each road should only have one function. Together, these three road types form a network that (schematically) can look like figure 9-1. The actual category must, of course, be consistent with the traffic function of the connection. If this is not the case there will be an insecure operational condition at the road network level.

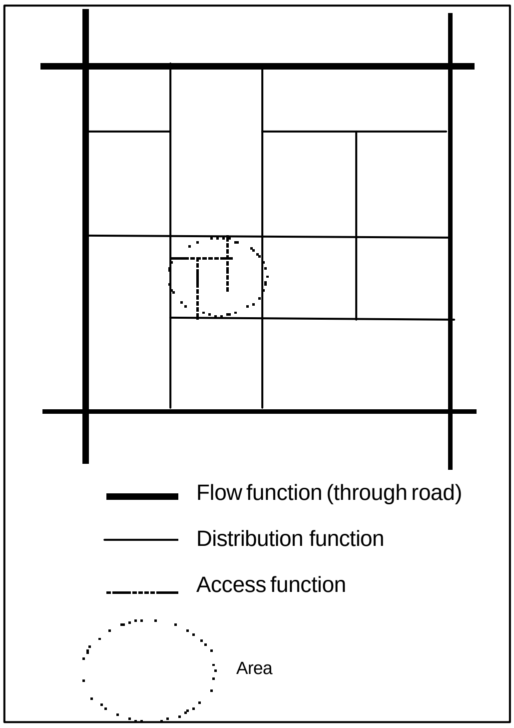


Figure 9-1: Traffic functions assigned to the different road classes in the road network

9.1.2 Road design

Road design and construction determine many of the conditions in which road users have to act. A road designer should design with safety in mind in order to create optimal conditions for the road users. However, the knowledge about relations between road design elements and (the resulting) road safety is still growing and by far not completed.
In sustainably safe road transport, the human road user is the measure of all things. This means that traffic, its surroundings and rules (the traffic and transport system) must be adapted to the limitations and possibilities of the road users. This is an efficient approach since over 90% of crashes result from human errors. Much effort should be put into preventing crashes and in case of unavoidable crashes, the crash severity must be reduced to the absolute minimum. This means that e.g. the infrastructure should be forgiving, both to the occurrence of human error and to the consequences of remaining error.

A high level of homogeneity is aimed at in sustainably safe traffic. This means that a mix of road users with different speed and characteristics (mass, protection and motorization) should be prevented. For this purpose, infrastructure has to be set up and designed such that there will be small speed and mass differences between transport modes that can collide. Table 9-1 shows the exceptional position of cyclists and pedestrians which are much more vulnerable than e.g. occupants of buses and lorries. In this chapter the term vulnerable road users (VRU) is used for these non-motorized means of transport.

		Motorized (high speed)		Non-motorized (low speed)
		Protected	Non-protected	
Mass	big	lorry bus tram	-	-
	medium	car van	motor cycle	-
	small	-	moped	bicycle pedestrian

Table 9-1: Differences between traffic participants in mass, physical protection and motorization

Although the relations between road design elements or road characteristics and road safety are not well known, we do know that certain conflicts and related crashes can be prevented by choosing the right elements or facilities. As an example, a bicycle path will prevent crashes between cyclists and cars on road sections. The presence of such a relevant facility gives an indication of the safety level. The relevance of these elements or facilities can be determined by analysing the safety problems in the existing road system.

Transport
Project co-financed by the European Commission, Directorate-General Transport and Energy

9.2 Literature Review

In this section, a concise series of studies and projects, concerning safety related to the quality of the road network and road design is discussed. It is not meant to give a complete overview of all relevant progress in this working field, but rather to consolidate scientific starting points and to identify links to current initiatives, in order to facilitate the selection and development process of SPIs. Some of the publications go into more detail than actually considered appropriate for defining SPIs at this stage. However, the knowledge described there is still valuable for understanding the context of the safety problem and for early understanding of the boundary conditions of SPIs that will be proposed later on in this chapter.

The OECD report 'Safety strategies for rural roads' [29] describes the importance of road safety improvements especially on rural roads. This study distinguishes three main crash types on these roads: running off the road, head-on collisions and collisions at intersections. The EuroRAP project introduces risk maps that rate the road safety level. Beside this, EuroRAP introduces a standard road inspection for safety features which results in a Road Protection Score (RPS). The RPS appears to relate to the same type of philosophy that is being aimed at in SafetyNet. EuroRAP distinguishes four main crash types on the main rural roads in Europe. In addition to the three crash types of the OECD study, crashes with vulnerable road users are identified. In the European project SAFESTAR, research has been carried out on roadside safety and design consistency. However, SAFESTAR primary deals with roads that are part of the Trans European Road Network between main European centres of population. Other research discussed in this section concerns the relation between road safety and the operational and physical characteristics of road infrastructure. The American IHSDM is an example of a project in which similar SPIs are used to predict safety on rural roads. At the regional level, network and design quality aspects of a safe road infrastructure, in this case a sustainably safe road infrastructure, are discussed in the Dutch study *Quality aspects of a sustainably safe road infrastructure.*

9.2.1 OECD Safety strategies for rural roads

In 1999 the Organisation for Economic Co-operation and Development (OECD) reports that each year, more than 75 000 people are killed on rural roads in OECD Member States [29]. These deaths are related to by economic costs on the order of $135 billion per year. According to this report the relative importance of rural road fatalities in relation to total road fatalities has increased from less than 55% in 1980 to more than 60% in 1996. Because OECD countries have experienced a reduction in the total number of road crash fatalities, it is clear that motorway and urban road safety improvements have been more successful than those on rural roads.

Around 80% of all crashes on rural roads falls into three categories: single vehicle crashes, especially running off the roads (35%), head-on collisions

(25%) and collisions at intersections (20%). Driver behaviour and road infrastructure are the key contributing factors to these types of crashes. Rural crashes are scattered over the entire rural road network. A main conclusion from this report is that the rural road system itself has inherent characteristics that significantly contribute to the high number of crashes and the high risks.

Various safety measures that can improve rural road safety are suggested throughout the report. Inappropriate and excessive speeds are a key factor in rural road crashes because the actual speeds on rural roads are relatively high under circumstances where these high speeds cannot be safely maintained. Rural roads require constant speed adaptation to the regularly changing situations and circumstances, thus increasing the opportunities for human errors and leading to higher risks for crashes. The OECD-report therefore concludes that reducing inappropriate and excessive speed together with safe road design and roadside design are the key elements to improve rural road safety.

9.2.2 The EuroRAP Road Protection Score

The European Road Assessment Programme (EuroRAP) was designed as a complementary activity to the European New Car Assessment Programme (EuroNCAP), developed in the 1990s. EuroNCAP involves crash tests of new cars and awards each vehicle with a star rating depending upon the protection given. According to EuroRAP [2003] a similar rating system for roads should help optimize the combined effect of road and vehicle safety. EuroRAP was therefore piloted to rate Europe's various roads for safety.

The Road Protection Score (RPS)
EuroRAP developed two standard test protocols. The first introduces measures and maps the rate at which people are being killed and severely injured, and the second is a standard road inspection for safety features. The programme focuses on dealing with fatalities and serious injuries within the philosophy that roads and vehicles should be developed together using best-affordable technology to protect against injury, and particularly against high-energy impacts.

Besides the so-called risk mapping, the EuroRAP programme contains a direct visual inspection of road quality. This is different from a normal road safety audit in that its aim is to assess the general standard of a route, not identify individual sites of concern. The aim of this survey is to produce a score for each route section that enables it to be compared with other sections. The RPS focuses on the road design and the standard of road-based safety features. "Protection" in this sense describes protection from crashes (elements of primary safety) and protection from injury when collisions do occur (secondary safety). The RPS should therefore be related as closely as possible to:
• the design elements known to affect the likelihood of a crash occurring;
• the safety features known to mitigate injury severity.

These two factors can be combined in a risk matrix to provide an overall assessment of risk for a route. The aim of this assessment is to evaluate the safety that is “built in” to the road through its design, in combination with the way traffic is managed on it. The approach recognises that road user errors cannot be removed completely, and therefore the design needs to provide a forgiving environment for those who are involved in crashes whilst driving within the law.

Crash types
According to EuroRAP four types of crash contribute about 80% of all fatal and serious crashes on major roads outside urban areas. The four types are head-on “meeting” crashes, crashes at intersections, single vehicle run-off-the-road crashes and crashes involving vulnerable road-users (VRU). The total percentage is common to many countries, but the distribution of the crash proportion between the four types differs according to the existing nature of the road network and the traffic patterns in each country. EuroRAP analyses show that, for example, the dominant factor in Sweden is head-on collisions, with intersection crashes making up a relatively small proportion of the total. The opposite is true in Great Britain. EuroRAP warns that care needs to be taken in interpreting differences between countries as the crash recording systems define these crash types in different ways. This matter is also discussed in section 9.3 Crash types and statistics.

The Road Protection Score is based on the four main crash types listed above. For each of the four crash types EuroRAP proposes some measures to improve road safety. This is described in Annex 9.9.1.

9.2.3 SAFESTAR

Research on roadside safety and design consistency was carried out within the EC fourth framework Project SAFESTAR (SAFEty STAndarts for Road design an redesign). SAFESTAR mainly deals with roads that are part of the Trans-European Road Network between main European centres of population. Furthermore a selection of other research, concerning the relation between road safety and the operational and physical characteristics of road infrastructure, is discussed.

Roadside Safety
There are more differences than similarities in the views of European countries on how to design the shoulders of motorways and express roads to make them safer. Sometimes the standards are presented on which the guidelines are based; but this is usually not the case. In the report *Criteria for roadside safety of motorways and express roads* [31], Schoon takes the perspective "injury prevention at off-the-road incidents", and makes suggestions for European design norms to ensure safe shoulders. The basis for this suggestion is the "Concept of a safe roadside". Knowledge has been gathered from European and American studies, and an inventory has been made from the completed questionnaires from 13 European countries.

It appeared that European standards are sometimes based on American research of the 1970s. This comes as no surprise because the US carried out roadside research in a systematic way. There are, however, reservations about the application of American research to Europe: the size of American cars was (then) much larger and the speeds driven on American roads were (then) lower, than in Europe.
Research in the Netherlands forms the counterpart of the American research. This research was fundamental in the sense that it examined the important design aspects: obstacle-free zones, slopes, fixed objects, crash cushions, and safety barriers (concrete and steel). These studies, conducted in the 1980s, have been underexposed because they were only published in Dutch.

In this report a strategy is described to design a safe roadside for motorways and express roads. This report proposes 'European standards' for Roadside Safety. To summarize, it can be stated that possibilities exist to reduce the relatively high percentage of serious crashes involving obstacles and dangerous zones. The safest way is to create obstacle-free zones or safe slopes where vehicular manoeuvres are possible. The proposed values for the width of these zones are given in Chapter 8 of the SAFESTAR report [31]. If there is a need for dangerous objects, such as lighting poles, to stand in this (otherwise) obstacle-free zone, they can be made to yield easily in case of a collision. Isolated rigid obstacles can be shielded with a crash cushion. The use of safety barriers is the next best solution, when a collision with it is less dangerous than hitting the obstacle. Because of this safety barriers are often involved in crashes; in some European countries in approximately 20% of all injury crashes on motorways. For motorcyclist safety, a shoulder with isolated obstacles is much to be preferred than a shoulder that is completely shielded by a safety barrier, unless the safety barrier itself was designed to secure low aggressiveness to motorcycle occupants.

Design Consistency
In the SAFESTAR project *Design consistency of horizontal alignment in rural roads* [2] research on design consistency was carried out. Consistency can be defined as the agreement between the characteristics of the geometric design of a road and the unfamiliar driver's expectations [14]. Expectancy is the tendency of a driver to react to a situation, an event or a set of information in a systematic way, based on his/her past experience.

The concepts of driver expectancy and geometric consistency are important in safety and road design, because inconsistencies on a road can surprise drivers and lead to errors that increase the crash risk [15]. In fact, when a driver's expectancies are violated, the probability that a situation will be correctly identified is significantly reduced. The incorrect identification of a situation greatly reduces the time available for executing the manoeuvres needed to successfully deal with it [16]. Expectancy may intervene at two levels [17]: a priori expectancies are related to long term strong representations (for example, a driver does not expect pedestrian crossings in a motorway-like road); ad hoc expectancies are created along a specific journey (for example, on a flat rural area, after several long tangents connected by long radial curves, a driver does not expect a sharp curve). *A priori* expectancies are related to road network characteristics; *ad hoc* expectancies are mainly constructed from road design characteristics.

There are several methods for representing driver expectancy and for evaluating the design consistency of a road [2]. The most used ones are based on selected parameters of the unimpeded speed distribution (mainly the average and the 85th percentile), and on their variation from road section to road section [2, 14, 18, 19, 20, and 21]. Their application requires the use of a procedure for estimating the unimpeded speed profile along the road. Unimpeded speeds are observed under very low traffic volumes (free-flow conditions). Other methods are related to geometric indices derived directly from the design characteristics of the road layout [2, 21 and 22] or require the estimation of driver workload [2], which may involve objective [14 and 20] or subjective evaluations [3]. Some of these methods for evaluating design consistency were directly related to crash risk using statistical models [1, 23, 24, and 25].

It was concluded that models incorporating selected road characteristics, average annual daily traffic (AADT) and explanatory variables related to the driver expectancies (such as speed reduction and average speed, or driver workload) have improved goodness of fit. The relation between road safety, road characteristics and Design Consistency is examined in more detail in Annex 9.9.2.

9.2.4 Interactive Highway Safety Design Model (IHSDM)

The US Federal Highway Administration (FHWA) developed an Interactive Highway Safety Design Model (IHSDM) for use by highway designers to incorporate more explicit consideration of safety and operational effects into the highway design process. IHSDM consists of a set of computer tools that can work interactively with the Computer Aided Design (CAD) systems used by many agencies to design highway improvements. The components of the IHSDM include a Policy Review Module (PRM), which covers roadside safety, a Crash Prediction Module (CPM), an Intersection Diagnostic Review Module (IRM), a Design Consistency Module (DCM), and some other modules. Initial priority in IHSDM development is being given to evaluation of rural two-lane highways.

According to IHSDM the independent variables representing geometric design, traffic control and traffic volume used in the modelling of roadway segment crashes included:
- Exposure (million vehicle miles of travel).
- State in which the roadway section is located (Minnesota/Washington).
- Lane width.
- Shoulder width.
- Roadside hazard rating.
- Driveway density.

• Horizontal curvature.
• Grade rate for crest vertical curves.
• Percent grade for straight grades.

All of these independent variables were found to have a statistically significant relation to roadway section crashes.

The roadside elements include fore slope, backslope, ditch, obstruction offset, bike facilities, driveway density, and hazard rating. The roadside hazard rating system is based on the system developed by Zegeer [30] to characterize the crash potential for roadside designs found on two-lane highways. Roadside hazard is ranked on a seven-point categorical scale from 1 (best) to 7 (worst).

Design consistency is evaluated using estimates of the expected 85th percentile, free-flow, passenger vehicle speeds along a highway (operating speed profile model). The influence of vertical grades on operating speed is considered using a special algorithm.

The design consistency module estimates two measures that are used to locate locations where additional attention may be warranted: the expected difference between estimated 85th percentile speeds along the highway and the design speed of the highway; and the expected reduction in estimated 85th percentile speeds from an approach tangent to its succeeding horizontal curve.

9.2.5 Quality aspects of a sustainably safe road infrastructure

During the last few years, the Sustainable Safety concept has become the leading traffic safety philosophy in the Netherlands. In the meantime, knowledge about the layout of sustainably safe road infrastructure has become widespread [34, 35].

Within the development and implementation of the Sustainable Safety concept there are still some open ends. For instance, it should be noted that, for not all layout elements it is known precisely a) how they influence the crash probability, and b) the extent to which this probability would change if a preferable layout was deviated from [32]. A second problem yet to be solved is that not all principles of Sustainable Safety have been transformed into design requirements. In particular, requirements for being able to plan sustainably safe road networks are missing. A third problem refers to the realisation of a sustainably safe infrastructure. In practice it seems that it is not always so simple to meet the requirements and to decide whether the actual, practical experiences already indicate the need to modify the requirements.

The underlying question is to what extent a greater road safety improvement in the Netherlands can be achieved if a higher quality implementation of a sustainably safe infrastructure had been achieved.

Dijkstra [32] has formulated new draft requirements for network features. These additional requirements concern the function of a connection in an area, the intersection type, the detour factor, and the route choice. In Dijkstra's study, an extensive addition to the layout requirements was also drawn up for intersections and road sections. Most of these requirements can be traced back to the requirement that certain conflicts on a sustainably safe road category should not occur and, if a conflict cannot be avoided, only small speed differences are permitted. Dijkstra recommends to add these extra features to the existing requirements. Dijkstra attempts to investigate the extent to which the current and planned road infrastructures meet the sustainably safe requirements. To do this, both the network features (road categorization) and the road sections and intersections features have been tested in a region in the Netherlands (part of the southern province of Limburg). Based on this sample, there is, at the most, an indication for the situation in the whole country.

Connections between residential centres

The type of connection (road class) between residential areas and business districts depends on the number of people (in vehicles) using the connection, e.g. two main (regional) cities should be connected by a motorway, while a village should be connected to a main city by a minor rural road. Our assumption is that a road network is performing safely when the actual road classes (including the facilities in an area) fit the types (or level) of connection following from the size of each area or centre. This size will be expressed by the number of inhabitants, since population is assumed to determine to a great extent the number of journeys to and from a centre.

For five centre types, 4 different sorts of connection are possible; see also Table 9-2. Each type of connection has it's own position in the road network and a characteristic traffic volume. The capacity of the connection (the number of motor vehicles per normative rush hour) has to fit this. The (sustainably-safe) road categories must fit the desired capacity and must be consistent with the traffic function of the connection

It is recognised that (residential) centres differ from each other in many ways. As an alternative for population as the most distinctive factor, the German guidelines for road categories [33], apply the functions of each centre in an area (government, laws, culture, service) in order to divide the centres into four classes. In between, there are various types of connections that fit the traffic that is the result of these functions (production/attraction of people and goods).

centre type	centre type				
	1	2	3	4	5
1	SW-I	SW-I	SW-II	via centre type2/3	via centre type 2/3/4
2		SW-II	SW-II	GOW-I	via centre type 3/4
3			GOW-I	GOW-I	GOW-II
4				GOW-II	GOW-II
5					ETW

Centre type: depending on number of inhabitants (city size).
In the Netherlands three sustainably safe categories are defined: sw = through-road with flow function (type I or II); GOW = distributor road (type I or II): and ETW = access road)

Table 9-2: Connections of centre types: road categories in the Netherlands

In the chosen system there is no need for direct connections between type 1 and 4, between type 1 and 5, and between type 2 and 5 centres; these connections (may) run via larger centres. In any case, such connections can already be present in practice, or be considered necessary for other reasons (than intended here).

Case study in the Netherlands
The three Dutch sustainably safe principles of functionality, homogeneity, and recognition/predictability are the starting points for the layout of road segments and intersections. However, the functionality also contains a dimension to be found at the network level of the traffic infrastructure. In order to comply, a number of additional requirements have to be formulated. Dijkstra selected a region in the Netherlands, the southern province of Zuid-Limburg, in order to study whether an existing and planned regional road network can meet these sustainably safe network requirements. Dijkstra shows that, to a large extent, the tested network meets the requirements made. However, it is striking that only a limited number of intersections of two distributor roads meet the current requirement, namely a roundabout.

9.3 Crash types and statistics

For a first investigation of infrastructure related safety problems, they can be reduced to possible conflicts between road users, in which road characteristics are assumed to play an important role. Five types are considered: vehicles driving in the same direction, merging or diverging vehicles, crossing traffic participants, opposing vehicles and finally single vehicles driving off the road (table 9-3). All conflict types include conflicts with unprotected, non-motorized road users (cyclists and pedestrians), but especially for conflict type 2 and 4 these vulnerable road-users have a significant share in crashes with serious injuries.

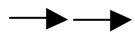
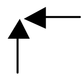
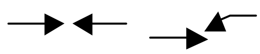
Type of conflict	Description	Illustration
1. off-road	vehicle driving unintentionally off the road	
2. same direction (longitudinal)	vehicles driving in the same direction: overtaking, passing, following; also conflicts with cyclists and pedestrians	
3. merging or diverging	vehicles starting or ending in the same direction	
4. crossing (side-impact)	vehicles coming from crossing directions; also conflicts with cyclists and pedestrians	
5. opposing (head-on)	vehicles in opposite directions	

Table 9-3: Different types of conflicts

Analysis has been made of crash data concerning fatal casualties per road type for task 6 partner countries. Table 9-4 shows the distribution of fatal crashes as a result of different conflict types on three main road types in the Netherlands, Greece, Israel, and Portugal.

Fatal crashes		urban main road speed limit 50-80 km/h				rural main road speed limit 80-110 km/h				motorway speed limits 100-120 km/h			
Type of conflict	conflicting traffic participant	NL	GR	IL	PT	NL	GR	IL	PT	NL	GR	IL	PT
1. Off-road/object on shoulder	motorized vehicle	8%	29%	7%	32%	31%	29%	7%	42%	46%	45%	26%	66%
2. Same direction	motorized versus non-motorized*	3%	-	3%	-	2%	-	3%	-	0%	-	9%	-
3. Merging or diverging	motorized vehicle	0%	8%	-	20%	0%	13%	-	17%	0%	14%	-	7%
4. Crossing (side impact)	motorized vehicles	6%	14%	8%		9%	9%	11%		0%	0%	0%	
	motorized versus non-motorized*	10%	-	22%	-	6%	-	8%	-	0%	-	0%	-
5. Opposing (head-on)	motorized vehicles	2%	7%	3%	39%	15%	23%	18%	33%	0%	8%	0%	3%
Number of crashes:	concerning only conflicts in this table	30%	58%	43%	91%	64%	74%	47%	93%	46%	67%	35%	76%
	total number on road type	315	563	182	161	457	576	229	511	59	78	23	91
Year		*2001*	*2001*	*2002*	*2001*	*2001*	*2001*	*2002*	*2001*	*2001*	*2001*	*2002*	*2001*
Roadtype			*Muni-cipal*		*National/ IC/IP*		*National*		*National/I C/IP*				
Speed limit (km/h)		*50*	*50*	*50-80*	*50*	*80*	*110*	*80-90*	*90*	*120*	*120*	*100*	*120*
*Motorized versus non-motorized**			*36%*				*17%*				*18%*		
**= VRU: Pedestrian +Bicycle+Animal involvement*													

Table 9-4: Distribution of fatal crashes as a result of different conflict types, related to road characteristics, on three main road types in the Netherlands, Greece, Israel and Portugal

An attempt is made to give a general overview in which the most important outcomes have been displayed. These general outcomes will be helpful for SPI specification:

There is quite some deviation between the countries regarding the percentage of all conflicts that is represented in the table. This is assumed to be mainly due to definition differences of conflict types. Part of it may as well be explained by a varying share of presumably road related conflicts in the countries.

Run off road: Crashes with vehicles driving off the road are a big problem on rural roads, and can be prevented by providing a sufficient obstacle-free zone or by installing barriers.

VRU: Conflicts because of conflicts between motorized and non-motorized vehicles in the same direction are a problem on (urban) main roads: a separation of these two types of road users is relevant for safety.

Merging and diverging are typical manoeuvres for motorways, and are not relevant on other road types.

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Intersection: Crossing conflicts are a problem both on rural and urban roads. It is common knowledge that e.g. roundabouts can take away many of these side impact conflicts at intersections.
Head-on: Conflicts between opposing traffic is a problem on rural roads. A separation of driving directions appears to be a good solution to avoid these head-on collisions. Safety barriers can only reduce the number of crashes partially, but the severity will be less when a vehicle crashes to a barrier instead of opposing traffic.
Road related conflicts appear to be significantly higher for rural main roads than for urban main roads or motorways in all countries.

The OECD report [29] mentions three main crash types (section 4.2.1). In the EuroRAP project Lynam [27, 28] identifies four main crash types on rural roads (section 4.2.2). In addition to the three crash types of the OECD study, crashes with vulnerable road users are also identified. These crash types lead to 80% of all fatal crashes on these roads (table 9-5). The crash distribution differs on different road types and in different circumstances. The quick scan analysis that has been made of fatal crashes per road type for Netherlands, Greece, Israel and Portugal shows these conflict types cover 47%-93% of the of fatal crashes on rural roads in 2001/2002.

Fatal Crash type	OECD	EuroRAP
Run off road:	35%	26%
VRU:	--	9%
Merging/diverging:	--	--
Intersection:	20%	27%
Head-on:	25%	19%
(VRU = vulnerable road users = cyclists and pedestrians; -- = not identified)		

Table 9-5 Main crash types OECD and EuroRAP lead to 80% of all fatal crashes on rural roads

Conclusion
Together with the OECD and EuroRAP data, the analysis of road-type/conflict-type data from the task 6 partner countries gives a first specification of frequently occurring safety problems in the roads domain. Especially in rural areas, road related safety problems are eminent. To obtain a starting point for the definition of SPIs a distinction is made in four crash types: run-off-the-road crashes, intersection crashes, head-on crashes, and crashes with involvement of vulnerable road users. Although the latter is not consistently addressed in all referred publications, it is considered to be very relevant for ongoing work. These crash types count for a substantial part of all fatal crashes on rural roads. Unfortunately there are no statistics available concerning the road network–safety relation.

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9.4 Development of SPIs

As a start, the identification of suitable SPIs has been inspired by the literature review and crash data analysis described in the previous section. They help to understand the processes that lead to road related crashes. For the identification of SPIs, a distinction is made in two groups. The first group concerns road networks, the second concerns road design characteristics. The network group deals with 'higher level' problems. It aims at giving a description of the road network in terms of functional road types and their actual usage. Subsequently, road design characteristics go into more detail for each road type.

Based on the observations in the previous section, it is appropriate to focus on rural roads rather than taking all roads into account. Road section-related crash shares on rural roads are significantly higher than on urban roads. Furthermore, diversification of rural roads types is estimated to be significantly less than for urban roads. Thus, focusing on rural roads will provide for a more 'workable' international comparison, than with urban roads included. Road design characteristics that relate to SPIs may become concrete more easily than road network SPIs, e.g. due to available crash statistics. However, they usually deal with more detailed issues, which may implicate that significant safety contributions may not always be expected. Furthermore, SPIs are meant to provide for a first impression of the operational conditions of road safety on a still rather high hierarchical level. Once this has given sufficient insight, a more detailed examination of the problems is appropriate, e.g. using methods such as design consistency or black-spot analysis. Crash prediction models like IHSDM are even more detailed and require a very comprehensive list of data demands. Design characteristics at this level lay beyond the scope of SafetyNet.

9.4.1 Methodological framework for SPIs translated to roads

In this section, first the methodological fundamentals for the development of SPIs will be described, as a summary of recent work in WP3 task 8 [26], and translated to the roads domain. Next, a draft selection of SPIs for roads is described.

Road safety interventions aim to influence insecure operational conditions. To select the right interventions, understanding the processes that lead to insecure operational conditions is necessary.
SPIs describe the operational conditions of road traffic and therefore aim to get close to the fundamentals of a road safety problem. Ideally, SPIs will react on every intervention in the safety system, regarding the operational condition that it aims to describe. For the task 'roads', the operational conditions mainly deal with crash prevention matters. To a smaller extent they also apply to the crash itself, where injury mitigation is at stake.

SPI definition:

A Safety Performance Indicator is any variable that is used, in addition to the figures of crashes or injuries, to measure changes in the operational conditions of road traffic, and give a first indication of the road safety level.

Implications of (suitable) SPIs:

- According to this definition, the set of SPI may include crash surrogates only and does not include figures of crashes and injuries.
- A more complete picture of the level of road safety can be given
- The identification of road safety problems can be done at an early stage before these problems show up in the form of crashes.
- An instrument is provided to monitor, assess and evaluate road safety progress, concerning the potential of processes and operations to solve the problems that they are trying to solve.

The purpose of a SPI 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 different road traffic systems (e.g. countries, regions, etc).

Quality levels of SPIs

Three quality levels can be distinguished, judged by the degree of intervention dependence and level of measurement:

- Level 1: direct measurement of the insecure operational condition is possible. The indicator will react on all possible interventions.
- Level 2: direct measurement is not possible. The identified problem can be seen as a latent variable. Indirect variables, still independent from interventions, can describe this latent variable.
- Level 3: measurement of indirect variables is not possible. Intervention related information might be the only clue to access reasonable information at all. This leads to a lack of independence from interventions. Reducing or splitting the problem might be necessary.

Quality reduction of SPIs due to intervention dependence, might be overcome by finding significant scientific evidence that a particular intervention has a traffic safety increasing effect on the insecure operational conditions (the identified problem). Next to that, a high level of transparency of what is actually measured, is necessary.

Other criteria to take into account in the selection of SPIs:

- Quantifiable: it is possible to obtain a reasonable score
- The SPI should express an ordinal relation with traffic safety (a change of score gives an unambiguous change of traffic safety level)
- SPI scores are verifiable and free from bias
- Country independent (suitable to compare different road safety systems in different countries, regions)
- A clear definition of the SPI is required

Possible external effects on SPIs:

- Population structure
- Legal conditions of road traffic
- Traffic volumes (usually expressed as Annual Average Daily Traffic, AADT)
- Modal split

Was it possible to find a direct indicator? No
A direct indicator of safety performance of road networks and road design in each Member State could not be attained and so inferences have to be made. This is because it is not possible to make direct measurements of the insecure operational conditions.

Was it possible to find indirect indicators? Yes
The identified safety problems on road network level and road design level can be seen as latent variables. Certain road network and road design characteristics could be the indirect variables that can describe the latent variable. These characteristics are more or less independent from interventions.

9.4.2 Development of road network SPIs

Road network characteristics

The network can be described according to table 9-6. It specifies the type of connection between different types of urban areas. The urban area types 1 to 5 are defined according to their number of inhabitants. Type 1 is a big city, type 5 is a village, and 2 to 4 are in-between. The type of connections is specified by road type I to V. These road types will vary between different countries, although some basic overlap will be present. For example a type I road is a road with a 'flow function', allowing for relatively high traffic volumes and relatively high speeds. Type V is a road with an 'access function' e.g. giving access to a residential area or one's own property. The network function of a road in a country or region can then be displayed in a uniform way by specifying what urban centres the particular road connects, according to table 9-7.

Urban area	Type 0	Type 1	Type 2	Type 3	Type 4	Type 5
Type 0	I	I	I	indirectly	Indirectly	indirectly
Type 1		I	I	II	Indirectly	indirectly
Type 2			II	II	III	indirectly
Type 3				III	III	IV
Type 4					IV	IV
Type 5						V
Type depending on number of inhabitants (city size) and might differ per country or region (example: type 0 > 1.000.000, type 2: 1.000.000-200.000, type 2 = 100.000-200.000, type 3 =30.000-100.000, type 4 =10.000-30.000, type 5 < 10.000) and road classes I - V to be defined later on.						

Table 9-6: Network indicator (connections): road types preferably connecting different types of urban areas (see also FGSV [33])

Urban centre type	Number of inhabitants
0	> 1.000.000
1	200.000 – 1.000.000
2	100.000 –200.000
3	30.000 –100.000
4	10.000 – 30.000
5	< 10.000

Table 9-7: Urban centre types based on the number of inhabitants. (Urban centres of type 0 only concern metropolises like London, Paris, Berlin, Warszawa, Madrid and Rome)

Functional road categorization

To obtain SPIs on the network level that allow for international comparison, an internationally harmonized road categorization is needed. The international IRTAD database can be a starting point. IRTAD applies the following road types according to the hierarchy shown in figure 9-2:

- Roads inside urban areas (urban roads, excl. all motorways)
- Roads outside urban areas (rural roads, incl. all motorways)
- Motorways
- Country roads
- A-level roads (roads outside urban areas that are not motorways, but belong to the top level road network)
- Other roads

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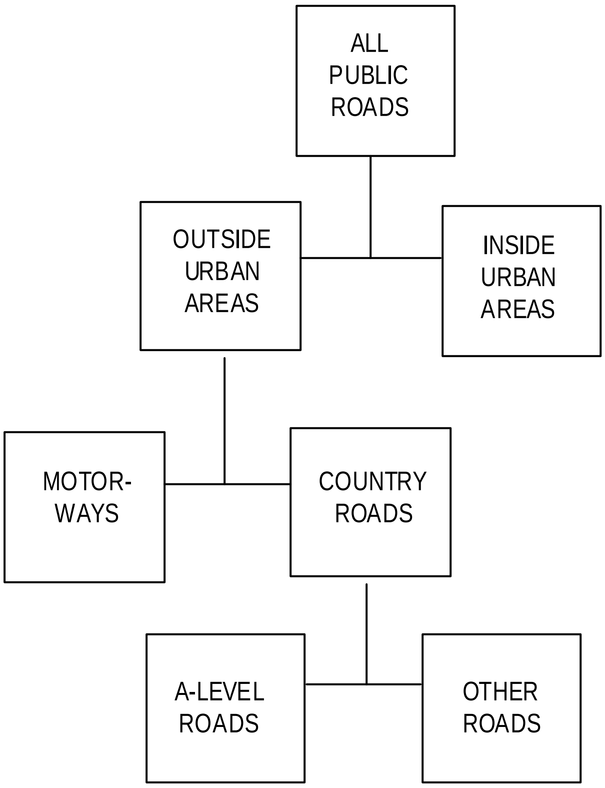

Figure 9-2: IRTAD road type definition

Total public road network = outside urban areas + inside urban areas
Outside urban areas = motorways + country roads
Country roads = A-level roads outside urban areas + other roads outside urban areas

For a safety assessment of road networks, the current IRTAD categorization is too superficial. At least a further specification of 'A-level roads' and 'other roads' is needed to monitor the functional specifications and actual usage of roads. A first indication of the proposed functionality of a road is given by the actual position of the road in the road network. To further link this to safety assessment, a harmonized description of road types is needed, in which functionality has been translated to the design and physical appearance of the road. For this purpose, the functional road classification presented in table 9-8 has been used. As explained before, it has been restricted to rural roads.

	Rural areas (outside built-up areas)					
SafetyNet road classes	AAA:	AA:	A:	BB:	B:	C:
	Motorway	A-level road 1	A-level road 2	Rural distributor road 1	Rural distributor road 2	Rural access road
Sustainable-Safety	Through-road (road with a flow function)			Distributor road		Access road
Separation of opposing directions	Dual carriageway	Dual carriageway	Single carriageway	Dual carriageway	Single carriageway	Single carriageway
Lane configuration	2x2 or more	2x1, 2x2	1x2, 1x3, (1x4)	2x1, 2x2	1x2, 1x3, (1x4)	1x2, 1x1
Obstacle-free zone	Very wide or safety barrier	Wide or safety barrier	Wide or safety barrier	medium	medium	small
Intersections	Grade-separated					

Table 9-8: Functional road classification

Three functional road categories have been distinguished:
Through-road; road with a flow function enabling high speeds of long distance traffic and, many times, high volumes.
Motorways and A-level roads have been assigned to this category. AAA refers to motorways. The characteristics of this road category are a dual carriageway; a wide obstacle-free zone or a safety barrier, and grade-separated intersections. AA and A refer to A level roads according to the IRTAD definition: roads outside urban areas that are not motorways but belong to the top-level road network. AA is a dual carriageway road; A is a single carriageway road. Other main characteristics of these last two road categories are an obstacle-free zone or at least a safety barrier. In EU Member States they are often known as primary roads, national roads, semi-motorways or non-interstate arteries.
Distributor road: serving districts and regions containing scattered destinations. Here a distinction is made between BB and B roads. The BB-road typically is a dual carriageway road, whereas a B-road typically is a single carriageway road. Obstacle-zones and intersections occur in various layouts among the various countries.
Access road: enabling direct access to properties alongside a road or street This type of road, indicated as category C, typically is a single carriageway road with one driving lane or two lanes separated by access marking only.

For cells that contain information, it is relatively straightforward to specify the information of concern. For empty cells, it appears to be not possible to give a specification beforehand for all countries.

SPI selection for road networks

Based on the tables 9-6 and 9-8, the following road network SPIs might be extracted (if an international agreement on a limited series of road categories can be achieved):

1 Degree of compliance of road network usage with the functionality of the road network. A rating should be developed for this e.g. taking into account the share of 'correct connections'.
- direct measurement possible
- suitable SPI: per connection the share of each road type related to the connection type

2 Share of different functional road categories in the whole network
- direct measurement possible
- suitable SPI: per connection and per connection type in a region or country the share of each road type and intersection type and the intersection density.

3 Share or amount of motor vehicle kilometres travelled on each functional road category
- direct measurement possible
- suitable SPI: traffic performance per road type

9.4.3 Development of road design SPIs

Once the network characteristics have become clear, for all different road types (representing connections between the urban areas mentioned before) an assessment can be made of road design characteristics. This assessment will then show if these roads are indeed suitable (safe enough according to current knowledge) for the type of function that has been assigned to it in the road network. A series of optional SPIs has been identified and their suitability has been estimated by evaluating them with respect to the methodological principles.

An aspect that plays a role in many of the items listed below is actual traffic volumes on a road. These will be specified on the road network level, preferably in vehicle kilometres. This dimension will make the analysis more transparent, since many of the design characteristics will be specified in terms of road kilometres (or in case of intersections, in numbers per section or connection). In general, SPIs will be the share of total road length which has certain (safe) design characteristics or the share of the total number of intersections with certain characteristics.

SPI selection for Run Off Road crashes:

1 Road width (e.g. based on carriageway-driving lane width levels per road type, kilometres of different levels per road type):
- direct measurement possible
- safety impact is related to width and presence of the obstacle-free zone

- wider driving lanes may result in higher and inappropriate speeds with a safety decreasing effect. This means that road width is not a good SPI as long as it is not possible to account for the speed compensation effect (road width could be used as a SPI only if included in a composite variable)
- unsuitable SPI

2 Obstacle-free zone (presence, width levels, and kilometres of different levels per road type)
- direct measurement possible
- safety impact is related to barrier presence
- safety impact is related to the character of the obstacle free zone (e.g. flat or steep slope. hard or soft, energy absorbing level, etc.)
- suitable SPI: share of wide obstacle free zone presence

3 Road side barrier (presence, absolute and relative number of kilometres per road type)
- direct measurement possible
- safety impact is related to obstacle free zone presence
- more effect on crash severity than on the number of crashes
- a barrier should be more a 'structural facility' than a specific local 'point facility'. From a theoretical point of view, safety barriers are very similar to pedestrian crossings. Both are installed as interventions. Safety barriers are obstacles installed to protect errant traffic from other more dangerous obstacles
- suitable SPI: share of road side barrier presence

Table 9-9 can be seen as a draft format for data specification later on in the SPI overview and hierarchy and the questionnaire (section 9.5.3 and 9.6).

<table>
<tr><td colspan="3" rowspan="2">Road XX</td><td colspan="2">Side of the road</td></tr>
<tr><td>side 1</td><td>side 2</td></tr>
<tr><td rowspan="4">Obstacle-free zone</td><td colspan="2">Wide</td><td></td><td></td></tr>
<tr><td colspan="2">Medium</td><td></td><td></td></tr>
<tr><td rowspan="2">if none or narrow: barrier</td><td>Yes</td><td></td><td></td></tr>
<tr><td>No</td><td></td><td></td></tr>
</table>

Table 9-9: Preventing off-road conflicts: percentage of length within each road section, per connection type.

4 Horizontal/speed consistency
Direct measurement is possible of some characteristics, but according to section 9.2.3 difficult. Safety impact is not only related to road curve radius, speed and obstacle-free zone, etc. but also to average curvature of the road and expectancies of road users. Estimates of consistency indicators are difficult due to need for detailed design characteristics that are often not available. Therefore consistency is not suitable as SPI in this context.
- unsuitable SPI

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SPI selection for crashes at intersections:

1 Safe intersection types in the road network, e.g. roundabouts or grade separated intersections
direct measurement possible
- time separation: traffic lights
- direct measurement possible (but problems with traffic signal obedience)
- suitable SPI: share of each intersection type (per connection)

2 Facilities for separating motorized and non-motorized traffic at junctions, intersections:
presence of bicycle lanes or pedestrians paths at intersections
- direct measurement possible (share or density of facilities)
time separation: presence of dedicated traffic lights for pedestrians, bicyclists
- direct measurement possible
space separation: presence of grade separated bicycle or pedestrian lanes/paths
- direct measurement possible
- suitable SPI: share of intersections with separating non-motorized traffic facilities (per connection)

3 Facilities for traffic calming at intersections:
Presence of speed humps, *'raised intersections', 'rumble devices', etc.*
- direct measurement possible,
- have less effect than roundabouts
- effect depends on aspects of design consistency like speed and expectancies.
- unsuitable SPI

Table 9-10 can be seen as a draft format for data specification later on in this section.

<table>
<tr><td colspan="2" rowspan="2">Road XX</td><td colspan="2">Separation according to differences in mass and protection</td></tr>
<tr><td>yes</td><td>no</td></tr>
<tr><td rowspan="4">Separating of conflicts with crossing traffic participants</td><td>grade-separated</td><td></td><td></td></tr>
<tr><td>roundabout</td><td></td><td></td></tr>
<tr><td>at level: signalized</td><td></td><td></td></tr>
<tr><td>not-signalized</td><td></td><td></td></tr>
</table>

Table 9-10: Preventing crossing conflicts at intersections: number of intersections per kilometre within each road section, per connection type

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SPI selection for crashes at road sections:

1 Facilities for separating opposing driving directions (focusing on rural main roads): e.g. barrier or median presence
- direct measurement possible
- other separation devices may be found, with variable degrees of containment: islands, bollards, etc.
- suitable SPI: share of median or barrier presence

2 Facilities for overtaking slow traffic (e.g. number per kilometre)
- direct measurement possible
- safety potential is related to the degree of compliance with overtake prohibition at other road segments and related to other road and environmental characteristics
- unsuitable SPI

3 Design consistency (road curvature, curve radius, road width, etc.)
- direct measurement for some elements possible
- traffic safety potential depends on more characteristics together and differs per road type
- unsuitable SPI

4 Facilities for separating motorized and non-motorized traffic at road sections: presence of bicycle lanes or pedestrians paths
- direct measurement possible
- different types of facilities with varying safety potential
- suitable SPI: share of road sections with separating non-motorized traffic facilities

5 Access control, from adjoining areas (e.g. pedestrian restrain systems, pedestrian crossings, bicycle crossings, parallel roads or alternative routes)
- direct measurement possible
- different types of facilities with varying safety potential

The number or density of these types of devices can be an indirect variable for the degree of separation of motorized and non-motorized traffic and for the type of prioritisation of non-motorized traffic. However, installing e.g. zebra crossings and pedestrian restrain systems is an intervention (SPI level 3) and therefore not the most suitable SPI.
- unsuitable SPI

6 Parking places separate from the carriageway ('parking harbours'/resting areas)
- direct measurement possible
- related to access control, but contribution of this item to the 'crash at road sections' problem is limited
- Sleeping at the driving wheel seems to be a relevant contributing factor to interurban fatal crashes. However, the safety potential of resting areas is unclear because it is dependant on the actual use.
- unsuitable SPI

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7 Facilities for traffic calming (e.g. speed humps, visual road design elements to stimulate driving with an appropriate speed, etc.)
- direct measurement possible
- effect depends on aspects of design consistency (speed, expectancies)
- unsuitable SPI

Table 9-11 can be seen as a draft format for data specification later on in this section.

Road XX		Separation according to differences in mass and protection	
		yes	no
Separation of opposing driving directions	physical median or barrier		
	medium overtaking is difficult or not possible	(Not in questionnaire: difficult to get this detailed data in partner countries)	
	none (axis marking only)		

Table 9-11: Prevention of conflicts with possible serious consequences: number of kilometres within each road section, per connection type.

This means that infrastructure has to be set up and designed so that there will be small speed and mass differences between transport modes that can collide (homogeny requirement). A SPI may therefore be the degree of separation of these road users or traffic participants. The SPI will be the percentage of the total road length which belongs to the road classes with the safest characteristics.

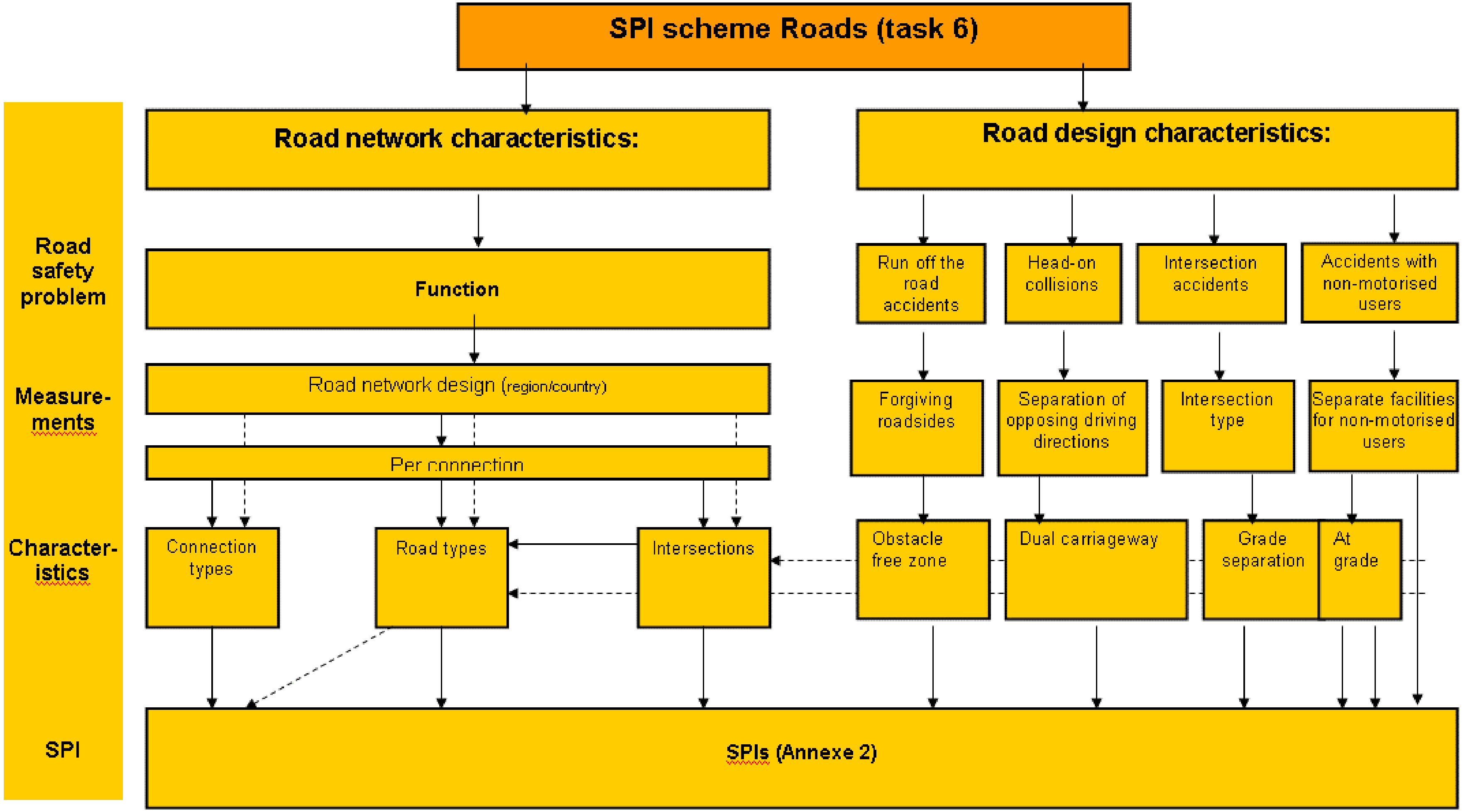
9.4.4 SPI overview and hierarchy

In the previous section we discussed which road and road network design characteristics or features are suitable to use as SPI. A hierarchical scheme has been developed to give an overview of the results. The top layer of the scheme is presented on the next page. Annex 9.2.2 contains the complete scheme, based on the theoretical framework of task 8 [26], including the formulas and data needed to calculate the SPIs. Below, some explanation of the scheme is given.

At the road design level four road safety problems have been distinguished for which eight SPIs could be formulated. Four of them are related to measurements to prevent crashes on road sections, and four are related to measurements at junctions/intersections.

At the road network level two sub-levels are proposed: the highest level is the total road network in a region or country. The second sub-level deals with individual connections. On the connection level three SPIs have been formulated concerning the road types and intersection types at each connection.

Each connection could be assigned to a connection type as proposed in section 9.4.2 (table 9-6 and 9-7). Per region or country, the distribution of these connection types can be presented. At the level of a region or country, SPIs could be formulated concerning also the road types and intersection types, summarized per connection type.


SPI scheme Roads (task 6)
Road safety problem
Measure-ments
Character-istics
SPI
Road network characteristics:
Road design characteristics:
Function
Run off the road accidents
Head-on collisions
Intersection accidents
Accidents with non-motorised users
Road network design (region/country)
Forgiving roadsides
Separation of opposing driving directions
Intersection type
Separate facilities for non-motorised users
Per connection
Connection types
Road types
Intersections
Obstacle free zone
Dual carriageway
Grade separation
At grade
SPIs (Annexe 2)

9.5 Questionnaire

The questionnaire aims to gather the necessary data for assembling the presented SPIs and is part of the overall questionnaire for WP3. It has been composed in such a way that it gives information of the function/position of the road in the network and more detailed information regarding the design of these roads. This will facilitate the understanding and international comparison of specifications of a particular road in the network and its safety impact. Only inter-urban, rural connections will be specified, as explained before. .

The national experts, that are responsible for filling in the questionnaire, have been provided with an introduction and explanation of the composition of the questionnaire. A lot of attention has been paid to the network description and the harmonized functional road categorisation that apply to the questionnaire. To be complete in this state of the art document, some of this information is presented in section 9.5.1. It shows some overlap with previous sections. The questionnaire itself is presented in section 9.5.2. Annex 9.9.3 shows the survey form that is used in the questionnaire.

9.5.1 Guidelines for filling in the questionnaire

Network description
The road network structure is displayed by connections between urban centres. Six urban centre types have been defined according to their number of inhabitants, as shown in table 9-7. The number of inhabitants concerns the city itself, not the whole agglomeration.

The network function of a road in a country or region can then be displayed in a uniform way by specifying what urban centres the particular road connects, according to table 9-6.

One road may connect different urban centre types, or one connection may be composed of different successive road types. In this case a differentiation to successive road sections enables a description of these different connections.

Functional road categorisation
The actual position that a road has in the road network gives an indication of its (proposed) functionality. To give an international comparison of how this functionality has been translated to the design and physical appearance of the road, it is necessary to have a harmonized description of road types. For this purpose, a functional road classification has been used, according to table 9-8. In the context of this questionnaire only rural roads are relevant.

In the questionnaire the national experts have to specify the type to which the concerning road (or road sections) belongs. Furthermore the national experts are requested to specify how the road is called in their country.
To understand the link between table 9-6 and table 9-8, please not that e.g. a type I connection is probably represented by a road with a flow function (AAA),

allowing for relatively high traffic volumes and relatively high speeds. Type V is probably a road with an 'access function' (C.) e.g. giving access to a residential area or one's own property.

Selection of roads for the questionnaire
The aim of the questionnaire is to provide data to increase international knowledge about the infrastructure impact on traffic safety. Therefore it is necessary to have information about the road network and individual roads that are representative for traffic in general (and safety in particular) for the concerning country. Ultimately, as many as possible connections according to table 9-2 throughout the whole country should be incorporated. If this is too comprehensive, an individual country may decide to focus on a part of the network (e.g. a region) that serves a considerable share of the country's traffic (preferably the highest share). In this case as well, it is important that all types of connections are represented.

9.5.2 Content of the questionnaire

The questionnaire is composed in the form of a table that applies to one connection. This means that for different connections, different tables had to be provided. For a correct interpretation of the work, a map has been requested to show the road network and highlight the selected connections. The map was made along with the questionnaire.

Different road types may apply to one connection. In this case, information should be supplied for successive road sections, as indicated. In case of one road type per connection, it is still possible to supply information per road section first and subsequently for the whole road. Furthermore, one particular road may be part of more than one connection. In this case, the roads or the concerning road sections only need to be specified for the connection at the highest hierarchical level. A reference to this higher level connection will then be sufficient for the lower level connection. In the annex 9.9.3 example of the used survey form is presented.

The objective of this questionnaire is to obtain the following information for each connection:
1. Country: name, population
2. Origin urban area: name, population, urban area type
3. Destination urban area: name, population, urban area type
4. SafetyNet WP3 road type: code
5. National road type: name, code /No.

For each road (section) of that connection:
6. Road section: No., start, end, length [km]
7. Flow volume: AADT [veh/24h]
8. Performance: vehicle-km travelled per year [veh*km/year]
9. Speed limit: leading value [km/h]
10. Carriageway: dual (median or barrier), single (axis marking only) [km]

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11. Separation according to differences in protection: no pedestrians, cyclists, or mopeds on the same road [km]
12. Obstacle-free zone at roadside 1 and roadside 2 (opposite driving direction): wide, narrow, barrier [km]
13. Definition of the width and critical steepness of the obstacle-free zone: 'wide' >_ meter from edge marking [m], steepness < _%.
14. Intersection type: grade-separated, roundabout, a-level signalized or not signalized [#]
15. Separation according to differences in protection: no pedestrians, cyclists, or mopeds on the intersection [#]
16. Road totals: absolute [km], percentage [%]
17. Intersection totals: number [#], density [# intersections/km]
18. Source and reference year of the data

9.6 National responses

In this section the responses on the questionnaire of the 25 European countries and 5 partner countries are presented as far as available at this stage of the project. Table 9-12 shows which country has sent a response and if this response was correct. The quality of the data is examined as well. On basis of the response and the data quality it can be concluded whether (a part of) the SPIs are realisable or not. The table shows also the number of road types and connection types mentioned in the national responses. The completeness of the other road design related SPIs is examined as well.

For at least 8 countries it will be possible to collect data of good quality. For 5 of them the response contains only data of main roads. Only 5 of the 8 'good' responses give a (more or less) complete answer on the requested data. It is not anticipated that a further questionnaire will be necessary, though modifications to the questionnaire may be necessary in order to make the best use of the (sometimes limited) data that is available. New responses are expected soon.

Conclusions from responses
As a follow-up of the Lisbon WP3 progress meeting, some items of concern have been listed.

Some misunderstanding may have occurred in the selection of roads that are to be specified. Information on different types of roads is aimed at (according to the functional classification), not only on high-level roads (AAA-AA-A type, that are commonly known to be relatively safe compared with other road types). These roads can be part of a region that has been selected or they can be taken from different parts of the country. Most important is that the selection is representative for the road network in terms of safety. For example the aim is not only to select roads with a good safety score, but provide 'bad' roads as well. It may be worthwhile to draw the attention to this item by contacting the national experts that are filling in the questionnaire. It may be also useful to encourage the countries (via the national experts) to carry out surveys in order to collect complete data for a number of representative roads. The experience from several partners involved in this task (Israel, Greece) has shown that little time and resources are required to organize and carry out such surveys, with very satisfactory results. More specific instructions for such surveys could be provided if necessary.

Connected to the previous item, a small extension of the questionnaire is anticipated regarding the number of fatalities per year on the specified roads (preferably as an aggregate average over e.g. the 2000 - 2003 period). Results of the questionnaire may be quite satisfying if information on a part of the road network in the countries can be obtained. However high interest will be in the overall overview of the network as well, in terms of traffic and casualty shares on different road types. The share of traffic on different road types is going to be assessed in WP 2 of SafetyNet, but this Work Package won't use the in this document newly proposed road classification. In fact, in WP2 only CARE common variables shall be treated (inside/outside, motorway yes/no etc.) and all the related risk exposure data (vehicle kilometres, road length etc) shall be aggregate data according to these variables. Additionally, little or no information on individual roads is expected to be available. As far as the road type definitions are concerned, no particular classification is proposed so far. The countries are asked to provide their own detailed definitions, which shall be exploited for the elaboration of a common framework (although a more detailed classification than motorway "yes/no" will be difficult to achieve for exposure data).
For our AAA, AA, and A roads this is not a big problem since they more or less coincide with motorways and A-level roads in IRTAD. For the others it will be much more difficult, although for road safety they are very important. For this reason it might be useful to extend the questionnaire with fatalities on road section level or at least at connection level.

Searching for appropriate Indicators and further proceedings
The first data set will be used as a pilot to test the indicator for usefulness and reliability. The assumptions and SPIs might be modified. Furthermore the comparability across countries will be tested. Transformation rules might need to be developed to improve international comparability. The data are currently being analysed and the first results are not yet available. These will be supplied the next deliverable 'Requirements for SPIs'. New responses are expected soon.

Country	Response (correct?)	Quality data	SPI realisable	Period	Road classes	City types	Comments
1 Belgium	Yes	++	Partly (certain region)	2003	AAA: 7 A: 1 B/BB: 1 B: 2	type 1: 2, type 2: 1, type 3: 5, type 4: 5, type 5: 4	complete
2 Cyprus	Yes	++	Partly (certain region)	2003/ 2004	AAA: 6 AA: (2) A: 7	type 1,2+5: 1, type 3: 2, type 4: 4	Complete (no data of obstacle-free zone)
3 Czech Republic	Yes	+ (minor errors)	Partly (certain region)	2000	AAA: 1 AA/B: 3 BB: 1 B: 2	type 0: 1, type 1: 1, type 3: 2, type 4: 3, type 5: 1	complete
4 Denmark	Yes	-	Partly (main roads)	2003	AAA: 5 A: 1 AAA/A: 1 ?: 1	type 1: 2, type 2: 1, type 3: 2, type 4: 3, type 5: 1	No data of barrier, obstacle-free zone
5 Germany	Yes (no)	--	no				No data
6 Greece	Yes	++	Partly (certain region, main roads)	2004	AAA/AA: 1 AA/A: 2	type 0, 1, 2 + 5: 1, type 3: 2	complete
7 Spain	Yes (no)	--	no				No data
8 Estonia	Yes	+	Only 1 route	2004	?: 1	?: 3	complete
9 France							
10 Hungary	Yes	++	Yes	2005	AAA/A:3 AA/A:1 , A:7 A/B:3 , B:2	type 0:1, type 1:1, type 2, 3, 4 + 5:3	
11 Ireland							
12 Italy							
13 Latvia	Yes (no)		No data				
14 Lithuania							
15 Luxembourg							
16 Malta	Yes (no)	--	no				
17 Netherlands	Yes	+	Partly (certain region)	2004 (AADT) / 2005		type 1: 2, type 2: 1, type 3: 2, type 4: 10, type 5: 1	
18 Austria	Yes	-	Partly (main roads)	?	Autobahn: 8 (7) (AAA,A), Schnellstrasse: (1) (A)	type 0: 1, type 1: 1, type 2: 4, type 3: 1	Only km, AADT, carriageway.
19 Poland	Yes (no)	--	Only part of SPI's (no data on connection types)				No data of barrier, obstacle-free zone, intersections, separation NMT
20 Portugal	Yes	+	Partly (only main roads)	2003	AAA: 11, AAA/A: 1, A: 1	type 1: 2, type 2: 2, type 3: 10, type 4: 2	No data of barrier, obstacle-free zone
21 Slovakia							
22 Slovenia							
23 Finland							
24 Sweden							
25 United Kingdom							
26 Iceland							
27 Israel							
28 Liechtenstein							
29 Norway	Yes	-	Partly (only 3 main roads)	?	AA2 1	type 1: 1, type 2: 2	No data of barrier, obstacle-free zone
30 Switzerland							

Table 9-12: Responses and Usability of Safety Performance Indicators (SPI) of task 6 Roads

9.7 Conclusions

In the development process of SPIs for task 6 'Roads' the following observations have been made so far:

- The domain 'roads' is related to a wide range of road safety issues. At the highest level a distinction can be made between road network and road design issues. A clear identification of roads related safety problems is necessary as a basis for finding suitable SPIs. The following problems have been identified: the road network layout is not optimized in terms of safety (right roads are not at the right place); at individual road level four types of crashes are eminent: run-off-the-road crashes, intersection crashes, head-on crashes and crashes with involvement of vulnerable road users.
- Crashes related to road characteristics appear to be more eminent in rural areas than in urban areas. Furthermore, international diversification of road types is assumed to be less for rural than for urban roads. Therefore, for this task, the focus will be on rural roads. The four crash types mentioned before, account for a substantial part of all fatal crashes on these rural roads.
- A road network is performing safely when the actual road classes in an area fit the types of connection according to the function of the road. On the road network level three SPIs could be formulated concerning the road types and intersection types at different connection types.
- The degree of presence (or absence) of relevant characteristics gives an indication of the safety level of a road section or intersection. Related to the four crash types, eight SPIs could be formulated at the road design level. Four of them are related to measures to prevent crashes on road sections and four are related to measures at intersections. SPIs at a detailed level, such as based on design consistency characteristics, are considered not appropriate yet at this stage.
- A methodology for network description and (safety related) road classification has been developed, that is assumed to be suitable for international harmonisation. As a basis, the functionality of a connection (consisting out of one or more road types) and a systematic combination of present (safety related) characteristics have been used.
- At this stage of the project only few countries are able to provide requested data on both connection types, road types and other road design characteristics. Part of this may be due to the fact that no complete systematic information on the performance of the roads is routinely available in the majority of countries. Hence, special efforts will need to be undertaken to collect these data.
- Based on the present country responses it can be stated that the suggested sets of SPIs seem realisable and definitely promising for comparing road networks and road design in the Member States.

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9.9 Annexes

9.9.1 EuroRAP crash types

According to EuroRAP, four crash types contribute about 80% of all fatal and serious crashes on major roads outside built-up areas. The total percentage is common to many countries, but the distribution of the crash proportion between the four types differs according to the existing nature of the road network and the traffic patterns in each country. The Road Protection Score is based on these four main crash types. From the EuroRAP research evidence [27, 28], the road design characteristics and safety features most likely to influence these crashes are (quote):

-Intersection crashes
Reducing the number and improving the quality of intersections. Junctions where traffic on the main road has to cede priority will be treated separately from road intersections or private accesses where traffic has to cede priority to the main road. A lower number of the latter will reduce crash risk. This is true for the former, but for these the type of intersection is also important, with roundabouts giving rise to less serious crashes than signalized intersections.

-Link crashes involving head on collisions with other vehicles
Dividing carriageway – this could be by road markings, narrow median strips, wide median strips, or safety fences. Each gives a different degree of protection. The legal regulations regarding crossing central road markings may influence their effectiveness in reducing these crashes. The only direct evidence is for safety barriers on median strips, although all devices which increase vehicle separation are expected to have some effect. Wider carriageways should, therefore, also decrease the frequency of this crash type. The degree of variation in vertical alignment, which is known to affect crash frequency, may also mainly influence this crash group.

-Link crashes involving single vehicles running off the nearside of the road
Safety fences to prevent direct contact with hard roadside objects, and prevent vehicles running down embankments, will improve safety. A narrow hard strip (in GB, a one metre strip) between the running lane and the verge also reduces crashes by about 20%, but no separate evidence is available for the effect on more serious crashes. A direct link has also been shown with bendiness of the road. Loss-of-control crashes are more frequent on narrow winding roads, but straight roads with unstimulating environments, although not having direct loss of control, may result in run of the road crashes through driver fatigue or loss of attention.

-Link crashes involving pedestrians and cyclists
Where there are substantial numbers of pedestrians and cyclists using the roadway, or wanting to cross it, safety will be improved if vehicle speeds are reduced, if continuous walking or cycle paths are provided alongside the road, etc. The assessment should also reflect whether the road is operating at a speed consistent with its safety standard.

9.9.2 Design Consistency

In the SAFESTAR project *Design consistency of horizontal alignment in rural roads* [2] research on design consistency was carried out. Consistency can be defined as the agreement between the characteristics of the geometric design of a road and the unfamiliar driver's expectations [14]. Expectancy is the tendency of a driver to react to a situation, an event or a set of information in a systematic way, based on his/her past experience.

The concepts of driver expectancy and geometric consistency are important in safety and road design, because inconsistencies on a road can surprise drivers and lead to errors that increase the crash risk [15]. In fact, when a driver's expectancies are violated, the probability that a situation will be correctly identified is significantly reduced. The incorrect identification of a situation greatly reduces the time available for executing the manoeuvres needed to successfully deal with it [16]. Expectancy may intervene at two levels [17]: a priori expectancies are related to long term strong representations (for example, a driver does not expect pedestrian crossings in a motorway-like road); ad hoc expectancies are created along a specific journey (for example, on a flat rural area, after several long tangents connected by long radial curves, a driver does not expect a sharp curve). *A priori* expectancies are related to road network characteristics; *ad hoc* expectancies are mainly constructed from road design characteristics.

There are several methods for representing driver expectancy and for evaluating the design consistency of a road [2]. The most used ones are based on selected parameters of the unimpeded speed distribution (mainly the average and the 85th percentile), and on their variation from road section to road section [2, 14, 18, 19, 20, and 21]. Their application requires the use of a procedure for estimating the unimpeded speed profile along the road. Unimpeded speeds are observed under very low traffic volumes. Other methods are related to geometric indices derived directly from the design characteristics of the road layout [2, 21 and 22] or require the estimation of driver workload [2], which may involve objective [14 and 20] or subjective evaluations [3]. Some of these methods for evaluating design consistency were directly related to crash risk using statistical models [1, 23, 24, and 25].

It was concluded that models incorporating selected road characteristics, average annual daily traffic (AADT) and explanatory variables related to the driver expectancies (such as speed reduction and average speed, or driver workload) have improved goodness of fit.

Road safety and road characteristics
Several variables describing operational and non-operational characteristics of the road infrastructure have been correlated with crash occurrence. Operational characteristics are related to the traffic system's performance; they include the AADT, spot speed, and speed reduction. Non-operational characteristics are related to physical attributes of the road and its environment, such as geometric design and roadside characteristics.

Usually, the exclusive correlation of crash occurrence with road geometric characteristics is poor. Firstly, due to the nature of the road design process, and the applicable design standards, road characteristics are not independent; rather, they are integrated according to the road class and its design speed. For instance, sight distance and cross slope are both related to road curvature. As a result, fitting separate crash models for different road types usually enables significant increases in the explanatory power of the models and in their goodness of fit. Secondly, the allowable values of some variables are bounded due to requirements set by the road administrations: this is the case of skid resistance and cross slope [1, 2].

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One way of solving the problems created by the auto-correlation of some non-operational characteristics is by including in the crash models explanatory variables that directly incorporate the influence of the associated characteristics. Variables related to driver workload and some operational variables fit this definition (especially those representing driver behaviour). In fact, it has been found that it is possible to enhance the goodness of fit of crash frequency estimates as a function of road characteristics, by incorporating in the empirical models explanatory variables related to the driver behaviour (such as speed reduction or the average speed) or to the driver workload in the relations between crash [3].

Several road characteristics are known to influence crash occurrence. The crash frequency is highly dependent on the road class, the number of carriageways, road environment, and AADT. Differences in road class, road environment, and the number of carriageways are usually taken into account by fitting separate models for different road classes in urban areas, rural areas and rural mountainous areas [4, 5]. Also, separate models are fitted for intersections and links (between intersections), due to the different nature of safety problems in these two elements of road networks. For a given class of road, AADT is the single most important explanatory variable for crash frequency [1, 6].

On links, access control (minor intersections and private accesses) is a very important and consistent explanatory variable, its influence having been detected in several studies [7].

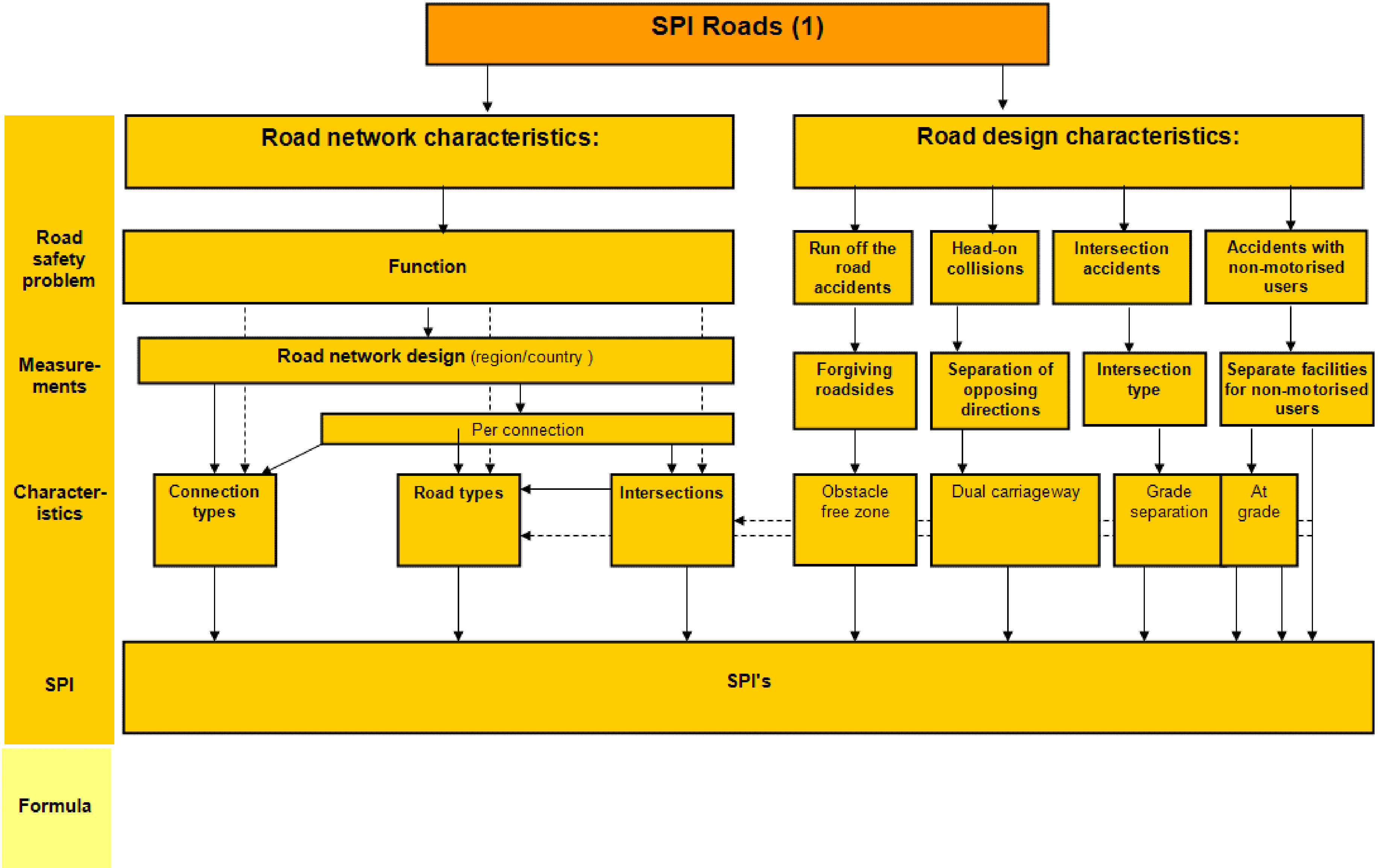
The influence on crash occurrence of several geometric characteristics has been reported, namely related to the major intersections, road curvature, longitudinal grade, lane and shoulder width, and superelevation. Other road characteristics have been related to crash occurrence outside of intersections: lateral clearance, maintenance conditions of road markings and signing; longitudinal and transverse profile of the pavement; and skid resistance. As already mentioned, the influence of each variable is very difficult to isolate as several variables are frequently correlated, due to the restrictions imposed by existing design standards.

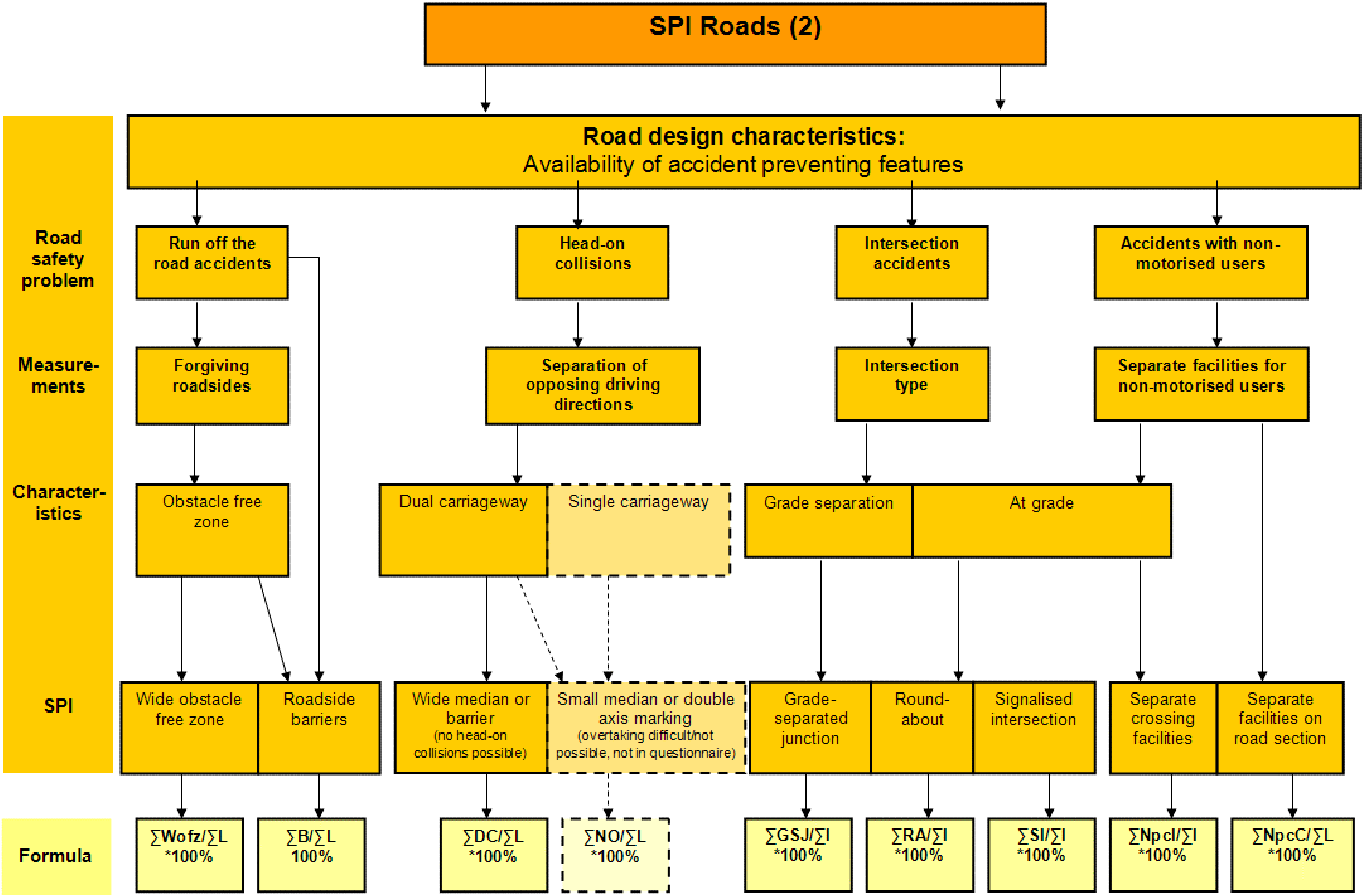
Amongst the geometric characteristics of the road, horizontal road curvature is one of the most important factors in crash occurrence. According to Hedman [8], horizontal curvature is associated with an increase in the crash rate, especially when the radius is below 1000 metres. In other studies, this influence is especially important for curves with radius below 350 metres [9]. A similar conclusion was obtained by Zegeer [10]. Castilho [11] studied geometric characteristics of the most important hazardous locations on the Portuguese National Road Network. He concluded that those locations are geometric inconsistencies and fitted a quadratic equation relating horizontal curvature and crash rate. It was also concluded that curves in bendy roads present lower crash rates than similar isolated curves. Similar conclusions are reported by Elvik and Vaa for Norway [12]. Zegeer fitted different models to both isolated and consecutive curves [10]. Thompson concluded that road stretches with successive curves and small road width have higher crash rates than similar curves with larger road widths [13].

The influence of several road characteristics on the crash rates was detected in a study of crashes on curves by Goodell-Grivas & Leisch (1983): curve radius; overall horizontal characteristics of the road, existence of private access, shoulder width, lateral clearance, lane width, traffic volume, and embankment slopes. Curve radius was especially important for values below 435 metres (1400 ft). Two types of effect associated with the horizontal curvature were detected:
- at the overall level, there is a negative correlation between the average curvature of a road and its crash rate;
- at the local level, there is a positive correlation between the radius of a curve and its crash rate.
Important interactions between the local and the overall effects were detected, as well. It was concluded that, for a given horizontal radius the expected crash rate of such a curve depends on the overall characteristics of the road layout.

9.9.3 Diagram

(see next pages)


SPI Roads (1)
Road network characteristics:
Road design characteristics:
Road safety problem
Measure-ments
Character-istics
SPI
Formula
Function
Run off the road accidents
Head-on collisions
Intersection accidents
Accidents with non-motorised users
Road network design (region/country)
Forgiving roadsides
Separation of opposing directions
Intersection type
Separate facilities for non-motorised users
Per connection
Connection types
Road types
Intersections
Obstacle free zone
Dual carriageway
Grade separation
At grade
SPI's



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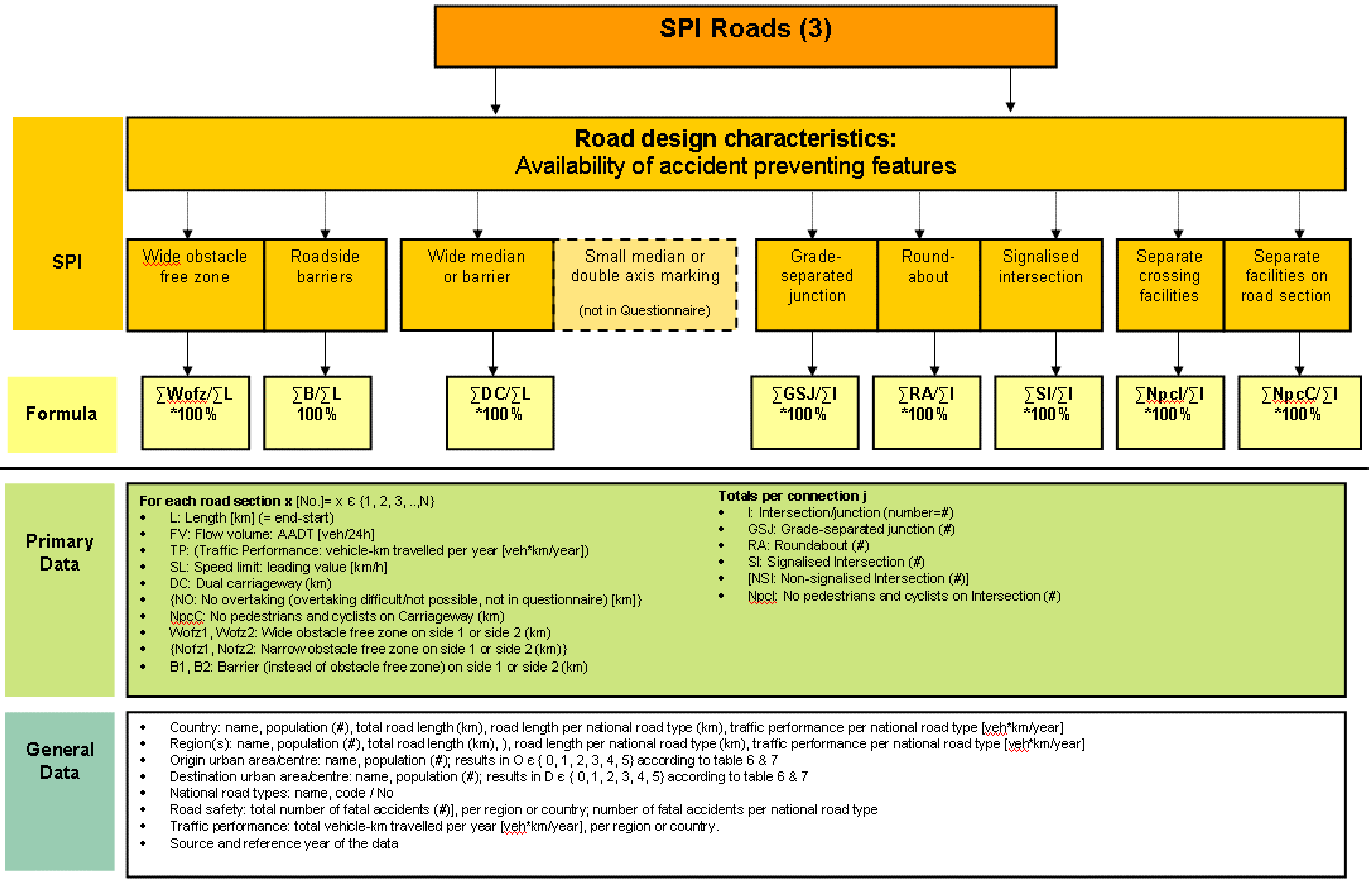
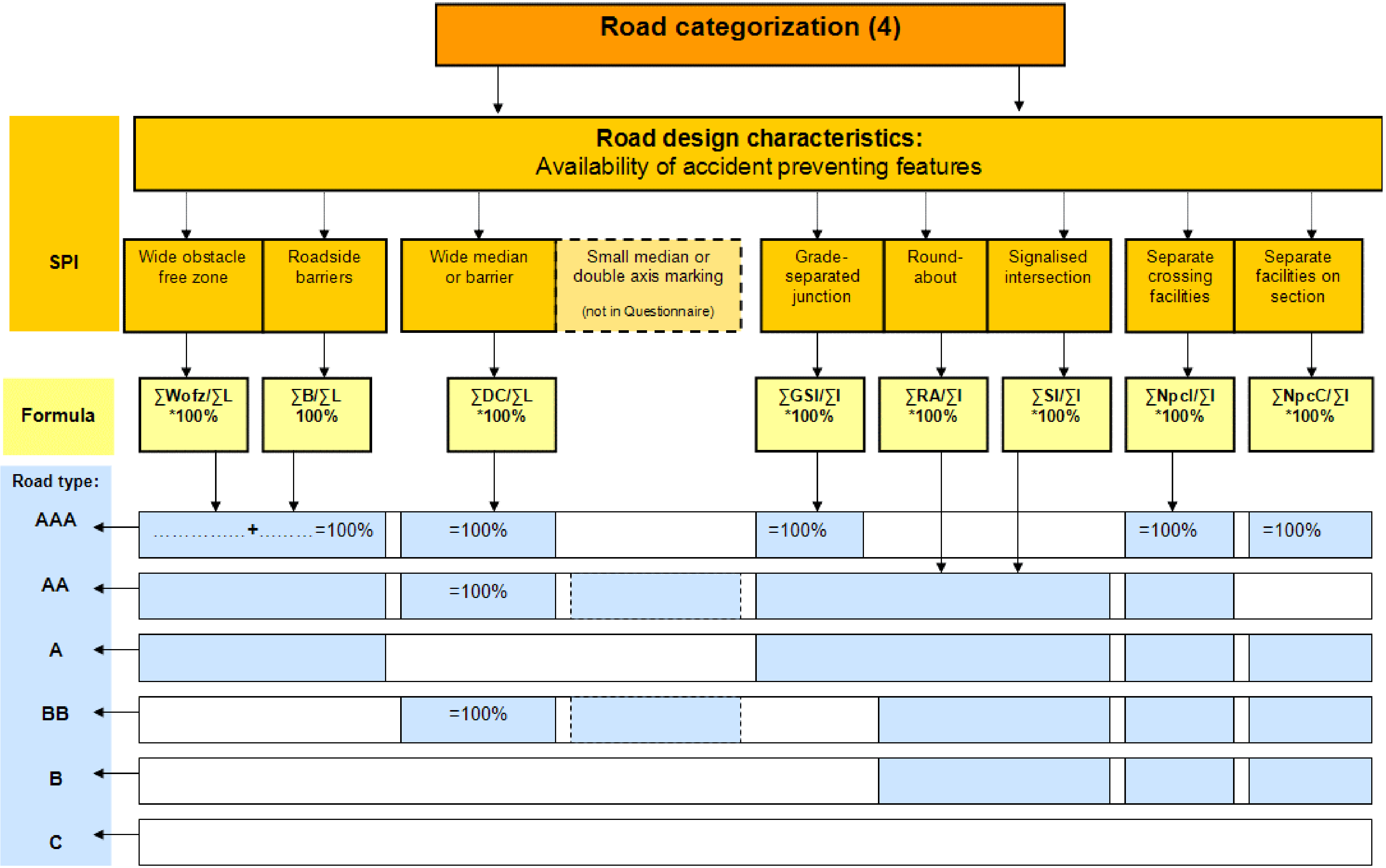

SPI Roads (3)
Road design characteristics:
Availability of accident preventing features
SPI
Wide obstacle free zone
Roadside barriers
Wide median or barrier
Small median or double axis marking
(not in Questionnaire)
Grade-separated junction
Round-about
Signalised intersection
Separate crossing facilities
Separate facilities on road section
Formula
∑Wofz/∑L *100 %
∑B/∑L 100 %
∑DC/∑L *100 %
∑GSJ/∑I *100 %
∑RA/∑I *100 %
∑SI/∑I *100 %
∑Npcl/∑I *100 %
∑NpcC/∑I *100 %
Primary Data
For each road section x [No.]= x ε {1, 2, 3, ..,N}
• L: Length [km] (= end-start)
• FV: Flow volume: AADT [veh/24h]
• TP: (Traffic Performance: vehicle-km travelled per year [veh*km/year])
• SL: Speed limit: leading value [km/h]
• DC: Dual carriageway (km)
• {NO: No overtaking (overtaking difficult/not possible, not in questionnaire) [km]}
• NpcC: No pedestrians and cyclists on Carriageway (km)
• Wofz1 , Wofz2: Wide obstacle free zone on side 1 or side 2 (km)
• {Nofz1 , Nofz2: Narrow obstacle free zone on side 1 or side 2 (km)}
• B1 , B2: Barrier (instead of obstacle free zone) on side 1 or side 2 (km)
Totals per connection j
• I: Intersection/junction (number=#)
• GSJ: Grade-separated junction (#)
• RA: Roundabout (#)
• SI: Signalised Intersection (#)
• [NSI: Non-signalised Intersection (#)]
• Npcl: No pedestrians and cyclists on Intersection (#)
General Data
• Country: name, population (#), total road length (km), road length per national road type (km), traffic performance per national road type [veh*km/year]
• Region(s): name, population (#), total road length (km),), road length per national road type (km), traffic performance per national road type [veh*km/year]
• Origin urban area/centre: name, population (#); results in O ε { 0, 1, 2, 3, 4, 5} according to table 6 & 7
• Destination urban area/centre: name, population (#); results in D ε { 0, 1, 2, 3, 4, 5} according to table 6 & 7
• National road types: name, code / No
• Road safety: total number of fatal accidents (#)], per region or country; number of fatal accidents per national road type
• Traffic performance: total vehicle-km travelled per year [veh*km/year], per region or country.
• Source and reference year of the data


Road categorization (4)
Road design characteristics:
Availability of accident preventing features
SPI
Wide obstacle free zone
Roadside barriers
Wide median or barrier
Small median or double axis marking
(not in Questionnaire)
Grade-separated junction
Round-about
Signalised intersection
Separate crossing facilities
Separate facilities on section
Formula
∑Wofz/∑L *100%
∑B/∑L 100%
∑DC/∑L *100%
∑GSI/∑I *100%
∑RA/∑I *100%
∑SI/∑I *100%
∑Npcl/∑I *100%
∑NpcC/∑I *100%
Road type:
AAA
AA
A
BB
B
C
...............+.........=100%
=100%
=100%
=100%
=100%
=100%
=100%

SPI Roads (5)

SPI	**Road network characteristics:** Share of connection types **Share connection types per region/country and connection types:** (0,0): %, (0,1): %, (0,3): %, (1,1):: %,...,(5,5): %
Formula	$\frac{L_{jR}}{L_R} * 100\%$ L_{ix} Length road type i at road section x L_{ij} Length road type i, at connection j $L_j = \sum_i L_{ij}$ Length connection j L_{ijR} Length road type i at connection of type j in region R $L_{jR} = \sum_i L_{ijR}$ Length connections j in region R $L_R = \sum_{i,j} L_{ijR}$ Length roads in Region R I_{zjx} Number of intersection type z at connection j f $I_{zj} = \sum_x I_{zjx}$ Number of intersection type z at connection j $I_j = \sum_{z,x} I_{zjx}$ Number of intersections at connection j $I_j R = \sum_{z,x} I_{zjxR}$ Number of intersections at connections j in reg i ε {AAA, AA, A, BB, B, C} j ε { (0,0), (0,1), (0,2), (1,1), (1,2), (1,3), (2,2), (2,3), (2,4), (3,3), (3,4), (3,5), (4, z ε {GSJ, RA, SI, NSI}
Primary Data	• Origin urban area/centre: name, population (#); results in O ε { 0, 1, 2, 3, 4, 5} according to table 6 & 7 • Destination urban area/centre: name, population (#); results in D ε { 0, 1, 2, 3, 4, 5} according to table 6 & 7 **For each road section x** [No.]= x Є {1, 2, 3, ..,N} • L: Length [km] (= end-start)
General Data	• Country: name, population (#), total road length (km), road length per national road type (km), traffic performance per national road type [veh*km/year] • Region(s): name, population (#), total road length (km),), road length per national road type (km), traffic performance per national road type [veh*km/year] • National road types: name, code / No • Road safety: total number of fatal accidents (#)], per region or country; number of fatal accidents per national road type • Traffic performance: total vehicle-km travelled per year [veh*km/year], per region or country. • Source and reference year of the data

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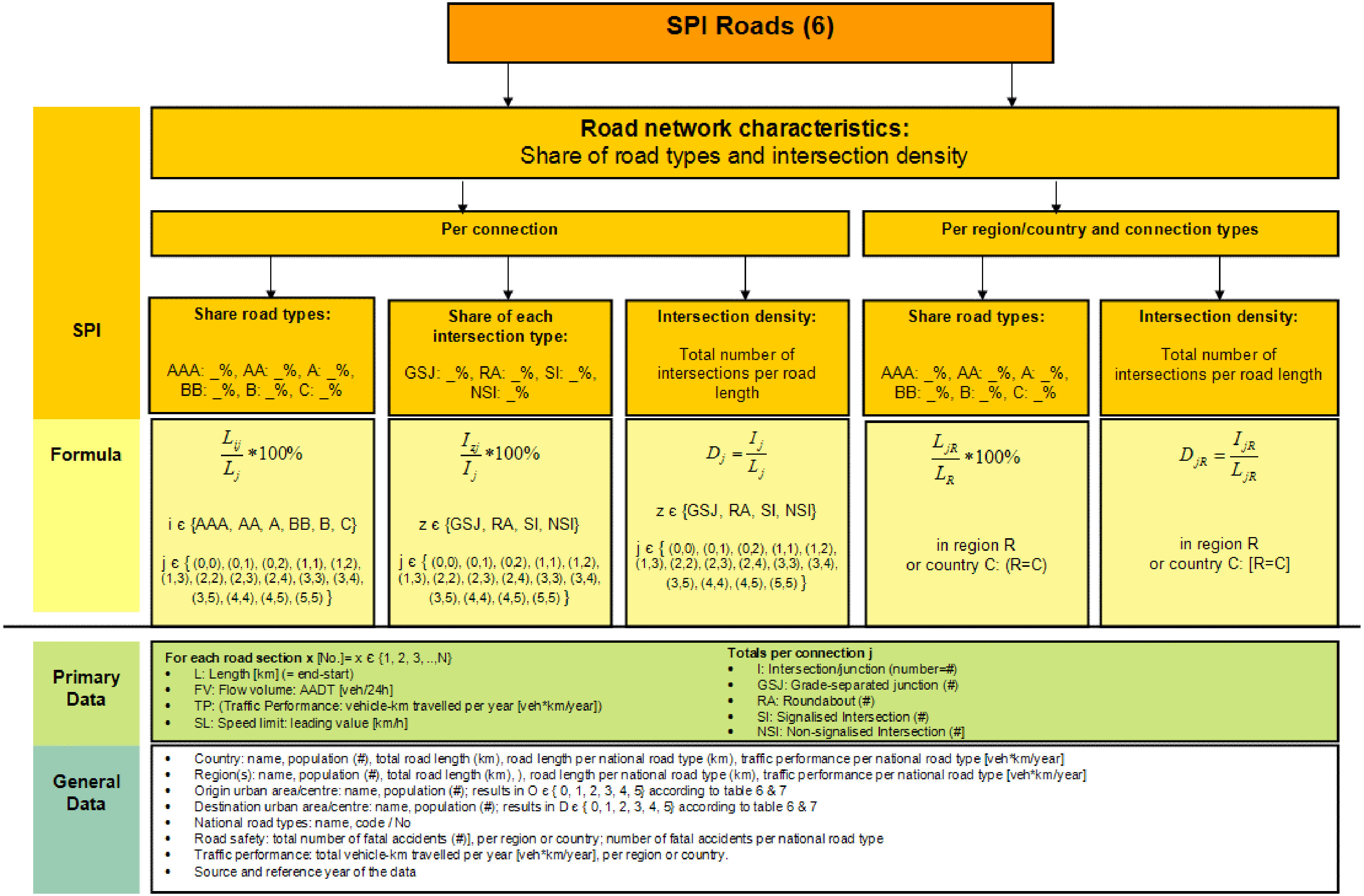
SPI Roads (6)
Road network characteristics:
Share of road types and intersection density
Per connection
Per region/country and connection types
SPI
Share road types:
AAA: _%, AA: _%, A: _%, BB: _%, B: _%, C: _%
Share of each intersection type:
GSJ: _%, RA: _%, SI: _%, NSI: _%
Intersection density:
Total number of intersections per road length
Share road types:
AAA: _%, AA: _%, A: _%, BB: _%, B: _%, C: _%
Intersection density:
Total number of intersections per road length
Formula
$\frac{L_{ij}}{L_j} * 100\%$
i ε {AAA, AA, A, BB, B, C}
j ε { (0,0), (0,1), (0,2), (1,1), (1,2), (1,3), (2,2), (2,3), (2,4), (3,3), (3,4), (3,5), (4,4), (4,5), (5,5) }
$\frac{I_{zj}}{I_j} * 100\%$
z ε {GSJ, RA, SI, NSI}
j ε { (0,0), (0,1), (0,2), (1,1), (1,2), (1,3), (2,2), (2,3), (2,4), (3,3), (3,4), (3,5), (4,4), (4,5), (5,5) }
$D_j = \frac{I_j}{L_j}$
z ε {GSJ, RA, SI, NSI}
j ε { (0,0), (0,1), (0,2), (1,1), (1,2), (1,3), (2,2), (2,3), (2,4), (3,3), (3,4), (3,5), (4,4), (4,5), (5,5) }
$\frac{L_{jR}}{L_R} * 100\%$
in region R or country C: (R=C)
$D_{jR} = \frac{I_{jR}}{L_{jR}}$
in region R or country C: [R=C]
Primary Data
For each road section x [No.]= x Є {1, 2, 3, ..,N}
• L: Length [km] (= end-start)
• FV: Flow volume: AADT [veh/24h]
• TP: (Traffic Performance: vehicle-km travelled per year [veh*km/year])
• SL: Speed limit: leading value [km/h]
Totals per connection j
• I: Intersection/junction (number=#)
• GSJ: Grade-separated junction (#)
• RA: Roundabout (#)
• SI: Signalised Intersection (#)
• NSI: Non-signalised Intersection (#)
General Data
• Country: name, population (#), total road length (km), road length per national road type (km), traffic performance per national road type [veh*km/year]
• Region(s): name, population (#), total road length (km),), road length per national road type (km), traffic performance per national road type [veh*km/year]
• Origin urban area/centre: name, population (#); results in O ε { 0, 1, 2, 3, 4, 5} according to table 6 & 7
• Destination urban area/centre: name, population (#); results in D ε { 0, 1, 2, 3, 4, 5} according to table 6 & 7
• National road types: name, code / No
• Road safety: total number of fatal accidents (#)], per region or country; number of fatal accidents per national road type
• Traffic performance: total vehicle-km travelled per year [veh*km/year], per region or country.
• Source and reference year of the data

9.10 Survey form Questionnaire task 6 Roads

SafetyNet WP3 Task 6 - Safety Performance Indicators for Roads

Survey Form for Roads

Page….. of…..

	name	population	Urban area type
Country[i]			
Origin urban area[iii]			
Destination urban area[v]			

	name	code / No
National road type[ii]		
SafetyNet WP3 road type[iv]		

Road section[vi]				National road type[vii]	SafetyNet WP3 road type[viii]	**Volume[ix]**	**Performance[x]**	**Speed limit[xi]**	**Carriageway[xii]**		Separation[xiii] (no pedestrians/bicycles)	**Obstacle-free zone[xiv]**						**Intersection[xv]**				Separation[xvi] (no pedestrians/bicycles)
									Dual	Single		Roadside 1			Roadside 2					At-level		
No	start	end	length			AADT	(vehicle-km travelled)	(leading value)	(median or barrier)	(axis marking only)		wide	narrow	barrier	wide	narrow	barrier	Grade-separated	Round-about	signalised	not signalised	
	(km)	(km)	(km)			(veh/24h)	(veh*km/year)	(km/h)	(km)	(km)	(km)	(km)	(km)	(km)	(km)	(km)	(km)	(#)	(#)	(#)	(#)	(#)
1																						
2																						
3																						
etc.																						
Road	total[xvii]																					
	percentage[xviii]																					
Intersection	total[xix] #											'wide' >…..meter from edge marking										
	density [xx]																					
data reference[xxi]	source																					
	year																					

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[i] Fill in the name of the country in which this survey took place and the number of inhabitants.
[ii] Fill in the name that is used in your country ([1]) for this kind of road type, together with the code or number of the road (like A1, E23 or N123).
[iii] Fill in the name of the urban area (=urban centre i.e. name of city, town or village) at which the road connection starts and fill in number of inhabitants together with the area type according to the SafetyNet WP3-typology (type 1 > 200.000, type 2 = 100.000-200.000, type 3 =30.000-100.000, type 4 =10.000-30.000, type 5 < 10.000 (exceptional type 0 = London, Paris, Berlin, Madrid and Rome).
[iv] Fill in which road type you think this road connection probably has, according to the SafetyNet WP3 functional road classification.
[v] Fill in the name of the urban area at which the road connection ends and fill in number of inhabitants together with the area type according to the SafetyNet WP3-typology.
[vi] The road connection between origin and destination area can be (probably is) divided in various road sections. Each road section has a number, a starting point and an end point. The difference between start and end is the length (km) of the road section. The summation of these lengths should be the total length of the road connection.
[vii] Fill in the code or number of the road (like A1, E23 or N123) that is used in your country ([1]) for this kind of road type. (for each road section)
[viii] Fill in which road type you think this road connection probably has, according to the SafetyNet WP3 functional road classification. (for each road section)
[ix] The definition of traffic volume is the annual average daily traffic (AADT) that is representative for each road section. Fill in for each road section.
[x] The definition of traffic performance is the amount of vehicle-kilometres travelled. This is the result of the road section length multiplied by the annual average daily traffic multiplied by 365 days per year. Fill in for each road section.The total traffic performance of the road connection is the summation of the values per road section.
[xi] The speed limit per road section is preferable the leading value. That is the value applied at 80% or more of the road (section) length. Fill in for each road section.
[xii] Dual-carriageways and single-carriageways are distinguished. At a dual-carriageway the driving directions are physically separated by a medium or safety barrier in order to prevent conflicts between opposing traffic. At a single-carriageway the driving directions are only separated (virtual) by axis marking. Fill in the length (km) of the (road) section at which a dual or single carriageway is present.
[xiii] We want to know if there is any separation of road users according to differences in mass, protection and speed. This is the case if there are no pedestrians, cyclists or mopeds on the same road as the cars and trucks, or if they can use a parallel separated (cycle-) path. Fill in for each road section at how many kilometres this separation has been applied.
[xiv] Fill in the length (km) of the road section at which the obstacle-free zone is wide or narrow or at which there is a barrier present. We also want to know the minimum width of 'wide' obstacle-free zone that is used. (an obstacle-free zone is wide (enough) if it can avoid an (serious) accident (given the speed limit) if a vehicle runs off the road)
[xv] In this case we distinguish grade-separated intersections, roundabouts or at-level intersections with or without traffic lights (signalised or not). Fill in for each road section the number of each intersection type.
[xvi] We want to know if there is any separation of crossing road users according to differences in mass, protection and speed. This is the case if there are no pedestrians, cyclists or mopeds or if they can use special facilities to cross separately. Fill in for each road section at how many intersections this is the matter.
[xvii] In this row the totals are obtained by summation of the column values (with the exception of speed limit [9])
[xviii] In this row the column totals are expressed as percentages of the total road length[6].
[xix] In this row the total number of intersections has to be filled in, together with the total number of each intersection type.
[xx] In this row the intersection density (i.e. number of intersections per kilometre) can be filled in.
[xxi] In this row can be used to fill in the source and reference year of all the data that is used in each column.

10 Trauma management

Victoria Gitelman, TECHNION; Kerstin Hafen, BASt; Vojtech Eksler, CDV; Shalom Hakkert, TECHNION.

10.1 Introduction

10.1.1 Trauma management: The problem

The better the post-crash care by emergency and medical services, the greater the chance of survival and, on survival, the quality of life (ETSC, 2001). The same goes for the opposite: Improper functioning of the post-crash care system leads to more fatalities and severe injuries, which could be avoided.
The term "Trauma Management" refers to the system, which is responsible for the medical treatment of injuries resulting from road crashes. Sometimes, this system is referred to as "the Post-Crash Trauma Care". Two recently published summary reports underlined the potential of improved trauma management for the reduction of road crash fatalities and injuries: OECD (1999) and ETSC (1999).

The OECD report "Safety strategy for rural roads" (1999) showed the importance of emergency services by indicating differences between the survival in severe (fatal and serious) crashes in rural versus urban areas. The ETSC report "Reducing the severity of road injuries through post-impact care" (1999) highlighted evidence-based actions for the organisation of optimal trauma care in the EU.

As stated by ETSC (1999) and other studies, rigorous experimental evidence in trauma care is often lacking. The following summary of the literature provides some evidence of the crash reduction potential from improved trauma management.

10.1.2 Trauma management: Scope of the reduction potential

Not all fatalities in road crashes die instantly at the scene. Typically, there are three time periods in which death from road trauma can occur. The first period comes immediately in the seconds and minutes that follow the injury. Death is usually due to disruption of the brain, central nervous system, heart, aorta or other major blood vessels. Only a few of those patients can be successfully treated and then only in large urban areas where very rapid emergency treatment and transport is available. The second period occurs in the one to two hours after the incident (“golden hour”). Death in these instances results from major head injuries (subdural and extradural haematoma), chest injuries (haemopneumothorax), abdominal injuries (ruptured spleen, lacerated liver), fractured femur and pelvis, or multiple injuries associated with major blood loss. Survival rates during this period are clearly dependent on early and appropriate medical intervention (OECD, 1999). The third death period occurs during several days or weeks after the initial injury. Major causes of death include brain death, organ failure and overwhelming sepsis. Improved survival rates during this period mainly depend on the quality of hospital treatment.

Thus, one can conclude that the potential to reduce fatalities by means of an early and appropriate medical treatment (in the form of emergency medical help and further hospital treatment) is given at least for the patients in the second and third periods after the crash.
International studies estimated the shares of road crash fatalities, which refer to different time periods after a crash. Australian data show that death at the scene occurs in 57% of rural fatal crashes, and in 44% of urban fatal crashes (OECD, 1999). Likewise, on the basis of a full-scale survey in Hungary (Ecsedy and Hollo, 1994) it was found that in the case of fatalities, about half of all the victims are taken to a hospital before they die. For the purpose of international comparisons of fatality data, the United Nations adopted a figure of 65% of fatalities, who died at the scene of a crash or on the way to the hospital (UN, 1994). The ETSC report (1999) also states that about 50% of deaths from road traffic crashes occur within minutes at the scene or in transit and before arrival at hospital; some deaths (15%) occur between 1-4 hours after the crash but the majority (35%) occur after 4 hours.

This implies that 35%-50% of cases are "treatable", i.e. occur during the second and third after-crash periods, and therefore, can be influenced (partly reduced) by an improved trauma management system. The chance to survive depends heavily on emergency help provided at the crash scene, on the way to the hospital and at the hospital. All the literature sources highlight the necessity for appropriate mechanisms to transport severely injured victims to proper (but frequently, distant) hospitals and the requirement for adequate medical equipment and personnel at the hospital.

10.1.3 Trauma management: Available estimates of the reduction potential

A 1995 study of 155 fatalities in 24 rural counties in the State of Michigan, United States, concluded that about 13% of the fatalities could be determined to be definitely preventable or possibly preventable (Maio et al, 1995) if rapid emergency treatment and transport were available.

A study conducted in the United Kingdom estimated that 12% of patients who had sustained serious skeletal trauma went on to have significant preventable disabilities (McKibbin et al, 1992).
In Germany, with a highly developed system of emergency services, it was estimated that every tenth person killed in a traffic crash could still be alive if only he/she could have been rescued more quickly and thus been placed under more qualified medical care, and that each 30 minute delay in the start of therapy triples the death rate (Pegler, 1989).

It was shown in France that the consequences of a crash could be reduced by 1% for every minute saved in the arrival of first aid (Bernard-Gely, 1998).
To summarize, according to specific estimates attained in different countries, 10%-13% of the fatalities can (probably) be prevented due to improved trauma management; similar figures are also relevant for serious injuries. The reduction potential of the measure will definitely be higher in those countries with a lower initial state of the trauma management system.
As estimated by ETSC (1999), several thousands of deaths could be prevented in the EU by optimal post crash care.

10.1.4 Trauma management: Basic ideas for developing Safety Performance Indicators

Emergency medical care has developed independently in each European country, and even within cities and regions of a country, resulting in a variety of definitions, legislations, and systems (Bossaert, 1993).
Efforts to facilitate planning and organisation of Emergency Medical Services (EMS) with the objective to improve the standards of the EMS in Europe were made by the Council of Europe and the World Health Organisation (e.g. concerning resuscitation). Despite of these efforts, the cooperation and uniformity of the different EMS systems are still inadequate. This may be illustrated by the still insufficient implementation of a unique emergency telephone number (112) within the European countries or by a great variety of definitions used to describe the EMS systems and their components. These definitions must be known in order to interpret the structure and the activities of individual EMS systems.
A concept describing the sequential functions in the process of preclinical care was introduced in the late 1960s by Professor Ahnefeld in Germany. Presently, the concept of the "chain of survival" is generally accepted and has validity in all European countries.
A typical post-crash chain of events can be presented as in Figure 10-1. When a crash occurs, first aid is sometimes provided by a bystander. Usually, an emergency call takes place, which is responded to by EMS. The EMS arrive at the scene of the crash and provide initial medical treatment at the scene and during the transportation to a permanent medical facility. The permanent medical facility takes further medical care of the injured patient.
In this chain of events the authorities of medical care are involved in steps 4-7 (see Figure 10-1). These steps compose the mechanism of the post-crash trauma care in the country. The mechanism of post-crash trauma care comprises two types of medical treatment: that provided by emergency medical services and that provided by permanent medical facilities.

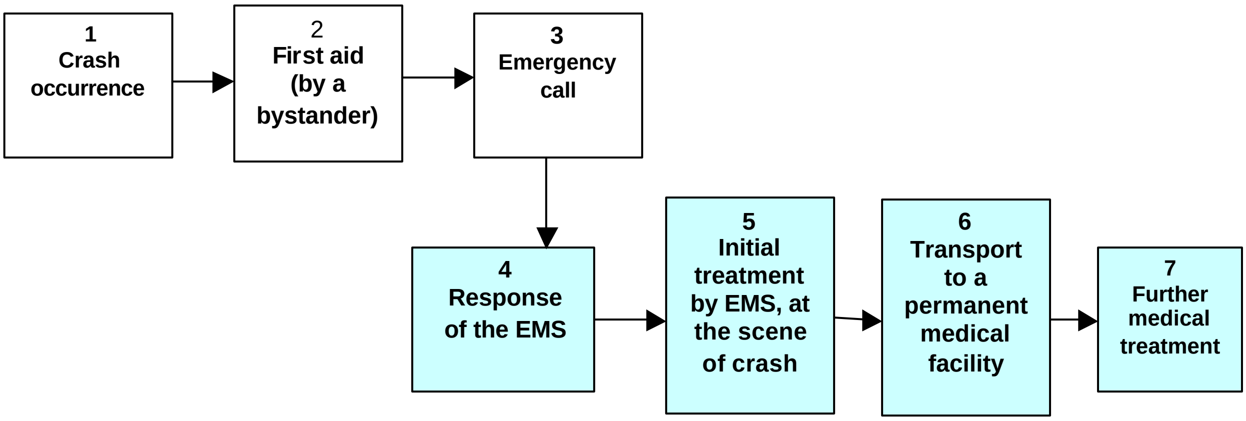

Figure 10-1: Post-crash chain of events

Emergency Medical Services are those, which normally answer the emergency calls and deal with the next steps, like sending an ambulance to the scene of crash. EMS staff provides basic medical assistance to injured patients on the scene and during the transportation to a hospital. There are different forms of EMS, which depend on:

- the type of transport means (ambulance, helicopter);
- EMS vehicle equipment (mobile intensive care unit; basic life support unit; regular ambulance);
- medical staff arriving with the vehicle (may include a physician, a paramedic, a "critical care" nurse, an emergency medical technician).

(For further details see *Glossary* of terms – Par. 10.8.2.)

Further medical treatment can be provided at a regular hospital or at a specially equipped Trauma Centre/the trauma department of a hospital, whereas minor injuries are usually treated by doctors/other medical staff outside a hospital. The focus of the trauma management system is on patients who are hospitalized.

The quality of the post-crash trauma care has a direct implication on the condition and the number of crash injuries. To reduce the severity and the number of road crash victims, ***the trauma management system should provide rapid and adequate initial care of injury, combined with sufficient further treatment at a hospital or trauma centre***. Improper functioning of the post-crash care system implies a lack of treatment and/or improper treatment of injuries (at any stage of the treatment).

Trauma management's Safety Performance Indicators (SPIs) intend to qualify and quantify the performance of the post-crash care system in the country. In order to do this, ***the speed and the quality of the post-crash care, both initial and further, should be estimated***.

10.2 Constructing Indicators

10.2.1 A need for multiple and indirect indicators

The question of how rapid and how proper the treatment was does not have a simple answer, as, for example, medical assistance never comes immediately

(in the majority of cases a notification takes place first), and the quality of the treatment provided should be judged, based on trauma care practices and rules which are established in each country. There are various forms of injury and different forms of trauma care, as well as sets of rules to take care of any specific case. As we intend to measure both the speed and the quality of the treatment, no single performance indicator will be suitable for this purpose. Due to all these reasons, a direct measurement of "unsafe operational conditions" (improper functioning of the trauma care system) is impossible in our case, and the evaluation should be based on understanding and measuring of the real processes of the trauma management system in the country.
Besides, the scope of consideration should be defined correctly, because the number of crash injuries known to the police and the number of persons treated by the trauma care system usually have an overlap but are never identical.

10.2.2 SPIs' identification

As was stated before, trauma management SPIs intend to estimate the speed of the initial treatment by EMS and the quality of the initial (by EMS) and further (by a permanent medical facility) post-crash care. Therefore, the three major characteristics of the trauma care system, which should be explored, are:
(1) time values associated with the initial treatment;
(2) quality of the initial treatment, on the scene and in transportation;
(3) quality of further treatment in a permanent medical facility.
In general, for estimating the trauma management's SPIs, two ways are possible:
(a) examining the correspondence of actual performance to the official demands;
(b) considering actual values of SPIs.
Both ways are essential because, first, the system should function in accordance with the legal norms established in the country and, officially, it can be judged in accordance with these norms only. However, as we aspire to know the actual performance of the system (being able to compare different systems as well), the actual values of SPIs are also important. As each way of estimation defines a group of indicators, in a general case, all kinds of interventions in the post-crash care system should be estimated by both groups of indicators.
Beside the indicators dictated by the mechanism of post-crash treatment, a group of general indices should be considered whose purpose is to evaluate the general level of trauma care in the country.
Further in this section, a general concept of trauma management SPIs, based on the aforementioned major characteristics of the trauma care system and the ways of their estimation, is presented. This concept served as a basis for the development of a Trauma questionnaire. Later, based on the questionnaire's responses, the concept was updated; the updated concept of Trauma management SPIs is detailed in Section 10.5.
A general classification of the trauma management SPIs can be presented as in Table 10-1.

SPI groups	(a) Way of evaluation: correspondence with official demands	(b) Way of evaluation: characteristics of actual values
(1) Time values of the initial treatment	Group A	Group B
(2) Quality of initial treatment	(Group C)	Group D
(3) Quality of further treatment	(Group E)	Group F
General indices	--	Group G

Table 10-1: General concept of trauma management SPIs

Accounting for the state of current practice of trauma management systems in selected countries[i], the following groups of SPIs were initially suggested for evaluation:

Group A – a percentage of EMS responses meeting regulations for response time;

Group B – characteristics of EMS time values such as average response time, the percentage of cases where the response time was below a certain value (e.g. the demand);

Group C – e.g. percent of cases meeting regulations/law for the type of EMS care of severe injuries – *cannot be estimated*. Reason: no official demands are available on the issue.

Group D – Presentation of the scope and the forms of EMS activity:

- the number of EMS dispatching centres and EMS stations;
- distribution of transportation means (total figures and shares of different types);
- distribution of medical level of EMS teams (total figures and shares of different types);
- annual number of EMS calls;
- annual number of EMS rides (total and shares of different transportation units and different EMS teams);
- average time for treating a case at the scene;
- average time for arriving to hospital.

The following comments are essential for estimating group-D indicators:

(a) The intention of group D indicators is to present the scope of EMS activity *in the service of road crashes*. However, as known, EMS requires various kinds of injury as well as for other diseases. When the source of the information is the national EMS statistics, where specific figures on serving road crashes are unavailable, general EMS figures should be presented with an indication of the share of activities related to road crash injury (e.g. the percent of road crash injuries out of total patients treated by EMS).

(b) An additional way for estimating the quality of initial treatment provided for road crash injuries is using a Trauma Registry (where such a system exists). For example, among motor vehicle injuries registered by the Trauma Registry, it

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[i] Based on the results of a preliminary survey of trauma management systems in three countries: Germany, Israel, and the Czech Republic (July-August 2004).

is possible to see the share of those delivered by different types of EMS transportation units.
Group E - e.g. percentage of cases meeting regulations/laws for the type of medical facility for care of severe injuries – *cannot be estimated*. Reason: no official demands are available on the issue.

Group F - Presentation of the possibilities of further treatment and the actual treatment applied. As to the first point, the types and the numbers of permanent medical facilities to deliver injured patients (with the number of beds) should be presented. To characterize the actual treatment provided for road crash injuries, the best way is to apply to the Trauma Registry, estimating indicators such as:

- share of those treated at a higher level of hospital (e.g. certified trauma centre);
- mean lengths of stay in the hospital;
- share of those who died during hospitalisation;
- share of treated in intensive care units;
- average number of days in intensive care unit;
- share of those who were in surgery rooms;
- share of transferred to rehabilitation facilities upon discharge.

For a better understanding of the scope of data presented by the Trauma Registry, the above characteristics of actual treatment should be accompanied by: (a) the share of severe cases (e.g. with ISS = 16) among the road crash casualties treated; (b) the relation between the number of cases presented by the Trauma Registry and the total number of road crash injuries reported in the country.

Group G – general indices of the level of trauma care such as:

- the number of EMS units per 10,000 population or 100 km road length;
- the number of trauma centre beds/trauma department beds per 10,000 population.

The idea of the group G indicators is that beside the absolute figures of the initial and further trauma care (which we have in group D and group F indicators), for the comparisons between the countries and over time, the values should be presented in the context of the area served. The area served can be characterized by the total population, the total length of roads, or the size of traffic (vehicle kilometres travelled).
It is also important to see the share of activity of the trauma care system associated with road crash injuries, e.g. share of EMS journeys associated with road crashes; share of injuries treated by trauma care facilities with the initial diagnosis of MVA (motor vehicle crashes). For a better understanding of the scope of EMS activity in the context of road trauma, the relation between the number of road crash injuries treated by the EMS and the total number of road crash injuries reported in the country should be presented.
It is worth mentioning that the above concept of trauma management SPIs accounts for the suggestions by ETSC report "Transport Safety Performance

Indicators" (2001) in the part of trauma management related indicators, and extends them significantly.
The above concept of the development of trauma management's SPIs was verified by:
(1) a literature review of empirical studies which analysed EMS systems/forms of post crash care in different countries;
(2) a detailed analysis of indicators which can be produced by Trauma Registry databases.
The findings of the literature study are given in *Annexes* (Par. 10.8.3). In general, they support the above concept. The capabilities of a Trauma Registry for improving trauma management's SPIs are discussed in Section 10.5.

10.3 Questionnaire

The questionnaire was constructed aiming at two purposes:

a) to describe the mechanism of the post-crash trauma care system in each country, and
b) to provide available data on the system's performance.

Both components are essential to examine the possibility of estimating trauma management's SPIs, for a specific country.
The questionnaire begins with an introduction of the typical post-crash chain of events and the definitions of basic notions. As the post crash care mechanism comprises two types of medical treatment: by emergency medical services (EMS) and by permanent medical facilities, the questionnaire consists of two main parts: "EMS" and "Further medical treatment".
Besides, general data on the country, the following are collected: total population and the share living in urban areas, the length of public roads, vehicle numbers, and vehicle distance travelled. These data may be of use in calculating rates and estimating correction factors for comparison of SPIs from different countries. In addition, the annual numbers of road crash injuries according to police records are requested; these are essential for a comparison of the national crash statistics with the number of injuries treated by the post crash trauma care system.
Concerning EMS, the questionnaire asks for a description of operational procedures, legal norms and regulations, staff and equipment in service, time values of initial treatment, numbers of patients treated and the quality of initial treatment. The questions cover all the data which is required for the evaluation of A, B and D groups of the SPIs (which were introduced in Section 10.2 above). Besides, using the data requested, the rates such as the number of EMS units per 10,000 population /100 km of road length can be estimated as well as the share of road crash injuries out of total patients treated by EMS (refer to the SPIs of group G – see Section 10.2).
Concerning further medical treatment, the questionnaire asks for a description of operational procedures, Trauma Registry and indicators of trauma care based on the Trauma Registry data (if available), other injury databases, and trauma management indicators in use. The questions cover all the data, which are required for the evaluation of group F of the SPIs (as introduced in Section 10.2). Besides, using the data requested, the rates such as the number of

trauma centre beds/medical facilities' beds per 10,000 population can be estimated as well as the share of road crash injuries out of total injuries treated by hospitals/special trauma centres (refer to the SPIs of group G – see Section 10.2).

10.4 National Responses

10.4.1 National General Conditions

Based on the questionnaire responses received so far, we conclude that European countries generally have norms and regulations for emergency medical services, but these differ between the countries and, sometimes, between areas within a country (e.g. in federal states). The norms regarding EMS response time exist, in a certain form, in half of the countries. Compliance with these norms is assessed from time to time. Recent estimates of EMS response times are available in half of the countries.

As stated by the questionnaire's responses, EMS databases exist in many countries; annual figures are usually produced but these are still not linked to other crash databases, i.e. the police crash files or other medical databases.

In the majority of countries, the composition of EMS teams, types of medical treatment provided at the scene, and the type of medical facility to transport the patient are regulated by internal rules. However, the quality of initial treatment provided following these rules usually is not estimated.

Trauma Registry and other medical databases exist in some countries, but these typically only cover selected hospitals or specially defined types of injury (e.g. severe injuries). Therefore, specific terms of reference should be defined presenting the data from these databases. Using this data, a direct comparison between the countries is not simple but possible, having pointed out the differences between the sampling rules in the databases.

Available trauma registry and other medical databases are generally not linked to the road safety research and management activities. Mapping the trauma data and integrating them with the road safety data would lead to significantly improved decision making in emergency medical treatment of road crash casualties.

In some countries, much data on the performance of post-crash trauma care in the country is lacking, i.e. not in use in the current decision-making practice. This means that special efforts will need to be applied to provide the data requested for the calculation of the trauma management SPIs.

Judging from the state of practice in the majority of countries, the data for estimating trauma SPIs should be collected and the values estimated not more frequently than on an annual/bi-annual basis.

10.4.2 Resulting Difficulties

Differences among the countries exist in:

- EMS regulations, e.g. norms for the response time, EMS teams' composition, transportation units in use;

- Further medical treatment, e.g. types of available medical facilities and regulations for their use;
- Population patterns, e.g. density of urban areas, length of rural roads, lack of territorial continuity.

The above differences complicate the comparisons as they may appear as confounding factors in estimating SPI values for different countries. To diminish the influence of these differences, typical estimation conditions should be defined for the SPIs recommended for use.

Besides, in some countries, uniform regulations, rules, and databases are not available for the whole country. In this case, a recommendation should be given to provide the data on *a representative sub-area* of the country.

Another significant obstacle for estimating SPIs in some countries is a lack in ready quantitative data on the performance of EMS and further medical treatment of crash injuries. The state of the data is not uniform among the countries, therefore a further subdivision of SPIs on more common (and presently realisable for the majority of countries) and less common (i.e. unrealisable for the majority of countries, at least in the near future) should be applied.

Applying the Trauma Registry data, one should remember that such a database usually contains a selected sample of injuries. Selecting rules of the databases should be accounted for working with their outputs and especially, comparing the values from different countries.

10.4.3 Examination of available responses

So far, the questionnaire's responses are available, in total, from 16 countries, as presented in Table 10-2. However, 3 countries, i.e. the United Kingdom, Spain and Switzerland provided general data only, with no information on the trauma care system in the country. Therefore, the detailed examination of the responses and further development of trauma management SPIs are based on the responses provided by 13 countries.

Country no	Country Name	Country Code	Task 7: available responses	General data: lacking	Trauma data: lacking
1	Belgium	BE	Y		
2	Czech Republic	CZ	Y		
3	Denmark	DK	Y	no data	
4	Germany	DE	Y		
5	Estonia	EE	Y		
6	Greece	EL	Y		
7	Spain	ES	Y		no data
8	France	FR			
9	Ireland	IE			
10	Italy	IT			
11	Cyprus	CY	Y		
12	Latvia	LV	Y		
13	Lithuania	LT			
14	Luxembourg	LU			

15	Hungary	HU	Y	incomplete	
16	Malta	MT	Y	incomplete	
17	The Netherlands	NL			
18	Austria	AT	Y	incomplete	
19	Poland	PL			
20	Portugal	PT	Y	incomplete	
21	Slovenia	SI			
22	Slovakia	SK			
23	Finland	FI			
24	Sweden	SE			
25	United Kingdom	UK	Y		no data
26	Norway	NO	Y		
27	Switzerland	CH	Y		no data

Table 10-2: State of responses on the Trauma questionnaire (July-2005).

The following are the results of examination of responses.

1. General

- In most cases, the information is provided by a medical expert or a researcher.
- More information is available on EMS (initial treatment) than on further medical treatment.
- None of the countries provided all the requested data (because some data is unavailable).
- Definitions of injury: in 14 out of 16 countries the definition of fatality is similar to the general one; in 11 out of 16 countries the definition of serious injury is similar to the general one; in 11 out of 16 countries the definition of slight injury is similar to the general one. All three definitions are similar to the general ones in 10 out of 16 countries. (see *Glossary* – Par. 10.8.2)
- Definitions of ambulance types and the demands for their equipment according to EN 1789 need a comment (see *Glossary*).
- Additional medical scales were mentioned by some countries and need to be explained[ii].
- Further clarifications of some answers are required[iii].

2. EMS

Legal norms and regulations

- In all countries EMS is working 24 hours a day, 7 days a week.
- Estimates of notification time are usually unavailable (except for Austria: an empirical estimate of 1-3 min is provided; and for Latvia: unreliably high values are mentioned).
- Demands for response time exist in the majority of countries (8); in 7 countries quantitative values are provided. The most frequent

[ii] Recently, the requests were formulated and turned to relevant experts of those countries.
[iii] The same

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general demand is that the response/arrival time should not exceed 15 min (5 countries).

- Typical EMS teams are provided by all countries. Usually, two levels exist: a paramedic and/or emergency technician (or a nurse) attends in regular cases, where for severe cases an emergency physician joins the team. The team members usually have a special medical qualification/passed special trainings in emergency medicine.
- In all countries, specially equipped ambulances are in use. Typically, several equipment levels are defined. Concerning the ambulance equipment, at least 5 countries mentioned a correspondence to the European Norms. 2 countries (Germany and Czech Republic) apply a RVS ("Rendezvous system") where the emergency physician arrives at the crash's scene by a separate car. At least 6 countries mentioned the use of helicopters/planes for delivering patients to hospitals.
- Policy for treating injuries on scene: 5 countries stated "scoop and carry/load and go"; 7 countries stated – "stay and play" (one – "pathology recognition") as the basic policy.
- Medical treatment at the scene: in the majority of countries BLS is usually applied at the scene of crashes; ALS is applied if necessary.
- In all countries, EMS vehicles usually transport the patient to the hospital.
- In all countries, an EMS team member accompanies the transportation.
- EMS database: usually unavailable, except for 4 countries (Greece, Latvia, Estonia, Malta), which stated that they have such a database. In Belgium there are databases of local EMS centres. In Hungary, a partial EMS database was reported to exist: the operation data are input in the computer where medical reports are kept as papers.

Staff and equipment in service

- The number of EMS dispatching centres and the number of EMS stations are reported by all the countries.
- The number of medical staff was provided by 9 countries (+ for one regional centre, in the Czech Republic). The number of EMS teams is known in 5 countries (+ for one regional centre, in the Czech Republic).
- The number of transportation units is known for all the countries. Using the general data on the population size and road length, the rates of EMS transportation units per inhabitants and the road length can be estimated.
- The annual number of emergency calls is known for the majority of countries (exceptions: unknown for Latvia; for the Czech Republic available for one region). The share of road crashes out of these calls is known for 5 countries.

- The annual number of EMS rides is known for the majority of countries (exceptions: unknown for Estonia, Latvia, Norway). The share of road crashes out of these rides is known for 6 countries.

Response Time of initial treatment

- 5 countries reported on the percentage of responses meeting the demands on response time; another 3 countries (Greece, Cyprus, Austria) state that the question is irrelevant (no demand exists).
- The average value of response/arrival time is provided by 7 countries.
- The value of average time for treating a case at the scene and the average time for transportation are frequently unknown. The value of average time for treating a case was estimated by 3 countries (Germany, Czech Republic, Hungary). The average time for transportation was reported by 3 countries (Belgium, Greece, Hungary, where the Hungarian values seem unreliably high).

Quality of initial medical treatment

- The total number of crash injuries treated by EMS is usually unknown. Only 2 countries: Germany and Greece answered affirmatively; the value was provided by Germany only. The types of transportation units applied and the types of EMS teams applied were detailed by one country only (Germany).
- According to the responses, a medical scale is used by EMS for a qualification of the level of injury in 6 countries. The most widespread scale in use is GCS (in 4 countries).

3. Further medical treatment

Operational procedure

- A mix of trauma centres, trauma departments of hospitals and regular hospitals are in use for treating the road crash injuries, in the majority of countries. Selecting a facility to deliver the injured person, a combination of two criteria is usually applied: the hospital's proximity to the crash scene and its suitability for treating the injury considered.
- The number of beds in the available facilities was provided by 6 countries (out of 13).
- The medical scale used by permanent medical facilities for the characteristic of the level of injury is unknown for Portugal only. The most widespread scale in use is the GCS (10 countries); in second place the ISS (5 countries). Some countries (5) apply several scales.
- The scale values for severe injury were provided by 8 countries.

Trauma Registry

- A Trauma Registry database is available in 2 countries only: Germany and Greece (for selected hospitals); in Denmark, several hospitals have such a database. In Norway, a national database will be established in 2006.

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- When a Trauma registry database is available, the country provides values on the annual number of road crash injuries (registered in the database), the number of severe injuries, and the share of road crash injuries out of the total injuries.
- The types of transportation units, which brought the patients to the hospitals, were detailed both by Germany and Greece.
- Besides, based on the Trauma Registry records, details on the quality of medical treatment provided by permanent medical facilities were reported by both countries, e.g. the average length of stay, the share of mortality among hospitalized injuries, the average stay in intensive care unit, etc. However, all these values should be treated with caution, i.e. accounting for the selection rules applied to the cases included into the database.

Other injury databases and trauma management indicators in use

- Other injury databases on road crash injuries treated by medical facilities are usually unavailable for use.
- No country reported on the use of any trauma management indicators.

In order to judge the quality of the received responses one should remember that the questionnaire's purposes were to describe the existing mechanism of the post-crash trauma care and to provide available data on its performance. We believe that the respondents are well familiar with post crash care in their countries, and that they provided the best data available in the country. Therefore, there is no basis to doubt the quality of the data provided.

The questionnaire was constructed using a uniform framework and was accompanied by a set of uniform terms. Still, different interpretations of the questions are possible, especially accounting for the variety of EMS forms existing in different countries.

Therefore, based on the data collected, only a preliminary characteristic of the trauma management systems in the countries is possible, as additional verification of the data (mostly concerning the terms of references, in each country) are needed.

As mentioned before, part of the requested data were lacking in some countries, especially that referring to further medical treatment. This means that this data is not collected in a systematic way in that country and that, at this moment, we cannot estimate the whole set of the initially suggested SPIs for all the countries.

10.5 Searching for Appropriate Indicators

From the viewpoint of SPIs development, the questionnaire survey aimed at:
(a) checking the availability of data on trauma management systems in different countries;
(b) checking the possibility of application of the suggested set of SPIs.

As became obvious from the responses received, not all the required data is available for immediate application, and more detailed definitions of calculation terms are generally required for those which are available.
In this section we present a proposal for the development of a revised version of trauma management SPIs.

We suggest two sets of indicators:
(1) **Set A** - an initial (reduced) SPIs set, including indicators for which the data is available in the majority of countries. This set provides an initial characteristic of the post crash trauma care in the country, with mostly general figures on the availability of the services;
(2) **Set B** - an extended set, including both set A and the indicators for which the data is available in selected countries only. This set enables the creation of a comprehensive picture of the post crash trauma care in the country, with both general figures of the availability of services and characteristics of the quality of the treatment supplied.

The concept of Trauma Management SPIs consists of two major topics: "Speed and Quality of Initial Treatment by Emergency Medical Services" and "Quality of Further Medical Treatment". The first topic is divided into three sub-topics, which are "Staff and Equipment in Service", "Scope of Activity" and "Time Values". The second topic is represented by "Facilities in Service". Thus, Set A covers four themes as follows:

1. EMS: Staff and equipment in service
2. EMS: Scope of activity
3. EMS: Time Values of Initial treatment
4. Further medical treatment: facilities in service

Other essential characteristics to assess the quality of the initial and further treatment are provided by Set B. Set B includes, in addition to the indicators of Set A, two groups of indicators, which cover the following themes:

5. EMS database: Quality of treatment
6. Trauma Registry: Quality of treatment

The topics covered by Set A and Set B are based on the general concept of trauma management SPIs (as it was introduced in Section 10.2 and further developed by the questionnaire) and, also, account for the availability of trauma management data in the countries.
As we indicated before, for the majority of countries the information on the *availability* of trauma care services usually can be obtained, and sometimes on the scope and characteristics of EMS activity. This means that presently we can learn mostly about the *possibilities* of trauma care to be provided for the road crash injuries. If we are interested to estimate the quality of the medical treatment, which was *actually applied*, e.g. in terms of EMS units which treated the casualties or the ways of treatment in the hospital, this information is unattainable. In an ideal case, such information could be obtained from the hospital databases, had it been properly collected. However, presently, it is not

the situation in any country, and the best information on the actual treatments provided for the road crash injuries, is from the Trauma Registry databases.

As known, Trauma Registries exist in selected countries only and, what is more problematic, they work with injury samples, never covering the entire phenomenon. In spite of these disadvantages, Trauma Registries present a valuable source of information on actual treatment of road crash injuries, both today and in the future. For example, among motor vehicle injuries in the Trauma Registry, it is possible to see the share of those delivered by different types of EMS transportation units, or in other words, to indicate which share of road crash casualties was actually treated by a higher level of EMS units. Concerning medical treatment provided by permanent medical facilities, using the Trauma Registry it is possible the see the share of injuries treated by intensive care units, the share of those who were operated on, the length of stay in the hospital, the rate of mortality during hospitalization and other parameters which typically characterize the quality of medical treatment.

Due to the limitations of Trauma Registry databases, the obtained characteristics of actual treatment should be considered in a relevant context, i.e. to be accompanied by a share of severe cases among the road crash casualties that appeared in the database, and by a relation between the number of cases presented by the Trauma Registry and the total number of road crash injuries reported in the country.

The Trauma Registry data and the information from another database on actual performance of the EMS (if such EMS database is available in the country) are the basis for Set B of the trauma management SPIs. At present, Set B represents indicators for which the data are available in selected countries only. In the future, all European countries ought to provide this data as Set B reveals important aspects of Trauma Management, especially of the further treatment at permanent facilities.

As stated before, trauma SPIs are created to characterize the performance of the trauma management system in a country, where the emphases are on speed of initial treatment and on quality of the initial treatment by EMS and of further treatment by permanent medical facilities. The trauma management SPIs should be able to provide a characteristic of the country, to compare among the countries, to perform over-time considerations, to assist in estimating safety interventions, etc.

The ways for estimating SPIs should be uniform for all the countries and at the same time, should account for possible discrepancies in the raw data.

In general, SPIs may have the form of shares (percentages), rates or average values which are estimated based on the initial data provided by the countries. Usually, they present a result of calculation but, in some cases, no calculation is required where an estimate provided by the country serves as an SPI. Therefore, detailing the ways for estimating SPIs, it is important: (a) to define the sources of data items in use, and (b) to make a distinction between the initial data items to be provided by a country and the values to be calculated using these data.

As to the first point, a distinction is made between: (a) data items to be provided by the country and (b) the values calculated using the data items provided by the country and General information. As to the second point above, a distinction is made between: (a) primary data which are used for the calculation of SPIs, and (b) SPIs which are the values applied for the characteristic of trauma management system in the country.

Concerning the types of data items, it should be noted that, basically, SPIs are the values which will be used for the characteristic of trauma management systems in the countries. However, a presentation of SPIs alone (which are typically relative values like percentages or rates) might sometimes be insufficient, and they should be accomplished by primary data items. For example, a value of "percentage of EMS responses which meet the demand for response time" should be accompanied by the value of "the demand for a response time". Another example: presenting the characteristics of "EMS: Staff and equipment in service" it would be useful, in certain cases, to accompany the relative figures of SPIs by absolute numbers of "EMS medical staff in service", "EMS transportation units in service", etc.

In total, the suggested Set A includes **19 SPIs** which are estimated based on 22 primary data items and 7 items of General information. The suggested Set B includes **12 SPIs**, manipulates with 6 primary data items and applies to the items of General information of Set A. Different to the SPIs of Set A, which are mostly calculated based on the primary data values, the majority of SPIs' values of Set B should be directly provided by the countries (however, typically their presentation should be supported by primary data values).
Following are lists of the trauma management SPIs in Set A and Set B, accordingly.

Set A (nineteen SPIs)

1. EMS: Staff and equipment in service (ten SPIs)

- EMS stations per 100 km road length of rural public roads (No 3[iv])
- Percentage of physicians (No 5a) and paramedics (No 5b) out of the total EMS medical staff
- EMS medical staff per 10,000 citizens (No 6)
- Percentage of BLSU (No 8a), MICU (No 8b) and helicopters/planes (No 8c) out of the total EMS units
- EMS transportation units per 10,000 citizens (No 9)
- MICU (Type C) vehicles per 10,000 citizens (No 10)
- EMS vehicles per 100 km road length of total public roads (No 11)

2. EMS: Scope of activity (three SPIs)

- Number of road crash emergency calls per 10,000 citizens (No 14)
- Number of road crash emergency calls per million vehicle km travelled (No 15)
- Number of road crash emergency rides per 10,000 citizens (No 18)

[iv] The number of a data item in Set A

3. EMS: Time values of initial treatment (two SPIs)

- Percentage of EMS responses which meet the demand for response time (No 20). This SPI should typically be accompanied by a primary data item of "The demand for a response time, min" (No 19).
- Average response time of EMS, min (No 21)

4. Further medical treatment: facilities in service (four SPIs)

- Percentage of beds in certified trauma centres out of the total (No 23)
- Percentage of beds in trauma departments of hospitals out of the total (No 24)
- Number of the total trauma care beds per 10000 citizens (No 25)
- Number of beds in certified trauma centres and in trauma departments of hospitals per 10000 citizens (No 26)

Set B (twelve SPIs)

5. EMS database: Quality of treatment (three SPIs)

- Share of road crash injuries treated by MICU or BLSU out of the total injuries treated by EMS (No 3a[v])
- Share of road crash injuries treated by EMS helicopters/planes out of the total injuries treated by EMS (No 3b)
- The relation between the number of road crash injuries treated by EMS and the number of road crash injuries according to police records (No 4)

6. Trauma Registry: Quality of treatment (nine SPIs)

- The relation between the number of road crash injuries in the trauma registry and the number of road crash injuries according to police records (No 7). (Should typically be accompanied by primary data such as: "Share of road crash injuries out of the total injuries in the Trauma Registry" (No 6); "Among road crash injuries in the trauma registry: share of severe cases (No 8)").
- Among road crash injuries in the trauma registry: share of those, who were brought to hospitals by MICU/BLSU (No 9)
- Among road crash injuries in the trauma registry: share of those, who were brought to hospitals by EMS helicopters/planes (No 10)
- For road crash injuries in the trauma registry: mean lengths of stay in the hospital, days (No 11)
- Among road crash injuries in the trauma registry: share of those who died during hospitalisation (No 12)
- Among road crash injuries in the trauma registry: share of those who were treated in intensive care units (No 13)
- For road crash injuries in the trauma registry: average number of days in intensive care unit (No 14)

[v] The number of a data item in Set B

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- Among road crash injuries in the trauma registry: share of those who were operated on (No 15)
- Among road crash injuries in the trauma registry: share of those continuing to rehabilitation centres upon discharge (No 16)

Comments:

Indicators, which were suggested by the general concept of trauma management SPIs (and, consequently, appeared in the questionnaire) but not included in the above sets, are:

1) "The distribution of medical level of EMS teams" (total figures and shares of different types) as these differ significantly among the countries; no international standard is available to serve as a basis for the classification;
2) "Values of notification time"; unavailable in the countries.
3) "Average time for treating a case at the scene", "average time for arriving to hospital"; the values are generally unavailable in the countries as well as no demands exist. Besides, the policies for treating injuries at the scene differ among the countries: some countries state "scoop and carry/load and go", others - "stay and play".
A scheme of trauma management SPIs - a general vision, demonstrating the course of their development and data required for their calculation, is given in Figure 10-2 (see Par.10.8.1).

Based on the information provided by the questionnaire responses', actual values of SPIs can be estimated, that demonstrates the usability of the SPIs suggested.

10.6 Conclusions

The preliminary lessons learnt from the developing Safety Performance Indicators for trauma management are as follows:

- No complete systematic information on the performance of the trauma care system and on outcomes of road crash survivors is routinely available in the majority of countries. Hence, special efforts will need to be undertaken to collect this data.
- The state and forms of the post crash trauma care differ among the countries. These differences should be accounted for in estimating SPIs.
- Only some countries are able to provide detailed data on the performance of different steps of the post crash chain of care. The majority of countries may provide only general figures on the availability of services but not on the characteristics of their functioning. Therefore, two sets of SPIs should be recommended for the application: an initial (reduced) set, which can be filled in by the majority of countries today, and an extended set, which should be available in the future, with the perspective to provide a comprehensive picture of the performance of the trauma management system in the country.

- Based on the SPIs estimation for the countries, which answered the questionnaire, we conclude that the suggested sets of SPIs seem realisable and definitely promising for comparing the trauma management systems in different countries.
- The primary data should be collected and the trauma management SPIs be updated on an annual/bi-annual basis.

10.7 References

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10.8 Annexes

10.8.1 Diagram

(see next pages)

Trauma Management – Set A

Speed of initial treatment: *see 3.*

Quality of Initial Treatment: *1. EMS: Staff and equipment in service*

Quality of Further Treatment: *see 4.*

SPI	FORMULA
EMS stations per 100 km road length of public roads outside built-up areas (No 3)	No 3 = No 2/ B x 100
Percentage of physicians (No 5a) and paramedics (No 5b) out of the total EMS medical staff	No 5a = No 4a/ No 4f x 100 No 5b = No 4b/ No 4f x 100
EMS medical staff per 10000 citizens (No 6)	No 6 = No 4f/ A / 100
Percentage of BLSU (No 8a), MICU (No 8b) and helicopters/ planes (No 8c) out of the total EMS units	No 8a = No 7a/ No 7e x 100 No 8b = No 7b/ No 7e x 100 No 8c = No 7d/ No 7e x 100
EMS transportation units per 10000 citizens (No 9)	No 9 = No 7e/ A / 100
Type C vehicles per 10000 citizens (No 10)	No 10 = No 7b/ A / 100
EMS vehicles per 100 km road length of total public roads (No 11)	No 11 = (No 7a + No 7b + No 7c)/ (B + C) x 100

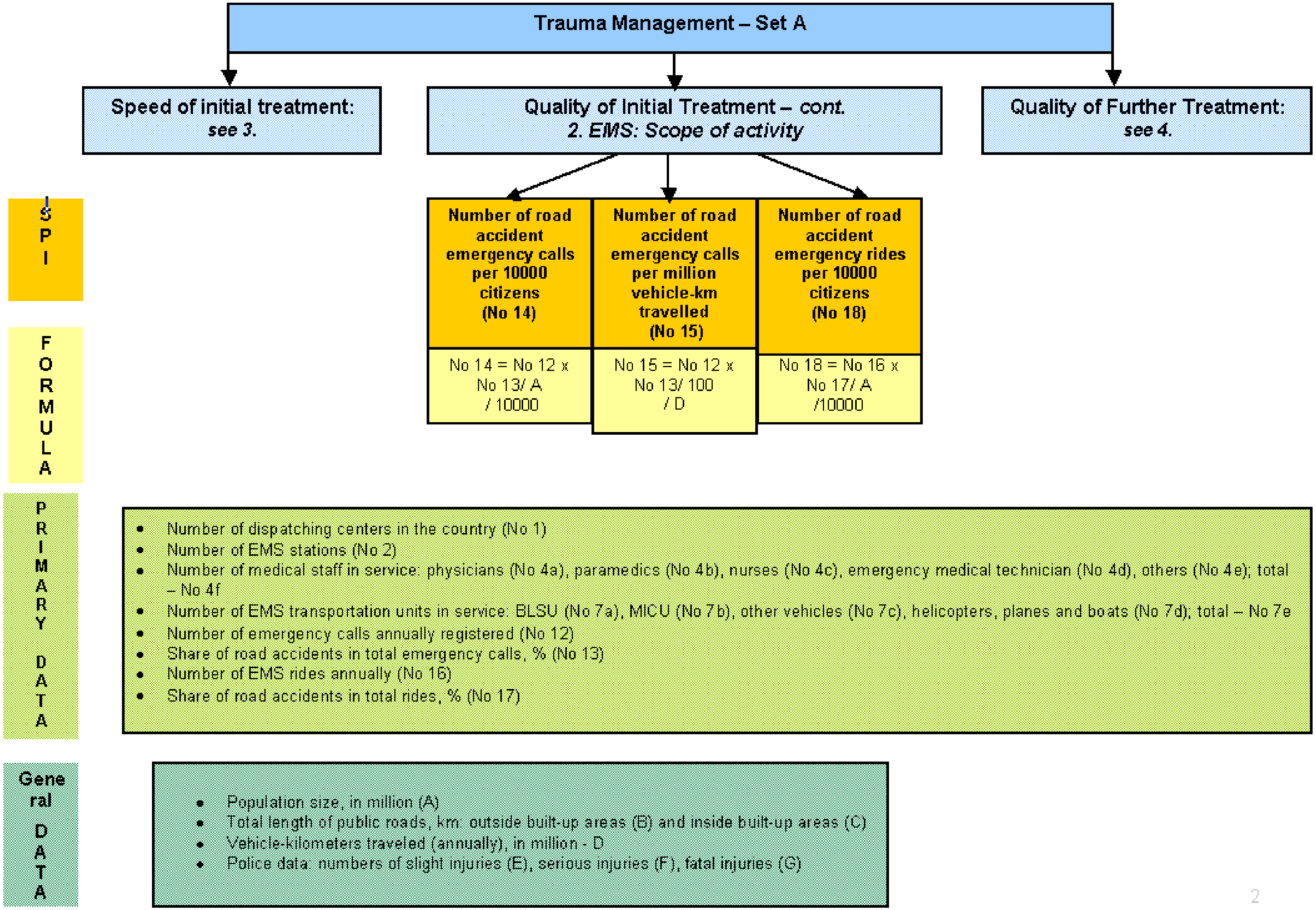
PRIMARY DATA

- Number of dispatching centers in the country (No 1)
- Number of EMS stations (No 2)
- Number of medical staff in service: physicians (No 4a), paramedics (No 4b), nurses (No 4c), emergency medical technician (No 4d), others (No 4e); total – No 4f
- Number of EMS transportation units in service: BLSU (No 7a), MICU (No 7b), other vehicles (No 7c), helicopters, planes and boats (No 7d); total – No 7e
- Number of emergency calls annually registered (No 12)
- Share of road accidents in total emergency calls, % (No 13)
- Number of EMS rides annually (No 16)
- Share of road accidents in total rides, % (No 17)

General DATA

- Population size, in million (A)
- Total length of public roads, km: outside built-up areas (B) and inside built-up areas (C)
- Vehicle-kilometers traveled (annually), in million - D
- Police data: numbers of slight injuries (E), serious injuries (F), fatal injuries (G)

1



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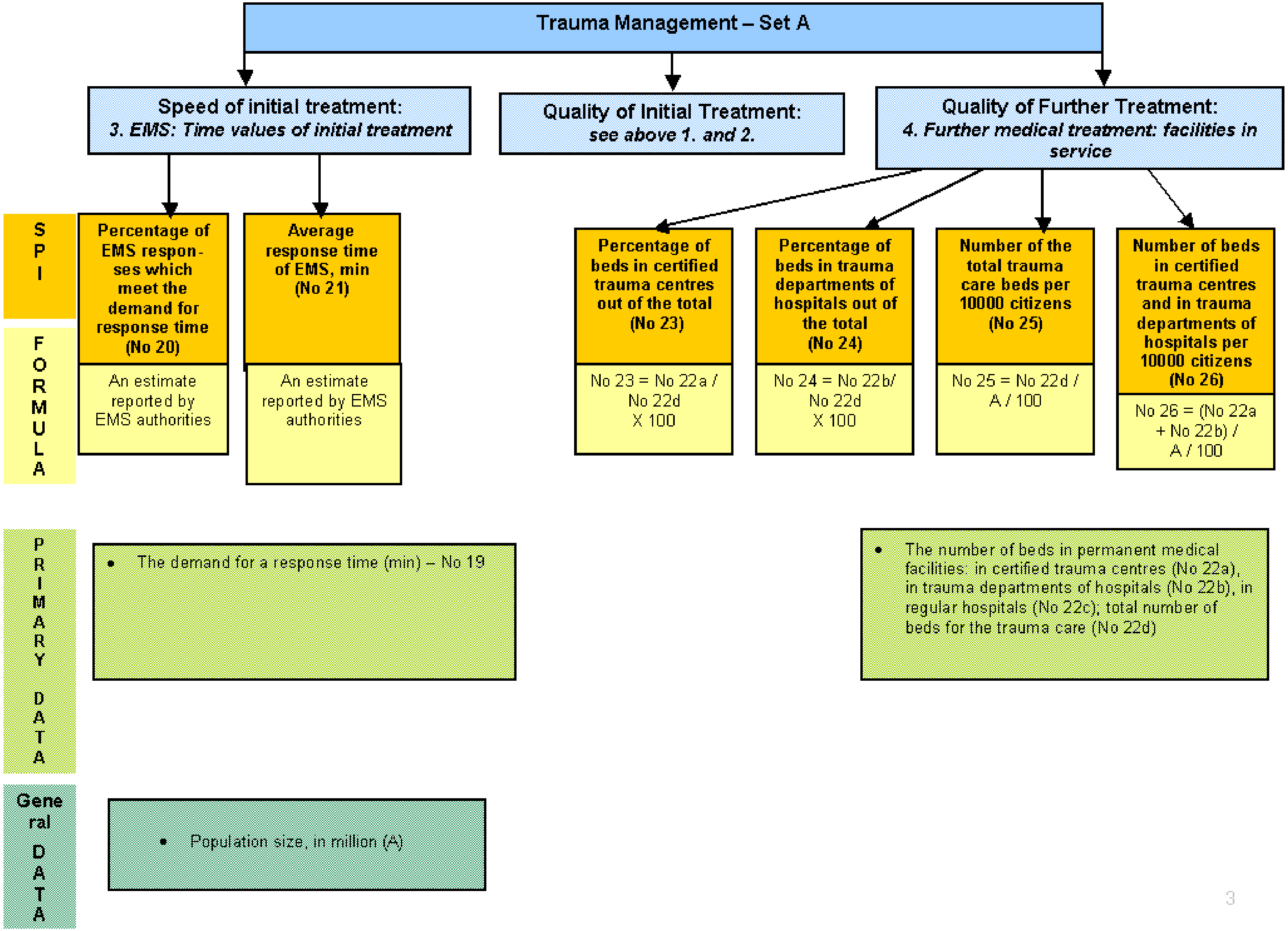
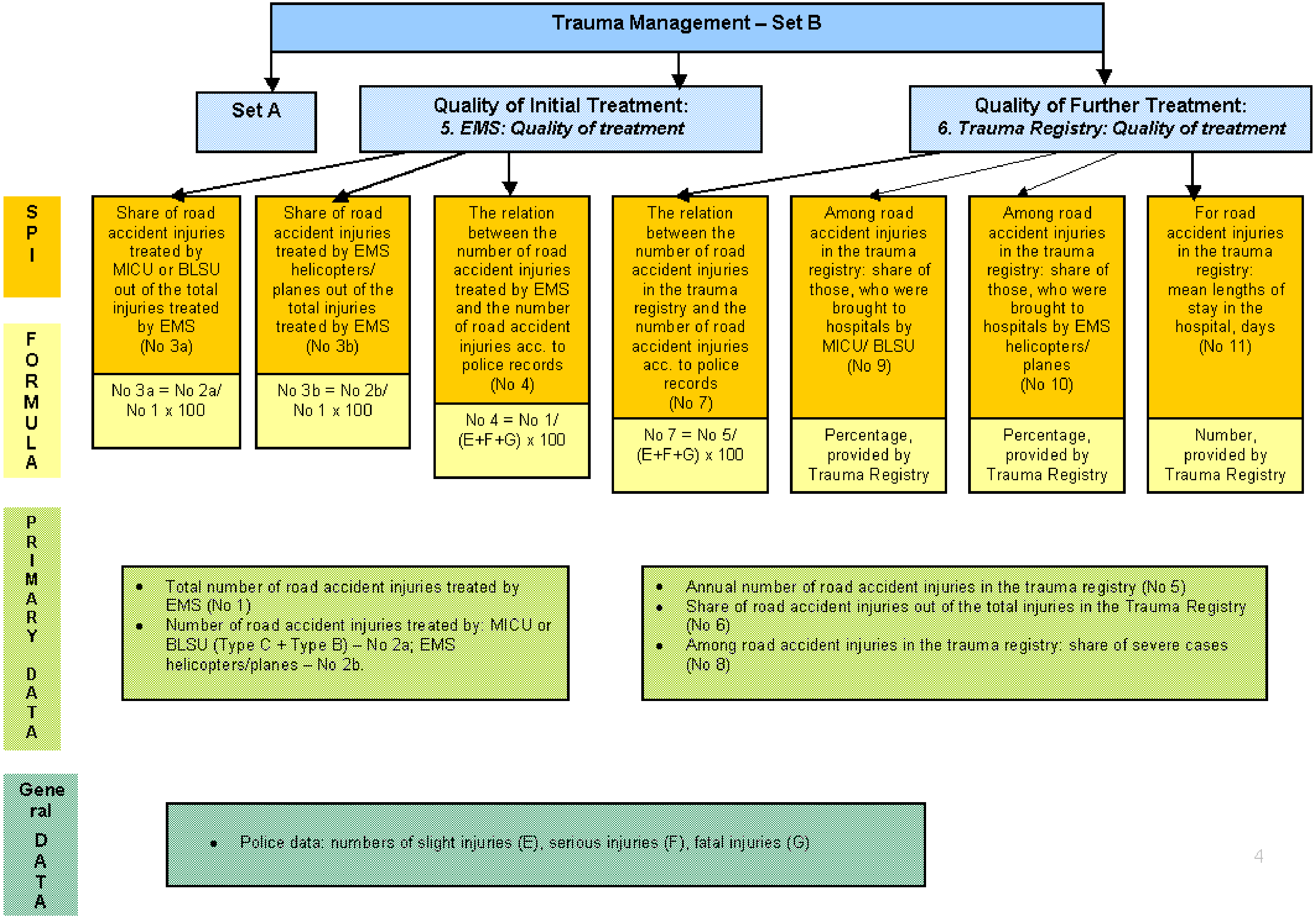
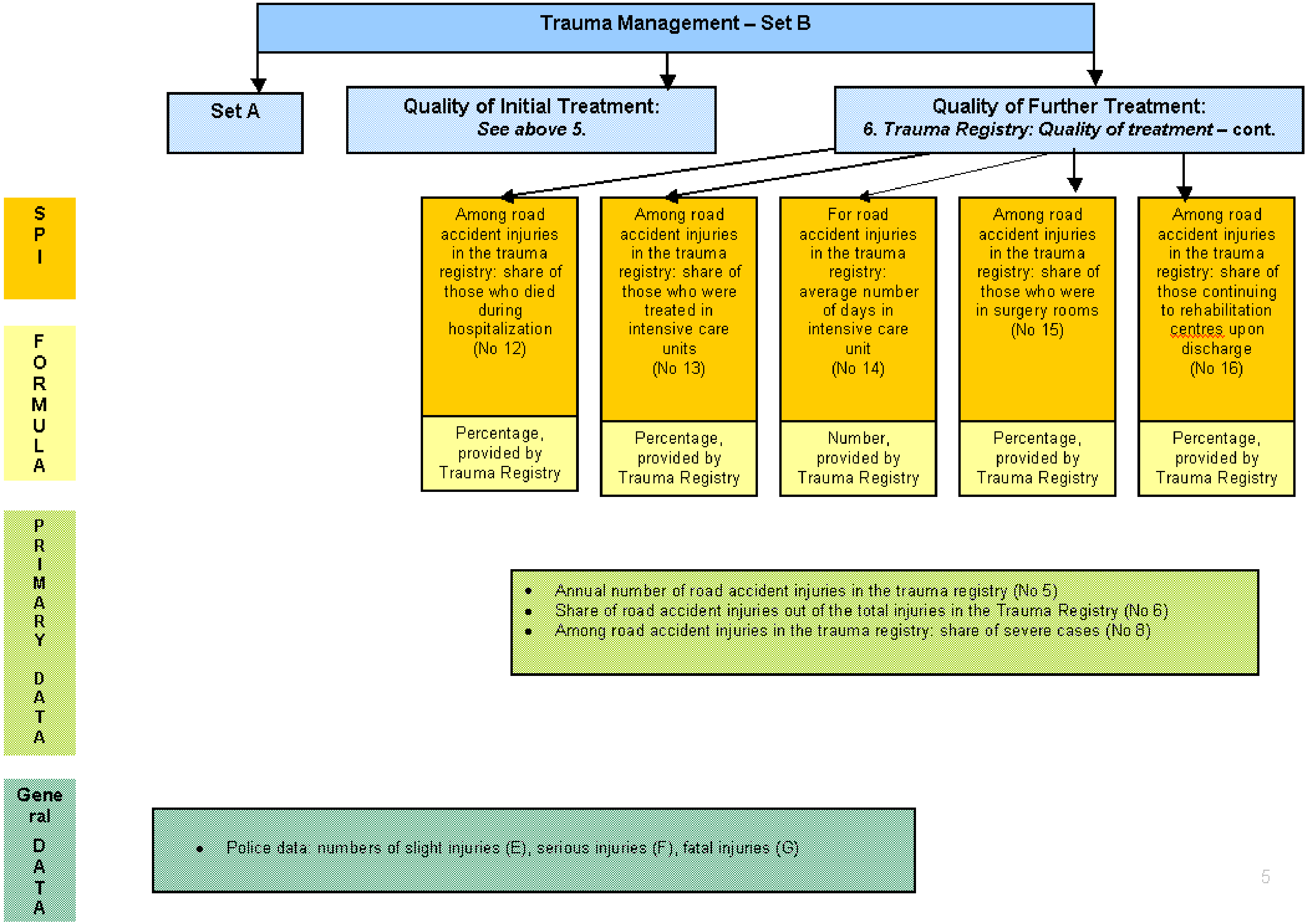

Trauma Management – Set A
Speed of initial treatment:
3. EMS: Time values of initial treatment
Quality of Initial Treatment:
see above 1. and 2.
Quality of Further Treatment:
4. Further medical treatment: facilities in service
SPI
FORMULA
Percentage of EMS respon-ses which meet the demand for response time (No 20)
An estimate reported by EMS authorities
Average response time of EMS, min (No 21)
An estimate reported by EMS authorities
Percentage of beds in certified trauma centres out of the total (No 23)
No 23 = No 22a / No 22d X 100
Percentage of beds in trauma departments of hospitals out of the total (No 24)
No 24 = No 22b/ No 22d X 100
Number of the total trauma care beds per 10000 citizens (No 25)
No 25 = No 22d / A / 100
Number of beds in certified trauma centres and in trauma departments of hospitals per 10000 citizens (No 26)
No 26 = (No 22a + No 22b) / A / 100
PRIMARY DATA
The demand for a response time (min) – No 19
The number of beds in permanent medical facilities: in certified trauma centres (No 22a), in trauma departments of hospitals (No 22b), in regular hospitals (No 22c); total number of beds for the trauma care (No 22d)
General DATA
Population size, in million (A)
3



Project co-financed by the European Commission, Directorate-General Transport and Energy


Trauma Management – Set B
Set A
Quality of Initial Treatment:
See above 5.
Quality of Further Treatment:
6. Trauma Registry: Quality of treatment – cont.
SPI
Among road accident injuries in the trauma registry: share of those who died during hospitalization (No 12)
Among road accident injuries in the trauma registry: share of those who were treated in intensive care units (No 13)
For road accident injuries in the trauma registry: average number of days in intensive care unit (No 14)
Among road accident injuries in the trauma registry: share of those who were in surgery rooms (No 15)
Among road accident injuries in the trauma registry: share of those continuing to rehabilitation centres upon discharge (No 16)
FORMULA
Percentage, provided by Trauma Registry
Percentage, provided by Trauma Registry
Number, provided by Trauma Registry
Percentage, provided by Trauma Registry
Percentage, provided by Trauma Registry
PRIMARY DATA
Annual number of road accident injuries in the trauma registry (No 5)
Share of road accident injuries out of the total injuries in the Trauma Registry (No 6)
Among road accident injuries in the trauma registry: share of severe cases (No 8)
General DATA
Police data: numbers of slight injuries (E), serious injuries (F), fatal injuries (G)
5

10.8.2 Glossary

Notification time: The time interval between the crash occurrence and the emergency call is made.

Response time: The time interval between emergency call and the response of the EMS (thus the time of arrival of the EMS at the scene of crash).

Arrival time: The time interval between the crash occurrence and the response of the EMS (thus the time of arrival of the EMS at the scene of crash).

Medical terms:

Emergency Medical Services (EMS) System includes the emergency dispatch system and the emergency units. The dispatch system takes incoming calls for emergency care.

A dispatching centre is an office which is informed in case of emergencies (mostly by telephone calls) to ask for medical assistance. The dispatching centre then alarms and coordinates the EMS units.

An EMS station is the location/base station where at least one EMS vehicle or helicopter/plane (and in most cases its crew) are positioned.

The EMS units are mostly ambulances but also helicopters/planes/boats, which arrive at the scene of crash and provide initial medical assistance to injured patients. There are different forms of EMS units, which depend on the type of a transport means (helicopter, ambulance); EMS vehicle equipment (mobile intensive care unit; basic life support unit); medical staff arriving with the vehicle.

The medical staff may include a physician, a paramedic, a “critical care” nurse, and an emergency medical technician.

Advanced life support (ALS): medical care given by medical doctors and nurses trained in critical care medicine with the use of specialized technical equipment, infusion of fluids and drugs aimed to stabilize or restore vital functions

Basic life support (BLS): consists of emergency medical care to restore or sustain vital functions (airway, respiration, circulation) without specialized medical equipment and to limit further damage in the period preceding advanced medical care.

Mobile intensive care unit (MICU): a unit with a medical doctor and a nurse transported to the scene of the crash with the knowledge, skills and equipment necessary for performing advanced life support.

Basic Life Support Unit (BLSU): a transportation unit with personnel and equipment necessary for performing basic life support.

Emergency medical technician: a person who received training in emergency medical care for sick or injured patients in need of transportation to a hospital. This training includes BLS and the ability to assist doctors and nurses in the delivery of ALS.

Paramedic: an emergency medical technician who received further training for the delivery of some aspects of ALS care.

The term „*emergency call*“ includes all calls which are answered by EMS dispatching centre and which lead to an emergency response by the EMS. The term includes false and abusive alarms, but excludes calls due to patient transportation requests.

EMS rides are rides of the EMS in consequence of emergency calls, including false and abuse alarms**.**

EMS vehicles according to European Norms 1789

According to the European norm EN 1789 (+A1:2003) there are three types of EMS vehicles:

Type A_1/A_2: A vehicle that is appropriate to transportation of one or more patients - transportation ambulances

Type B: A vehicle that is equipped for transportation, basic life support and medical monitoring of patients (similar to *BLSU*).

Type C: A vehicle that is equipped for transportation, advanced life support and medical monitoring of patients (similar to *MICU*).

Meanwhile, there is no European norm for helicopters, planes, and boats. Thus any helicopters, planes, and boats that are in use by EMS can be mentioned.

Definitions of crash injury severity used by the police and national crash databases:

Killed (fatality): a person who died as a result of the crash, or died of his injuries within 30 days of the crash.

Seriously injured: a person who was hospitalized as a result of the crash for a period of 24 hours or more.

Slightly injured: a person who was injured as a result of the crash and was not hospitalized, or was hospitalized for a short period (up to 24 hours).

Hospitalized[vi]*:* non-fatal victims who are admitted to hospital as in-patients.

Definitions of crash injury severity using medical scales:

Abbreviated Injury Scale (AIS): a score from 1-6, for anatomically different injuries, indicating the chance that such injuries lead to death. AIS 6 injuries are usually considered to lead to inevitable death, AIS 5 to probable death, AIS 4 to possible death; other grades rarely lead to death. AIS 0 means "no injury". ***AIS 3-6*** correspond to patients which are ***hospitalized***.

Injury Severity Score (ISS): a score based on the AIS, which accounts for multiple injuries in one patient; calculated as a sum of the squares of the highest AIS grades in each of the three most severely injured body regions (out of 6 body regions). Groups of ISS values, which are usually applied for a qualification of injury's severity, are: ISS 1-8 for slight injuries, ISS 9-14 for medium injuries, ISS 16-25 for serious injuries, ISS 25+ for very serious injuries. ***ISS 16+*** indicates ***severe*** injuries.

Glasgow-Coma Scale (GCS): a score that focuses on the neurological situation of the patient by the item „eyes open" and on the verbal and motoric reactions of the patient. Maximum value: 15 (no neurological disorders), minimum value: 3 (severe neurological disorder). Groups of values, which can be applied for a quantification of injury's severity, are: GCS 13-15 - slight craniocerebral injury, GCS 9-12 - „medium severe" craniocerebral injury, GCS < 9 - severe craniocerebral injury, possibility of long-term/lasting disorders. ***GCS < 9*** indicates ***severe*** injuries.

10.8.3 Literature Review

Victoria Gitelman (TECHNION), Kerstin Hafen (BASt), Malka Avitzur (Technion), Vojtech Eksler (CDV), Shalom Hakkert (TECHNION)

Introduction

Emergency medical care has evolved independently in different countries resulting in a variety of definitions, legislations, and systems. The mechanism of post-crash trauma care comprises two types of medical treatment: the one provided by emergency medical services (EMS) and the other provided by

[vi] In use by IRTAD – International Road Traffic and Crash Database

permanent medical facilities. According to the concept of the "chain of survival" and to the legal, technical, and organizational conditions of the EMS in a country, different indicators can be defined to measure the quality of the EMS system. In a similar way, different indices can be applied to express the quality of treatment provided by permanent medical facilities, or to characterize the whole trauma care system.

The objective of this literature review is to consider the results of empirical studies which analysed systems/forms of post crash care in different countries, with an emphasis on the system performance indicators applied in these studies. The literature study's findings are grouped according to the following issues:

1. The relation between the performance of the trauma management system (or post crash care system) and road crash outcomes (i.e. the number and severity of injuries).
2. Trauma care performance indicators, which were estimated by different studies.
3. The evaluation of different forms of post-crash care, with the emphasis on indicators of trauma care system's performance and the outcomes (i.e. reported changes in injury numbers and severity)

The studies were sought for the English- and German-speaking European countries, CEE countries, Israel, and some other countries with highly developed trauma care systems. The literature selection was conducted by means of the TRANSPORT and DIMDI databases. The keywords in German and English, which were used, are: Notfall, Rettungsdienst, Rettungswesen, EMS, emergency medical service, trauma management, trauma centre (centre), accident, and evaluation, etc. As there was a rapid development of the EMS systems in Europe (and of medical care in general) since the 1970s, the focus of the literature search was on publications over the last decade. Besides, relevant publications from medical journals on the development of trauma care were also considered. For the CEE countries, some information was collected through personal contacts with medical experts in those countries.

Relation between the performance of the trauma management system and road crash outcomes

Elvik and Vaa (2004) reviewed and summarized a number of studies, which considered the effects of the availability of ambulances and ambulance response times on the chance of surviving traffic crashes. In one of these studies, by Brown (1979), a relation between ambulance response times for traffic crashes and the proportion killed in crashes was as follows:

Ambulance response time, min	1-10	11-20	21-30	31-120	> 120
Proportion killed in traffic crashes	6.3	9.3	10.8	12.2	13.4

Table 10-3: Relation response time – proportion killed

Obviously, the proportion killed in traffic crashes increases with increasing ambulance response time.

Brodsky and Hakkert (1983) studied the relation between the availability of ambulance services and fatalities in traffic crashes in Texas, USA. They showed that the proportion of fatal crashes was smallest where ambulance availability was best, and largest where ambulance availability was poor. In another study, Brodsky (1990) considered the effect of response times on the number of fatalities in fatal road crashes in the USA. He indicated a tendency for the proportion of fatal crashes where more than one person is killed to increase when the ambulance response time increased from less than 5 min to 29 min.

In a German study by Bouillon et al (1993) the efficiency of the EMS concerning the treatment of patients with trauma was analysed. In the time period from 1987 to 1989 the EMS of Cologne supported 35,472 emergencies. In 26,475 cases the patient was treated by an emergency physician and in 6,938 cases the patient was a crash victim. 50% of these accidents were road crashes (the rest are sport and home, work and other accidents). The response time of the emergency physician (terrestrial or air rescue) was 5.9 min, on average. 80% of the emergency locations were reached in 8 min and 95% in 12 min. The emergency physician stayed at the scene of emergency, on average, for 18.4 min, the average time of transportation was 8.3 min.

These results can be complemented by a study conducted by Oestern et al (2001). The study analysed data of the Trauma Register of the German Society of Traumatology. 5,353 patients with an average age of 38.5 years were analysed. The proportion of blunt injuries was 94.3% and the mean ISS was 24.8. The emergency doctor arrived, on average, 22.4 min after the crash and stayed at scene of crash for 32.9 min. The transport lasted 18.3 min. The mean stay at hospital was 31.1 days, at the intensive care unit 13.1 days, with a mean time of 8.7 days of artificial respiration. Over the years the authors attest to an improvement of outcome throughout all participating hospitals.

Comparing the results of Boullion et al. (1993) and Oestern et al. (2001) significant differences become apparent, e.g. concerning response time, length of stay at the scene of crash, and the time of transportation. Differences in these time characteristics might be caused by different application areas, e.g. urban and rural areas.

Another German study focused on the additional notification of emergency physicians, when at first a regular EMS team (one paramedic and one emergency medical technician) was alarmed and sent to the emergency (Puhan, 1994). The objective of the study was to identify the causes and the number of delayed alarms of emergency physicians. Data collection was conducted in 14 control rooms. The results show, that in 8.3% of the cases no physician was alarmed at first, although the supply of a physician would have been necessary. Furthermore the results show that control room members, who worked as paramedics themselves, assessed the severity of symptoms of the emergency patient much more accurately. Concerning internist emergencies and road crashes the chance to underestimate the severity of the emergency was greater. The same holds true when a private individual or the police issued the emergency call. One reason that led to an underestimation of the severity of the emergencies was the communication problems (every eighth emergency call), which are often caused by alcoholized/boozed callers. These results affirm the results of a previous study conducted by Puhan (1992), which showed that in every fourth road crash a supply of an emergency physician is needed.

Elvik and Vaa (2004) cite two studies, which considered the effects of advanced initial treatment (presence of doctors in ambulances) on the number of road crash fatalities. The first study, by Alexander et al (1984) analysed the data for different counties in Florida, USA. They found that in areas without access to advanced initial treatment, the mortality rate (accounting for the population size and traffic volumes) was around four times higher than in areas with access. The second cited study, Bundesminister fur Verkehr (1992), considered the proportion of injury crashes where a doctor was called versus the proportion of fatalities in injury crashes, reported to police in Germany in the years 1985-1991. A regression line was drawn and a negative statistical relation was stated between the two characteristics.

The role of helicopters in EMS is discussed in a German study by Sefrin, Kuhnigk and Lohs (2003). They examined the responses of Chistoph 18 (a helicopter service in Bavaria) over a period of 15 years, 1980-1995. During this period there were 17,277 responses: 60.5% primary responses and 23.6% secondary responses. There were 15% false alarms. 15,328 patients were treated, of whom 5,333 patients were transported by helicopter. The probability that a patient was transported by helicopter increased according to the severity of the injury or illness (according to NACA-score). The average length of time of a response was 56.1 (± 27.7) min. A helicopter required 11.5 (± 5.9) min to get to the scene of emergency. The results show that there is an interrelation between the response time and the length of stay in hospital: when the response time was shorter than 5 min, 28% of the patients had to stay in hospital for more than 20 days; when the response time was longer than 15 min the share was 45.5%; when the response time was longer than 20 min the share rose to 61%. A similar dependency could also be seen in the length of stay in intensive care units. 70% of all responses were due to road crashes, though there was a decreasing trend in the number of road crashes as a cause of EMS helicopter responses, between 1980 and 1995.

Elvik and Vaa (2004) summarized findings of 19 studies, which considered the effect of ambulance helicopter transport on the probability of surviving a crash or an acute illness. The studies were conducted in Germany, Norway, USA, Great Britain and the Netherlands. The summary results showed that using helicopters to transport patients does not influence the probability of survival very much.

Noland and Quddus (2004) analysed the role of improvements in medical care and technology in reductions in traffic-related fatalities in Great Britain. Cross-sectional time-series models were developed for the numbers of casualties, whereas among the explaining variables three proxies of medical care were used. They are: the average length of in-patient stay in the hospital, the per-capita level of National Health Service staff and the number of people per capita waiting for hospital treatment. The first variable, which has declined over time, was stated as more representative of changes in medical technology. The authors concluded that the model results demonstrated an effect of changes in medical care on traffic-related fatalities.

Noland (2004) supports the above findings by US and OECD data analysis. In the US case, the infant mortality rate was used as a proxy variable to represent medical technology change. This variable was found to be statistically significant indicating the directional effect: as infant mortality rates improved, traffic related fatalities were reduced; a similar effect was not found for total crash injuries. In the study of OECD data, Noland (2004) stated that the changes in fatalities are associated with the improvements in medical care which can be expressed by three parameters: infant mortality rates, physicians per capita, average acute care days spent in the hospital.

Elvik and Vaa (2004) cite a Belgian study (Janssens and Thomas 1996), which indirectly indicates the effect of the quality of treatment given in hospitals on the number of road crash fatalities. The study considered the development of the ratio between the numbers killed in traffic within a 30-day period and the numbers killed in traffic before arriving at a hospital, from 1950 to 1994. The ratio has a decreasing trend since 1970, indicating an improvement in the quality of medical treatment given in hospitals. Presently, the numbers of those who died in hospital comprise around 10% of killed in traffic crashes.

A kind of relation between the performance of the trauma care system and crash outcomes can be considered by means of the analysis of general trauma statistics, which is regularly collected and published in the country.

For example, in Germany, in 2003, there were 2.2 million road crashes, with 354,534 cases of personal injury: 6,613 fatalities, and 462,170 injuries (85,577 severe injuries and 376,593 slight injuries). According to a report by Hoitz and Lampl (2004) road crash fatalities are mostly caused by polytrauma. In the age group younger than 15 years about 50% die from polytrauma. Out of the whole group of polytrauma patients, about 70% are injured due to road crashes (where the remaining 30% are due to work, home, or sport accidents). On the other hand, polytrauma is rare and the incidence is about 2% of all EMS responses (with a physician) (Hoitz & Lampl, 2004).

In Switzerland in 1997, 95,000 persons were injured in road crashes; this is 8.3% of all crash victims or 1.6% of the Swiss population (Ewert & Beer, 2002). 40% of these road crash victims were between 15 and 24 years old. 75% of all road crashes happened in urban areas. Out of the 95,000 casualties, 29% helped themselves, 53% received ambulant treatment, and 18% were admitted into hospital (for ambulant or in-patient treatment). Within these three groups, 9% of self-helped patients, 54% of having ambulant treatment and 88% of having in-patient treatment could not go to work for at least one day. The length of not being able to go to work was, on average, 15, 23, and 37 days, accordingly.

Nathens et. al (2000a) attempted to analyse the effect of organized trauma systems on mortality from motor vehicle injury, in 22 USA states having trauma systems versus 18 states lacking formal trauma systems. The 1995 data were applied. They found a significant reduction of 9% in adjusted crash mortality rates in the states having trauma systems. Among young people the reduction was 17%.

Nathens et. al (2000b) stated that about 15 years following initial trauma system implementation, crash adjusted mortality among front seat passenger vehicle occupants reduced by 8% (CI: 3-12).

Liberman et al (2004) looked on retrospective efficacy, in term of mortality, of the changes that took place during the process of implementation of a trauma system in Quebec, Canada, over the years 1992-2002. The graph below illustrates the percentage of mortality among severely injured patients by year and stages of changes during the process of getting into trauma system.

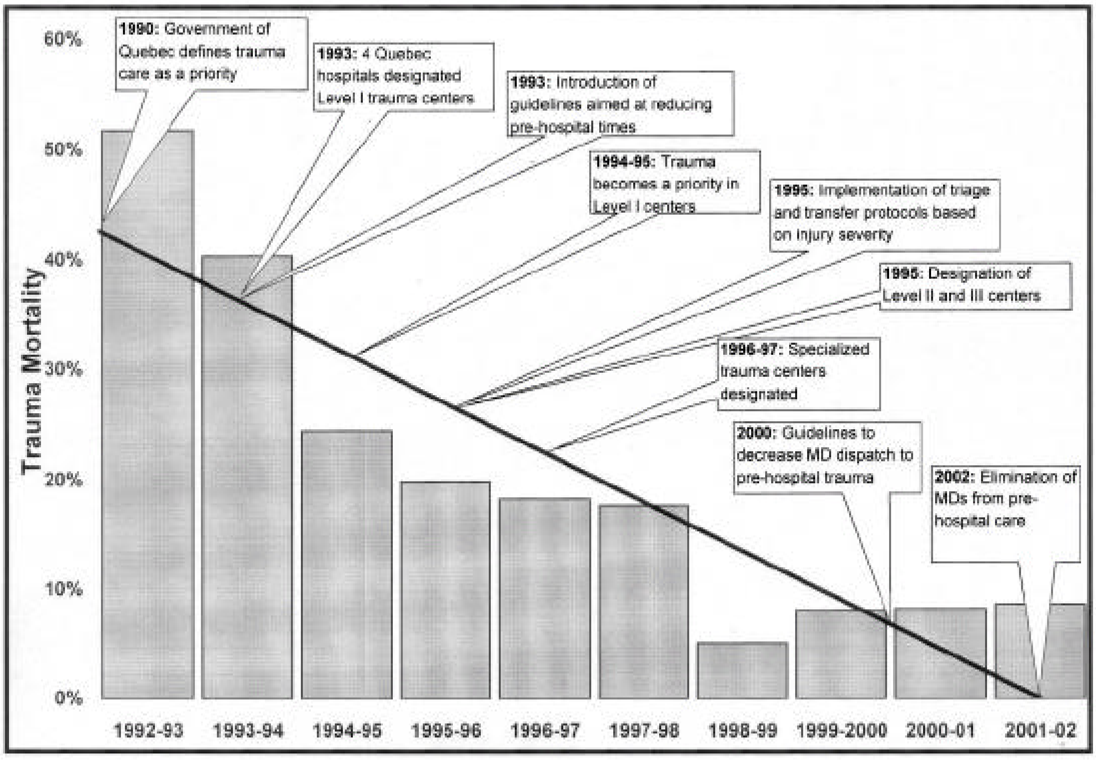


Figure 10-3: Changes in trauma mortality over the last decade (Quebec, Canada).

Trauma care performance indicators estimated by different studies

EMS performance

On behalf of the German Federal Ministry of Transport, Building and Housing, BASt conducts regular studies to evaluate the performance of the emergency medical service (EMS) in Germany. At present, data collection for the years 2004/2005 is being carried out. The objective of the studies is to get representative performance data of the EMS. Due to the similar design of the studies, there are time series of essential performance indicators, some of which cover a time period of 30 years. The studies include structural/organizational indicators, but do not include medical process or outcome parameters (ISS, diagnoses etc.). Road crash injuries are part of the sample, but there is no special focus on this group. The sample consists of all EMS responses (injuries and diseases) coordinated by 60 control centres during 4 weeks. The sample data are applied for the evaluation of the whole EMS system in Germany.

The data analyses include parameters such as:

- Causes of EMS responses
- Types of emergency vehicles involved
- Response time
- Use of ambulance sirens
- Assistance of emergency physicians
- Incidence of false alarms

For example, the results of the analysis of the year 2000/01 can be found in a report by Schmiedel & Behrendt (2002).

While the BASt studies focus on terrestrial EMS, a study by Reinhardt (2004) concerns air rescue. The study's objective was to analyse the complete structural data, response data and costs of the air rescue in Germany in the year 2002. The study indicated that in Germany there are 104 locations of helicopters and aircrafts, working with 1,451 emergency physicians and 583 paramedics. The costs of the service in 2002 were €126.3 mln.

A German study by Baethmann et al (1999) provides information on the management efficiency, including logistics and organization of patients care in the prehospital and early clinical phase (dispatch of the emergency service, documentation of relevant time intervals, as well as the patient's state at the scene, during transport, and upon hospital admission, and occurrence and nature of complications). 100 patients with severe head injury were prospectively documented. The time values of treatments were as follows:

- in 75% of all cases arrival of the rescue team (in most cases by helicopter) at the scene of the crash was within less than 11 minutes after alarm of the dispatch centre.
- intubation was made within 37 minutes,
- admission to the hospital within 74 minutes,
- the cranial CT-scan was performed within 120 minutes,
- the acute clinical procedures were concluded within 3.6 hours.

Process factors of pre-clinical treatment were analysed in a study by Regel et al (1998). The authors retrospectively analysed the pre-clinical treatment of all multiple trauma patients admitted to the department of surgery of the Medizinische Hochschule Hannover between 1985 and 1996 (N=1,297). Regarding the triage it was noted that 28% of patients who should have been admitted to a level 1 trauma centre considering the severity of their injury, were first admitted to a level III hospital and needed to be transferred later. In 7% of patients, two additional mistakes, and in 4% more than two mistakes in the triage were noted. On the other hand there were records of patients who were considered to be slightly injured but received invasive treatment. Preclinical intubation and mechanical ventilation was not performed in 16.5% although the severity of injury clearly demanded this. A thoracic drain tube was not positioned in 38% of patients suffering from severe thoracic trauma ($AIS_{Thorax} \geq 4$). Insufficient application of resuscitation volume was evident in 17% of all documented patients.

According to Meier, Heim & Reinhardt (2003) and Planta (2004), in Switzerland there is no national database or epidemiological data, therefore the evaluation of EMS is difficult. Several case studies analysed trauma care performance in Switzerland. For example, Zingg et al (2003) distributed a questionnaire asking for the working rules of EMS departments around the country, types of vehicles involved, staff on service, amount of responses and their types, etc. It was estimated, for example, that in 2001, 38% of responses were of level 1; in about 89% (82% in Alpine regions, 94% in urban areas) of all cases the EMS response time was less than 15 minutes; in 9 of 10 level 1 cases at least one graduate paramedic (Rettungssanitäter) supports the EMS team. Planta (2004) estimated that the EMS responses due to road crashes comprise, in different cantons, 17%-35% of the total cases.

In-patient treatment

Performance indicators of the treatment at hospital were studied by Bouillon and Neugebauer (2001) on the basis of the Trauma Register of the German Society of Traumatology. The authors point out that time delays, mistakes concerning the management and diagnosis, and insufficient documentation of data are frequent problems that often cause secondary harm to the patients. The relevance of these factors is proven by correlations between an optimized treatment process and mortality rate.

Detre (2003) considered the level of trauma care in Hungary. Intra-hospital mortality due to multiple trauma was applied as an indicator for a comparison among the countries; the indicator's values were estimated to be around 10% in the USA, around 20% in Germany, and 30% in Hungary. An analysis of data of patients treated in the National Institute of Trauma as well as in the Trauma Department St. János Hospital during the last 20 years was carried out to throw light on reasons related to the differences between the Hungarian survival rate and those of highly developed countries. Among such reasons were mentioned: long pre-hospital time; insufficient technical conditions, equipment level and staff experience; lack of treatment algorithms and exercises of emergency care; financial problems.

Smith et al (1990) compared trauma centres versus non-trauma centres with regard to femoral shaft fracture (ages 0-87) in Pennsylvania and Maryland between 1985-1987. The results indicated that more severe cases were admitted to trauma centres, however no differences in death rates were found. Waiting time to surgery was shorter in trauma centres (0.4 days) as compared with in non-trauma centres (0.9 days). Besides, the rates of trauma complications were considered in both groups of medical facilities, in the form of share of patients, which arrived with solitary femur fracture, and the share of patients with multiple trauma injures.

DeKeyser et al (2002) compared the performance indicators of two trauma centres, one in Jerusalem, Israel and the other in Fairfax County, Virginia, USA, using 1999 data. There was a difference both in survival rates and in length of stay (LOS). The ratio of surviving with ISS 25+ related to ISS 16-24 was 11.5 (range 5.3-25.0) in Israel and 9.5 (range 4.8 – 17.7) in Virginia. The ratio for short LOS for severe cases was 5.8 (range 1.36-25.0) in Israel and 2.65 (range 0.59-11.9) in Virginia.

In a study of 27 hospitals in the USA, Glance et al (2004) stated that fatality numbers were of limited use as an outcome. They suggested to look at functional outcomes, i.e. functional independence in all three dimensions of FIM_{MTOS} at time of discharge: feeding, locomotion, and expression. The authors developed a prediction model for three dependent categories: good functional outcome, poor functional outcome, and death; and applied the results to define outliers among different hospitals. Depending on the definitions applied, 4 to 11 out of 27 hospitals were found to be low performance hospitals.

Mock et al (1993) compared the performance of a developing Trauma centre in Berekum, Ghana, with a Level 1 Trauma Centre in Seattle, Washington, using the data for 1987-1991. The resulting indicators were as follows:

Indicators, %:	Berekum	Seattle
Time to treatment: % of arriving at hospital within 24l	41	96
Pre-hospital care: % arriving on their own	75	18
Hospitalisation: mortality - ISS 15-24	36	6
mortality - ISS 25-40	73	39
mortality - principle injury in head	20	13

Table 10-4: Trauma centres' comparison.

Long-term survival, functional outcome, and quality of life two years after trauma were analysed by Zettl et al (2004). The complete consecutive data sets of patients admitted through the ER (Schockraum) from 8/1998 until 8/2000 were documented and analysed by a standardized protocol (Glasgow Outcome Score (GOS), SF-36, EuroQuol) precisely two years after the trauma. 2-year mortality was based on the information provided by family physicians and community officials. A total of N_1=482 patients (mean ISS=24) was prospectively included (mean age=39 years). Two years after trauma (N_2=348) 26% had died, 68% were fully rehabilitated according to GOS, the rest remained severely disabled, whereof 13% needed permanent care. EuroQuol and SF-36 revealed chronic pain and anxiety states in more than 50% of the patients. Everyday activities and mobility were permanently impaired in 40-50%. The social situation after trauma included increased unemployment (5% to 13.5%), disablement (0% to 15.3%), retraining (9.9%) and job changes (15.8%). Very often (30%) patients had to tolerate significant financial losses. Private life and family situation was seemingly unchanged.

A general concept for evaluating trauma care

The establishment of trauma centres creates a commitment to prevent preventable deaths, as well as to prevent future morbidity and disability, and to improve the quality of life of the injured. This commitment is created when there exists a complete trauma system that includes both EMS services and trauma centres within hospitals, and can provide full services i.e. comprised of all of the necessary departments required in order to treat an injured person with multiple injuries, and a team that has undergone the necessary training. The team is in a continued state of preparedness to absorb the injured and is skilled in working together.

In order to evaluate whether these centres are living up to their commitments, one needs to answer the following questions (Mock et al, 1993; Nathens et al 2004; Eckstein et al 2000):

- As to the treatment process:
  1. To what extent does the trauma system fulfill its mission in terms of case coverage: at the EMS level, the hospital level and in rehabilitation?
  2. What is the level of functioning of the EMS services?
- As to the outcome:
  1. Are the outcome conditions of the injured, who arrive at trauma centres, better that those who arrive at other hospitals?
  2. Is there improvement over time?

The evaluation parameters can be as follows.

At the EMS Level (Mock et al 1993; Nathens, Brunet, Maier 2004)

- Type of training that EMS teams receive: BLS (Basic Life Support) versus ALS (Advanced Life Support);
- Type of evacuation to trauma centre: self, regular ambulance, MICU, helicopter;
- Time values (Smith et al 1990): arrival at scene, treatment in the field, arrival for definitive treatment in hospital (are they within "the golden hour" rule?);
- Type of field treatment;
- Treatment implementation according to protocols, to the extent that protocols exist.

At the Hospital Level

- Level of coverage: to what extent do critical patients arrive at trauma centres and not at hospitals of other levels?
- Severity of injury according to ISS and according to part of body injured (Barel Matrix) with emphasis on head, chest and stomach injuries;
- Performance of specific surgical procedures and evaluation of outcome, comparisons of treatment in specific procedures;
- Speed of treatment in the hospital, speed of arrival to Emergency Rooms, extent of work according to protocols.

For outcomes – in terms of death rate, hospitalisation in ICU, total length of hospitalisation.

Comparisons between the trauma care applied are possible in the following forms:

- Multivariable comparisons of length of stay and mortality taking into account age, severity of injury, co-morbidity, mechanism of injury and transfers of injured between hospitals (Rogers et al 1997; DeKeyser et al 2002). *Mortality* is considered during the first 24 hours of hospitalization, after 24 hours, within a month following discharge and one year following discharge (Clark, Anderson, Hahn 2004). Knowledge of the health status of the individual prior to being injured greatly increases the ability to predict the outcome (Stewart, Lane, Stefanits 1995).

- Level of incapacity at discharge from hospital via the FIMM questionnaire and 6 month follow-up after discharge (Mann et al 1999), locating preventable deaths via autopsies and analysis of causes of death.

- Investigating to what extent those injured, whose chances of dying were high, survived; and those who died even though there chances of death were low. There are two measures, which can be used for this purpose. The preferred measure is ASCOT (A Severity Characterization of Trauma), which is more sensitive in characterizing the anatomical injury (Champion et al 1996). The second measure, on which there are differing opinions (Lane et al 1996; Demetriades et al 2001; Guiguis et al 1990), is TRISS which is a combination of the Trauma Score, ISS, age and type of injured, blunt or penetrating.

Possible data sources for performing the evaluation are as follows (Clark, Anderson, Hahn 2004; Esposito, Nania, Maier 1992):

- *Ongoing Admission and Discharge Statistics.* Advantage: allows for retrieval of statistics of patients from all hospitals. Disadvantage: incomplete registration information in particular with regard to medical information as the emphasis is on administrative registration.

- *Trauma Registries.* Advantages: Designated for trauma victims; contain a lot of detailed information. Disadvantages: Generally limited to the hospitals, which have trauma centres. These registries are expensive to operate and maintain.

- *Death Registries* (Ministry of the Interior or the like). Advantage: includes all deaths. Disadvantages: do not include autopsy information; matching of cases can be problematic due to inaccuracies in registration as well as privacy requirements.

- *Ad hoc Surveys* (for various purposes). Advantage: focus is on specific questions. Disadvantages: limited by time; expensive.

Evaluation of different forms of post-crash care

Pre-hospital care

Differences in post-crash care were analysed in a German study by Guenther et al (2003). The purpose of the study was to evaluate the process and outcome of treatment of severely injured patients admitted during on-call (Monday to Friday from 4:00 p.m. to 6:59 a.m. and weekends and holidays) versus regular (Monday to Friday from 7:00 a.m. to 3:59 p.m.) trauma service. The evaluation was based on the Trauma Registry of the German Trauma Society. This database includes all patients with severe trauma admitted to the hospital with signs of life and in potential need in intensive care treatment. The Registry collected the prospective and multicentric data on 3,814 severely injured patients, which were treated in 33 German and Swiss hospitals over the years 1993-1998. The data were collected by means of standardized protocols. The participating hospitals include university hospitals, teaching hospitals, and municipal hospitals with resources of trauma care corresponding to all three levels. Patients with missing data and an ISS =15 were excluded from the study. Only the patients who were directly admitted from the scene of crash were analysed (N=1,753).

The results show that almost 70% of patients were admitted during on-call service (OC). Patients admitted during OC were significantly younger than those admitted during regular service (RS). No differences between RS and OC were found for gender, injury severity (ISS), and probability of survival (TRISS). During OC, significantly more motor vehicle crashes (+9%) occurred, mainly because of car crashes (+5%) and crashes involving motor bikes (+5%). During OC, the time to arrival of the ambulance at the scene was significantly longer (3 minutes). The time from crash until arrival at the emergency department was not substantially different between groups.

In the emergency departments, no substantial differences were found for the time to initial basic diagnostic procedures; surprisingly, the time from the admission to emergency departments to the admission to intensive care units was 45 minutes longer during RS. The comparison of the outcome parameters such as the length of stay in the intensive care unit or in the hospital, the incidence of organ failure, and hospital mortality, showed no significant differences between groups. A conclusion can be drawn, that the quality of trauma care provided 24 hours per day, 7 days per week (in the participating hospitals) is consistent throughout regular and on-call service.

Other German studies examined the mortality and recovery rate of emergency patients, when treated by emergency physicians versus less qualified EMS staff. For example, according to IVR (1993), the differences in mortality rates during a transportation of emergency patients were as follows: without qualified help - 11-16%; with help by a qualified paramedic - 5%; with help by a qualified emergency physician - 1%. When emergency physicians or paramedics were involved in the initial care of patients, a 25-50% reduction in the length of stay in intensive care units was observed. When an emergency physician was involved in the treatment, a recovery from polytrauma was observed in 72% of cases; a similar figure without emergency physician was 22%.

Sefrin (1991) reported the results of a prospective study with 150 polytrauma patients. He found that the survival rate was higher when the patients were treated by an emergency physician, in comparison with treated by less qualified EMS staff, during initial care and during transportation. Besides, Sefrin (1991) pointed out that the infection rate of compound fractures differed according to the EMS vehicle and staff which were sent to the scene of crash: for helicopters (with emergency physician) the infection rate was 3.5%; for mobile intensive care units (with emergency physician) - 9.1%; for ambulances (without emergency physician) - 12.2%.

In a study reported at Dresdner Tagung (2003) four possible pathways for transportation of polytrauma patients were compared. The sample comprised 403 patients with ISS >16 which were treated over 1998-2000. The ways of transportation were as follows:

1. HEMS-UNI (n=140) – a transfer by helicopter emergency medical service (HEMS) into a university hospital;
2. AMB-REG (n=102) – a transfer by ground ambulance into a regional hospital;
3. AMB-UNI (n=70) – a transfer by ground ambulance into a university hospital;
4. INTER (n=91) – a transfer by ground ambulance into a regional hospital, followed by transfer to a university hospital.

Age, gender, and mean ISS (range 33.3 – 35.6) of the groups were homogeneous, enabling the comparison, for which two indicators were applied: a mortality rate and the rescue time. As found, the mortality of the AMB-REG group was almost double (41.2%) compared to HEMS-UNI (22.1%) patients (p=0.002), where AMB-UNI group demonstrated the lowest mortality rate (15.7%, n.s.). The average rescue time was 90 min for HEMS-UNI patients, 68 min for AMB-UNI and 69 min for AMB-REG group.

Oppe and De Charro (2001) reported on the results of a Dutch experiment on giving extra medical help by helicopter to patients who need emergency treatment. The main idea was to bring specialized medical care, in the form of Helicopter Trauma Team (HTT), directly to the scene of the crash. This form of medical assistance was given to polytrauma patients, in daylight conditions, in an area with a radius of 50 km around AZVU-hospital. The effect of the emergency assistance was considered in terms of mortality (% of fatal cases out of the total) and the quality of life of those who survived their injuries (a score estimated by means of EQ-5D questionnaire). The effect was estimated by means of a comparison with a control group and making a correction for injury severity. The correction was performed considering 3 groups of patients with different severity indices, where the latter was constructed on the basis of the Revised Trauma Scale and the Injury Severity Scale and their sub-scores. The HTT treatment was found to be effective, mostly for patients with intermediate probability of survival.

A number of studies estimated the changes observed after establishing a pre-hospital trauma care system. Marson and Thomson (2001) noted a decrease in mortality rates: before the system was established the rate was 7.1% and 5.9% after.

Ali et al (1997) showed that following the system's establishment, there was an increase in the utilization of PHTLS skills by paramedics in the pre-hospital setting. The frequency of interventions increased from 2.1% to 99.7% for airway control, from 2.1% to 89.4% for C-spine control, from 22% to 60.4% for splinting extremities and from 16% to 96.9% for haemorrhage control.

Simons et al (1999) considered the impact of a trauma programme on trauma care delivery in Canada and Vancouver, British Columbia, in 1997. They noted that compliance of trauma team activation rose from 28% to 94%, however delays in transfer to the ICU did not improve. The guidelines and protocols developed for improving performance resulted in improved cost outcome. Introduction of focused abdominal sonography for blunt abdominal trauma reduced the need for a screening CT by 84%. No difference was found in overall mortality rates and in mortality rates for those injured with ISS 16+. Average LOS decreased from 10.1 days to 9.1days, despite having more severe cases.

In-patient care

Draaisma (1987) examined methods for evaluating hospital trauma care in the Netherlands. Three categories of hospitals were considered: (A) 5 general hospitals without neurosurgical department, (B) 3 general hospitals with neurosurgical department and (C) 4 university hospitals. The study included all trauma patients sustaining severe blunt or penetrating injuries (HTI-ISS $\geq$ 18; N=547) who required admission to one of the participating hospitals in the period October 1, 1984 – October 1, 1985.
The author analysed the relation between HTI-ISS and mortality and found out that the mean HTI-ISS for fatalities was significantly higher than the mean HTI-ISS for survivors. As patients in the Netherlands are usually transported to the nearest hospital, a similar distribution of HTI-ISS would be expected in all three hospital categories. A lower than expected actual mortality rate was found in category C hospitals. In both other hospital categories, the actual mortality rate was higher than predicted. Different mortality rates between B and C category hospitals might be a result of differences in management or stem from factors, which were not included in the prediction model.

Sampalis et al (1999) found that during the period of the established regional trauma systems in Quebec, Canada the mortality among patients with major injuries decreased. This was a result of the reduced pre-hospital time and of establishing tertiary trauma centres. The process of establishing a regionalized trauma system includes the introduction of highly specialized facilities and the implementation of protocols for care.

The authors found a decrease in mortality rates in tertiary hospitals from 40% to 18% during the 6 year period between 1992-1998 (mean ISS >25). Among patients with ISS 25-49, the mortality rate declined from 66% to 16%. The odds ratio of dying in a tertiary hospital as compared with a primary centre was 0.25.

As found, the pre-hospital time decreased from 66 min to 44 min. Time to admission (from the arrival in emergency room until a discharge to ward) decreased from 152 min to 114 min. The proportion of severe cases (ISS 25-49) treated at the tertiary level increased over the period of study from 36% to 84%. 54.3% patients were transferred from primary and secondary centres to tertiary centres as compared with 33% at the beginning of the process.

In order to evaluate the impact of a recent trauma verification programme on an academic health centre, Ehrlich et al (2002) evaluated 47 clinical indicators in 12 hospitals in West Virginia, USA. The results were that 14 clinical indicators improved significantly, 20 did not change and 13 achieved their goal from the very beginning. The indicators of improvement were divided into three groups: 1 - pre-hospital; 2 - emergency room; 3 - in-hospital.

The findings were as follows:

	Indicator, %	At the beginning	After
1	Treated at scene less than 20 min	79	99
2a	Evaluation of trauma patient in less than 20 min	21	77
2b	% Injured that had hourly nursing charting	50	90
2c	CNS monitoring (injured with GCS <15)	18	85
2d	Those who had CAT in less than 2 hours	70	95
3a	Hospitalisation in ICU for less than 7 days	87	98
3b	Back transfer from floor to ICU	82	96
3c	Number of re-intubations	Decrease	No data
3d	Delayed laparotomies	Decrease	No data
3e	Shortened length of stay (LOS)	12 days	9.8 days

Table 10-5: Clinical indicators

Conclusions

Studies analysing the relation between the performance of the trauma management system and road crash outcomes, are not frequent. Some evidence can be found in the literature concerning the effects of improved trauma care (in the form of lower response time, more qualified emergency staff, better equipped emergency vehicles) on the frequency of fatalities and (sometimes) severe injuries.

Trauma care performance is usually characterized by shares/rates of different forms of treatment, with an emphasis on higher levels of treatment and on percentages of correspondence to the demands/protocols. The values of EMS response time and the time values of treatment at the hospital are usually emphasized. The inputs of the medical system (EMS and hospitals/trauma centres) are typically considered together with the outcomes, the state of the patients treated. The mortality or survival rates are frequently used for comparison of different forms of treatment. Such a comparison usually needs a correction for injury severity.

Other parameters, which are frequently applied to the characteristic of medical treatment at permanent medical facilities are the length of stay in hospital, the length of stay in intensive care unit, the time of waiting for treatment.

For a specific trauma programme, a wider range of clinical indicators is usually applied.

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11 Conclusions

This report constitutes deliverable D3.1 of the SafetyNet project.

In this report, we present to you an overview of the state of the art in road safety performance indicators (SPI). For seven areas essential to road safety, we show how we developed realistically applicable safety performance indicators. These areas are:

- Alcohol & Drug use,
- Speeds,
- Protective systems,
- Daytime Running Lights,
- Vehicles,
- Roads, and
- Trauma management.

All safety performance indicators were developed using the same methodology. This methodology, which is also described in this report, is more widely applicable; it can be used to develop safety performance indicators also for other areas relevant to road safety.

Road safety performance indicators can be developed on a theoretical basis. These indicators, however, may not be realistically applicable on short notice. They all rely on specific data of sufficient quality, which may not become available. The reason for a lack of certain data may lay in legislation. For example, roadside surveys on alcohol usage may not be permitted in some countries, prohibiting the collection of data in the general driving population. Lack of data of sufficient quality may also stem from insufficient technology to date.

To be able to develop SPIs that are realistically applicable on the short notice, we need knowledge on the current availability of data related to each of the seven SPI areas. Therefore, a questionnaire was dispatched to all 25 EU member states and to Switzerland and Norway, asking about the availability of certain data, or asking for the data itself. Paradoxically, such a questionnaire can only be developed after developing – at least partly – a first set of SPIs. In other words, sound, realistically applicable SPIs will have to be developed in an iterative way, iterating the development of SPIs and the inquiry after available data and legislation. This report describes the results after the first iteration: one round of questionnaires and one round of SPI development.

By the time we wrote this report, we had received roughly 60% of the responses to the questionnaires, with varying quality over the seven areas. In some cases, this iteration, however, still seems to be sufficient for the development of realistically applicable SPIs (e.g. Daytime Running Lights). Most of the other areas, though, need more iteration to finetune the SPIs.

Transport
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