Deliverable D3.11b: Safety Performance Indicators for Trauma Management: Theory Update

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Executive Summary

The report published in 2007 (Hakkert et al, 2007) provided details about the theory behind the development of safety performance indicators (SPIs) in seven predefined road safety domains, including trauma management. The current report presents an update to the basic SPIs Theory report: it provides the findings of the research activities which were undertaken for further development of the trauma management SPIs, during the last period of the SafetyNet project.

Trauma Management (TM) covers two types of medical treatment: the initial medical treatment provided by Emergency Medical Services (EMS), at the scene of accident and during the transportation to a permanent medical facility, and further medical treatment provided by permanent medical facilities (hospitals, trauma centres). To reduce the severity and the number of road crash victims, the TM system should provide rapid and adequate initial care of injury, combined with sufficient further treatment at a hospital or trauma centre. Thus, trauma management SPIs should estimate the speed and the quality of the post-crash care, both initial and further, in the country.

Accounting for the limitations of data available in the countries, a minimum set of TM SPIs was introduced for the characteristic of the TM system's performance. The set of TM SPIs includes:

Availability of EMS stations

- the number of EMS stations per 10,000 population and per 100 km length of rural public roads

Availability and composition of EMS medical staff

- percentage of physicians and paramedics out of the total number of EMS staff
- the number of EMS staff per 10,000 population

Availability and composition of EMS transportation units

- percentage of Basic Life Support Units, Mobile Intensive Care Units and helicopters/planes out of the total number of EMS transportation units
- the number of EMS transportation units per 10,000 population
- the number of EMS transportation units per 100 km of total public road length

Characteristics of the EMS response time

- the demand for an EMS response time (min)
- percentage of EMS responses meeting the demand
- average response time of the EMS (min)

Availability of trauma beds in permanent medical facilities

- percentage of beds in trauma centres and trauma departments of hospitals out of the total trauma care beds
- the number of total trauma care beds per 10,000 citizens

Furthermore, a combined indicator was suggested which is built by means of multiple ranking of separate SPIs (Hakkert et al, 2007).

To estimate the TM SPIs, a data set is requested for each country, which includes: total number of EMS stations; number of EMS staff in service, according to categories; number of EMS transportation units in service, according to categories; the demand for a response time, min; percentage of EMS responses which meet the demands for response time; average response time of EMS, min; total number of beds in permanent medical facilities, according to categories. In addition, the estimation of TM SPIs requires for general information for the country, on population size, total road length and road length outside built-up areas.

In the process of the development of TM SPIs (Hakkert et al ,2007), the potential of trauma registries and other medical databases for providing better insight into the actual TM system's performance was indicated. In the last step of the project, a literature study was undertaken to check recent publications on issues concerning application of trauma registry and other medical databases for exploring road safety injury. Studies of road safety injuries using medical databases were found for France, the Netherlands, Israel, Italy and Sweden.

Summing up the findings, it was concluded that once a trauma registry or a similar database is maintained in the country, many in-depth traffic injury studies are usually carried out. Moreover, the information system based on hospital records can assist in providing corrected figures of the scope and characteristics of traffic injury in the country and in assessing the performance of the trauma care system and its components. At the same time, the national trauma registries are not common in the EU countries yet, leaving for the future the issues of application of trauma registries or similar databases for the estimation of TM SPIs.

During the last project year, a new questionnaire survey was sent out and filled in by the countries, which resulted in creating a dataset with TM SPIs for 21 countries. On this dataset, a number of analyses were carried out: examination of new basic SPIs; an extensive analysis of the combined indicator built by multiple ranking (old form) and creating a composite indicator by means of statistical weighting (new form).

The new basic SPIs considered were: the percentage of EMS stations with at least one physician; the number of EMS stations per country's area and the number of EMS transportation units per country's area, where both "per area" indicators could serve as substitutes of relevant "per road length" indicators. However, the analysis of influence of the new indicators on country comparison results, both in separate and in the process of building combined SPIs, did not support their inclusion in the basic set of TM SPIs.

The analysis of the old form of combined TM indicator considered seven variants of building a combined estimate, which differed by ranking methods and by the sets of basic SPIs involved. The final estimates based on the seven trials enabled the countries to be attributed to five levels of the TM system's performance, which are: "high", "relatively high", "medium", "relatively low" or "low".

Neither single method of ranking was fully consistent with the final estimates based on the results of all the trials performed. Therefore, it is advisable, when the countries are compared by the level of the TM system's performance, to apply several ways of ranking for the estimation of the combined TM SPI.

A new way of creating a composite TM indicator, by means of statistical weighting - principle component analysis and common factor analysis, was explored. Three trials of creating the factors were performed. The results of trials were consistent as to the recognition of countries with high or low level of the TM systems' performance, but the grouping of countries with intermediate levels of the system's performance changed between the trials. This means that the definition of intermediate levels of the TM system's performance is sensitive to the set of basic SPIs, which are involved in countries' estimation and grouping.

In general, the statistical weighting enabled us to identify several groups of countries with similar levels of the TM system's performance. At the same time, contrary to expectations, we did not arrive at a composite indicator which could be applicable for a meaningful classification of countries in accordance with the level of the TM system's performance. Applying the tools developed by each analysis we preferred to deal with separate factors created and not to weight them together because such weighting would bring us to a less clear picture of the results. Nevertheless, the factors created were useful both for recognizing similarities in basic indicators' behaviour and for the definition of each country's position in comparison with other countries.

Another important finding of the statistical weighting was recognizing, among the list of basic SPIs, those items which are more essential for the characteristic of the TM system's performance. This core set of the TM SPIs includes:

- The number of EMS stations per area,
- The number of EMS transportation units per road length,
- The number of EMS transportation units per citizens,
- Percent of physicians and paramedics out of the total EMS staff,
- Percentage of highly-equipped transportation units out of the total,
- The demand for response time,
- Average response time of EMS,
- Percentage of EMS responses meeting the demand,
- The number of trauma care beds per citizens.

The core set of the TM SPIs provides a concise but reasonable characteristic of the TM system in the country as it reflects both the availability and quality issues of the emergency medical services along with the characteristics of response time and the availability of permanent medical facilities.

Two case studies demonstrated additional applications of the TM SPIs developed: for comparison of regional trauma management systems (in federal states in Germany) and for estimating the TM system's performance for a new country (on the example of Israel). To properly judge the TM SPI values estimated for federal states and for Israel, they were compared with corresponding values estimated for the EU countries. It was found that in the majority of cases (10 out of 17 SPIs), the federal states are characterized by high level of the TM SPIs in comparison with the ranges observed for the EU countries. Similarly, the SPI estimates obtained for Israel ascribe it to the group of countries with high level of the TM system's performance.

Contents

1 Background

1.1 The role of Trauma Management

Trauma management (TM) or post-crash trauma care refers to the system, which is responsible for the medical treatment of injuries resulting from road crashes. It typically covers the initial medical treatment provided by Emergency Medical Services (EMS), at the scene of the crash and during the transportation to a permanent medical facility, and further medical treatment provided by permanent medical facilities (hospitals, trauma centres).

A typical post-crash chain of events can be presented by Figure 1.1. The medical care authorities should be involved in steps 4-7, which, therefore, compose the mechanism of the post-crash trauma care (or TM) in the country.

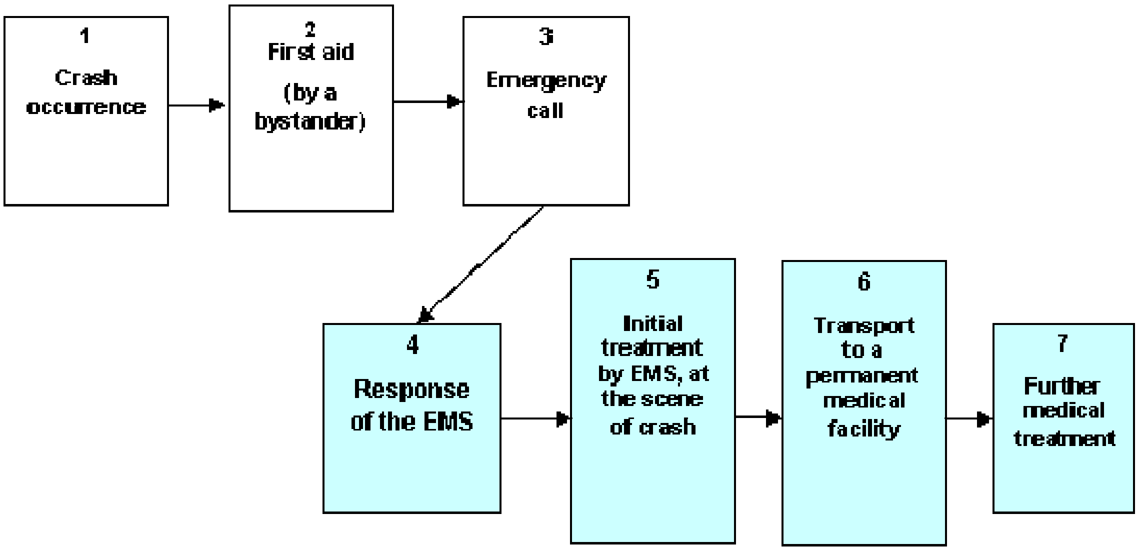

Figure 1.1 Post-crash chain of events.

There is a consensus in the professional literature that appropriate management of road casualties following the crash is a critical determinant of both the chance of survival and, on survival, the quality of life (ETSC, 1999; ETSC, 2001). Conversely, improper functioning of the post-crash care system leads to more fatalities and severe injuries, which could be avoided.

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 European Union (EU). The 2003 European action programme (CEC, 2003) stated that several thousands of lives could be saved in the EU by improving the response times of the emergency services and other elements of post impact care in the event of road traffic crashes. The World Report on Road Traffic Injury Prevention (Peden et al, 2004) indicated the importance of improving medical care delivered after crashes.

Hakkert et al (2007) provided a summary of the literature concerning the evidence of the crash reduction potential from improved trauma management. Considering this issue, it is customary to distinguish between survivable and unsurvivable injuries.

Typically, three time periods in which death from road trauma can occur, are defined (OECD, 1999; Sasser et al, 2005).

The first period comes immediately in the seconds and minutes that follow the injury, when deaths occur immediately or quickly as a result of overwhelming injury. Death in this period 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 typically 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 event ("golden hour"). Death in these instances results from major head injuries, chest injuries, abdominal injuries, 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 in this period include brain death, organ failure and overwhelming sepsis. Improved survival rates during this period mainly depend on the quality of hospital treatment. For example, a national evaluation study carried out in the USA found that the adjusted risk of death in trauma centres was significantly lower than in non-trauma centres (MacKenzie et al, 2006).

Thus, the potential to reduce fatalities by means of early and appropriate medical treatment is given at least for the patients in the second and third periods after the crash. Summing up the published estimates, it was concluded (Hakkert et, 2007) that 35%-50% of cases could be considered as "treatable", i.e. occurring during the second and third after-crash periods, and therefore, can be influenced (partly reduced) by an improved TM system.

Further, summarizing the findings of specific trauma studies (presented in Hakkert et al, 2007) and additional evidence on changes in road traffic fatalities before and after introducing changes in trauma care (Chiara et al, 2002; McDermott et al, 2007), it can be stated that 5%-10% of the fatalities can be determined as definitely preventable and a higher share of the fatalities - as possibly preventable due to improved trauma management. A similar figure is also relevant for serious injuries. Moreover, the reduction potential of the measures will definitely be higher in those countries with a lower initial state of the TM system.

1.2 Trauma Management safety performance indicators: basics of concept

Safety performance indicators (SPIs) are measures (indicators), reflecting those operational conditions of the road traffic system, which influence the system's safety performance (Hakkert et al, 2007). SPIs are aimed to serve as assisting tools in assessing current safety conditions of the road traffic system, monitoring the progress, measuring impacts of various safety interventions, making comparisons, and so on.

The ETSC report "Transport Safety Performance Indicators" (2001) highlighted a need for the development of trauma management related indicators. Such indicators would be useful:

- in estimating the quality of emergency medical services and hospital care of road crash victims;

- in recognizing weak chains and current needs of the system for decision-making purposes;

- in following-up progress through time;

- in providing evidence of efficiency of different policy measures.

However, recognizing the importance of the post-crash trauma care indicators for road safety programs and for road safety policy-making in general, the ETSC (2001) report could provide only a few examples of such indicators in use. Typically, the national road safety programs do not include an explicit target on improving rescue services and medical care of crash injuries.

Based on the best practice recommendations in the field of post crash care (ETSC, 1999; Mock et al, 2004 and others – see Hakkert et al, 2007), a number of features were named which are definitely associated with better performance of the TM system. They are:

- shorter response time by EMS;

- higher level of the EMS staff;

- standardisation of the EMS vehicles;

- adequate hospital trauma care.

(In addition, establishing a strategic approach to national trauma care is considered to be a prerequisite for high-quality hospital trauma care in the country.)

Based on the above considerations and extended literature survey of indicators in medical practice (SafetyNet, 2005; Hakkert et al, 2007), it was defined that to reduce the severity and the number of road crash victims, the TM system should provide rapid and adequate initial care of injury, combined with sufficient further treatment at a hospital or trauma centre. Therefore, the trauma management SPIs, which intend to qualify the performance of the post-crash care system, should estimate the speed and the quality of the post-crash care, both initial and further, in the country.

Along with the definition of meaningful characteristics to be measured, an important question concerned the availability of data for estimating the indicators suggested. A detailed examination of this issue was performed within the SafetyNet project (SafetyNet, 2005), by means of a series of questionnaires distributed to the countries and direct contacts with national experts.

Based on the information collected from national experts, it was concluded that EU countries generally have EMS norms/ regulations which, however, differ among 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 some countries, whereas the compliance with these norms is assessed from time to time. 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. The information on the EMS components is generally available. However, the quality of initial treatment provided or the extent of following the internal regulations usually is not estimated. In addition, at least in some countries, the information on the availability of trauma beds in permanent medical facilities can be provided (Hakkert et al, 2007).

In general, the majority of countries are able to provide, at least some data, on the *availability* of trauma care services, where quantitative data on actual *performance* of the EMS and further medical treatment, are typically lacking. Moreover, the data on the post-crash trauma care in the country are usually not in use in the current decision-making practice, meaning that special efforts are typically required to provide the data requested for the estimation of TM SPIs.

Besides, the international comparisons of the TM systems should be performed with caution due to a variety of definitions, legislations and systems, which are available for both the emergency and in-hospital trauma care, in different European countries (Hakkert et al, 2007).

Accounting for both the quality needs and data availability limitations, a minimum set of trauma management SPIs was introduced for the characteristic of the TM system's performance in the country. This SPI set is detailed in Sec.1.3. The set of TM SPIs enables to characterize both the scope and the quality of the post-crash care in the country, in terms of the EMS treatment potential (the availability and quality of resources), EMS response time and the treatment potential of permanent medical facilities (the availability and quality of resources).

1.3 The Trauma Management SPIs developed

As mentioned above, trauma management SPIs should estimate the speed and the quality of the post-crash care, both initial and further, in the country. Accounting for the limitations of data available in the countries, a minimum set of TM SPIs was introduced, to represent the characteristics of the TM system's performance (Hakkert et al, 2007).

The set of TM SPIs includes fourteen indicators which characterize five issues as presented below (see *Abridged Glossary*, for the terms):

Availability of EMS stations

- the number of EMS stations per 10,000 population and per 100 km length of rural public roads

Availability and composition of EMS medical staff

- percentage of physicians and paramedics out of the total number of EMS staff
- the number of EMS staff per 10,000 population

Availability and composition of EMS transportation units

- percentage of Basic Life Support Units, Mobile Intensive Care Units and helicopters/planes out of the total number of EMS transportation units
- the number of EMS transportation units per 10,000 population
- the number of EMS transportation units per 100 km of total public road length

Characteristics of the EMS response time

- the demand for an EMS response time (min)
- percentage of EMS responses meeting the demand
- average response time of the EMS (min)

Availability of trauma beds in permanent medical facilities

- percentage of beds in trauma centres and trauma departments of hospitals out of the total trauma care beds
- the number of total trauma care beds per 10,000 citizens

Furthermore, a *combined indicator* was developed to measure the overall TM system's performance in the country, relative to other countries (Hakkert et al, 2007).

To estimate the TM SPIs, a minimum data set is requested for the country, which includes seven items as follows:

1. Total number of EMS stations

2. Number of EMS staff in service (according to categories)

3. Number of EMS transportation units in service (according to categories)
4. The demand for a response time (min)
5. Percentage of EMS responses which meet the demands for response time
6. Average response time of EMS (min)
7. Total number of beds in permanent medical facilities (according to categories).

The estimation of TM SPIs requires general information for the country, on population size, total road length and road length outside built-up areas.

Tables 1.1 and 1.2 provide a detailed description of data items to be collected and rules to be applied for calculating TM SPIs, for a country.

General information

No	Item	To be filled in
A	Population, million	
B	Road length - total, km	
C	Road length - public, outside built-up areas, km	

Data on TM

No	Item	To be filled in	Description
1	No of dispatching centers		Absolute number, for the whole country Average annual figure
2	No of EMS stations		Absolute number, for the whole country Average annual figure
4a	Number of EMS staff in service: No of physicians		Absolute numbers, for the whole country; Average annual figures
4b	No of paramedics		
4c	No of nurses		
4d	No of medical technicians		
4f	Total (including others)		
7a	Number of EMS transportation units in service: No of BLSU		Absolute numbers, for the whole country; Average annual figures
7b	No of MICU		
7d	No of helicopters/ planes		
7e	Total (including others)		
19	The demand for EMS response time, min		A value reported by the EMS authorities
20	Percentage of EMS responses meeting the demand		An estimate reported by the EMS authorities; according to a special algorithm to assess the value
21	Average response time of EMS, min		An estimate reported by the EMS authorities; according to a special algorithm to assess the value
22a	Number of trauma beds in permanent medical facilities: In certified trauma centres		Absolute numbers, for the whole country; Average annual figures
22b	In trauma department of hospitals		
22d	Total (including others)		

Table 1.1. Data to be collected for estimating TM SPIs

Topic	No	SPI	Calculation rules
Quality of initial treatment by EMS: Staff and equipment in service	3a	EMS stations per 10000 citizens	Number of EMS stations (No 2) divided by the population size (A) and divided by 100
	3b	EMS stations per 100 km of rural road length	Number of EMS stations (No 2) divided by the length of public roads outside built-up areas (No C) and multiplied by 100
	5a	Percentage of physicians out of EMS staff	Number of physicians (No 4a) divided by the total sum of EMS medical staff in service (No 4f) and multiplied by 100
	5	Percentage of physicians + paramedics out of EMS staff	Number of physicians (No 4a) plus number of paramedics (No 4b) divided by the total sum of EMS medical staff in service (No 4f) and multiplied by 100
	6	EMS medical staff per 10000 citizens	Total sum of medical staff in service (No 4f) divided by the population size (A) and divided by 100
	8b	Percentage of MICU out of the total EMS units	Number of MICU (No 7b) divided by the total number of EMS transportation units (No 7e) and multiplied by 100
	8	Percentage of BLSU + MICU + Helicopters/ planes out of the total EMS units	Number of BLSU (No 7a) plus number of MICU (No 7b) plus number of helicopters/ planes and (No 7d) divided by the total number of EMS transportation units (No 7e) and multiplied by 100
	9	EMS transportation units per 10000 citizens	Total sum of transportation units (No 7e) divided by the population size (A) and divided by 100
	11	EMS transportation units per 100 km of road length	Total sum of transportation units (No 7e) divided by the total length of public roads (B) and multiplied by 100
Speed of initial treatment by EMS: Time values of initial treatment	19	The demand for EMS response time, min	A value as reported by EMS authorities
	20	Percentage of EMS responses meeting the demand	A value as reported by EMS authorities
	21	Average response time of EMS, min	A value as reported by EMS authorities
Quality of further treatment: facilities in service	24a	Percentage of beds in certified trauma centres and trauma departments of hospitals out of the total number of trauma beds	Number of beds in certified trauma centres (No 22a) plus number of beds in trauma departments of hospitals (No 22b) divided by total number of beds (No 22d) and multiplied by 100
	25	Number of the total trauma care beds per 10000 citizens	Total number of beds (No 22d) divided by population size (A) and divided by 100

Table 1.2. Calculation rules for estimating TM SPIs

1.4 Topics of this report

The SPI Theory report was published in 2007 (Hakkert et al, 2007). That report provided methodological fundamentals and results of the SPIs' development in seven predefined road safety domains, including trauma management.

The current report presents an update to the basic SPI Theory report. This report provides the findings of the research activities which were undertaken for further development of the trauma management SPIs, during the last period of the SafetyNet project.

Chapter 1 summarized the basics and essentials of the TM SPI concept as those were previously developed. The next chapters of this report present the results on the following topics:

Chapter 2 briefly summarizes the findings of a literature study which sought to examine recent developments in trauma/ medical databases, with emphasis on their applicability for exploring road safety issues;

Chapter 3 provides the results of additional examinations of both basic and combined TM SPIs. In particular, additional forms of basic TM SPIs, which were suggested by national experts, are considered and a more extensive analysis of the combined indicator is performed. Besides, a new way of combining basic indicators into a composite one is explored, using statistical weighting by means of Principle Component Analysis and Common Factor Analysis;

Chapter 4 provides the results of two case studies which considered additional applications of the TM SPIs developed: a comparison of regional TM systems (in Germany) and estimating the TM system's performance for a new country (following the example of Israel);

Chapter 5 provides the report's conclusions.

2 Recent developments in trauma databases and their applications (literature survey)

2.1 General

In the process of the development of TM SPIs (SafetyNet, 2005; Hakkert et al, 2007), the potential of trauma registries and other medical databases for providing better insight into the actual TM system's performance was indicated. However, the questionnaire survey of the EU countries revealed that such databases exist in a few countries only, where they are typically limited in scope (cover selected areas only or specially defined types of injury) and not easily accessible. Moreover, the major problem was that available medical databases are generally not linked to the road safety research and management activities. As stated by ETSC (1999), ETSC (2001), 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.

As discussed in Hakkert et al (2007), the indicators based on the information from trauma registries and similar databases would enable to assess the quality of the initial treatment provided by EMS and of further treatment provided by permanent medical facilities. For example, using a trauma registry, within the motor vehicle injuries 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 a trauma registry it is possible to see the share of injuries treated by intensive care units, the share of those who were operated on, the rate of mortality during hospitalization, etc., i.e. indices which typically characterize the quality of medical treatment.

A number of indices based on the information from trauma registries and similar databases were considered as an extension for the minimum set of the TM SPIs (Hakkert et al, 2007). However, due to availability problems, application of the extended set of TM SPIs was postponed to the future.

The purpose of the literature study undertaken during the last phase of the project was to check recent publications on issues concerning the application of trauma registry and other medical databases for exploring road safety injury (e.g. characteristics, medical treatments applied, trauma management system's performance), where special interest was in newly established trauma registries and similar systems in the EU countries. Moreover, the comparisons of data from the police accident files and medical databases were in focus as well.

The search was based on Medline and Transport databases, and focused on publication years 2003-2008.

2.2 Summary of findings

Studies of road safety injuries using medical databases were found for France, the Netherlands, Israel, Italy and Sweden. The studies reviewed concerned mainly the following issues: comparing the scope of road traffic injury based on medical versus police databases; in-depth considerations of specific populations of road traffic injury and evaluating efficiency of various components of the trauma care system using trauma databases.

A number of studies compared the scope of road traffic injury based on medical versus police databases.

In the study of Amoros et al (2007), the police data (from Rhône county, France, in years 1997-2001) were linked with a road trauma registry, which covers all hospitals of Rhône county and its close surroundings, includes inpatients and outpatients. The purpose of the study was to analyze police severity (mis-) classification of serious and slight casualties. Injury severity was measured by the New Injury Severity Score (slight injuries: NISS≤15, serious injuries: NISS≥16) in the trauma registry. In the police data casualties requiring a hospital stay of 6 days or more were categorized as "seriously injured", whereas casualties requiring less than 6 days of hospital stay were categorized as "slightly injured". A semi-automated record-linkage procedure was used, based on the following linkage variables: date and time of crash, crash location, type of road user, date of birth, and gender. The results revealed that 72% of NISS 16-75 casualties were classified as seriously injured by the police, and 89% of NISS 1-15 casualties were classified by the police as slight injuries. In addition, the over- and under-classification by the police depends on the characteristics like road user type, injury severity, reporting police force, casualty's age, and calendar year.

A study by Peleg, Aharonson-Daniel (2004) compared the trends in the numbers of road accident injuries in Israel based on the Israeli National Trauma Registry (ITR) versus the officially published accident statistics (the Central Bureau of Statistics - CBS) which is based on the police reporting. The ITR includes data of all those patients that were injured and hospitalized as well as those that were injured and died in the emergency rooms. In the study, significant discrepancies were identified between the CBS and the ITR numbers: according to the CBS, the number of patients with severe injuries from road traffic accidents, ranged from 2,573 to 3,378 per year, for the period 1998-2000. During the same time period, the ITR, recording data from only 8 of Israel's 24 hospitals, noted a total of 4,442 to 4,800 patients per year. Thus, the CBS database representing formal national data comprised less than half of the actual number of cases. Another important finding was that while the CBS figures showed a reduction in the number of injured, the ITR data indicated an increase. A major conclusion of the study was that road safety decision-making should be based on data gathered from multiple data sources.

Another Israeli study (Avitzour, Bigman, 2007) used the ITR data to estimate the share of hospitalized injured pedestrians among all road users, while comparing data from the CBS and the ITR (only severe injuries – those who were hospitalized, were considered). It was found that during the years 2003-2005, ten hospitals in the ITR, included 18,907 road accident accidents, of which 4,567 were pedestrians. During the same period, the CBS reported on 7,204 injuries, among them, 2,214 pedestrians. In other words, from the ITR data, the road accident related hospitalizations were 2.6 times greater than reported by the CBS and 2.1 times greater for pedestrians. Moreover, the differences observed were not random, where greater differences were found among males, during evening hours and among young children.

Rossi et al (2005) performed a descriptive study with the purpose to quantify the burden of injuries caused by road-traffic crashes in the Lazio region, Italy, and to characterize the demographics of the affected population in comparison with police-based statistics. The data source was the Emergency Information System (in years 2000/01) which collects all emergency-department-visit records in Lazio. The system records: name, date, and place of birth, the triage code, up to 4 diagnoses, therapeutic procedures, and the type of place, where the accident occurred. Further data sources were the Mortality Registry which collects all death certificates of residents and nonresidents who died in Lazio, and the Hospital Information System. All databases were linked. The results reveal that for road accidents an overall incidence of emergency-department-visits was of 2,700 per 100,000 inhabitants per year, and a mortality rate of 15.1 per 100,000. The medical surveillance system reported six times more injuries and 1.21 more fatalities than official statistics based on police reports.

The results of the above studies belong to the problem of incomplete road accident reporting which is well known in the road safety literature. Hauer and Hakkert (1988) examined the implications of incomplete accident reporting and stated that it increased the uncertainty of the estimated effects of road safety measures. The lower and more variable the level of accident reporting, the more uncertain are estimates which are supposed to provide a basis for road safety policy and interventions. Ideally, the results of studies based on official accident statistics should be adjusted to account for the level of accident reporting prevailing at the time of analysis (Hauer and Hakkert, 1988).

The level of underreporting is typically identified comparing accidents and casualties recorded at hospitals with those recorded by the police in the area serviced by the hospitals. Elvik and Mysen (1999) summarized the reporting level of hospital-treated traffic injuries in thirteen countries (based on 49 evaluation studies) and found that it ranges from 88% to 21%, with a weighted mean of 39%. The reporting level was higher for injuries that resulted in admission to hospital as in-patients: 72%-88%. (The "reporting level" in this analysis was defined as the number of police reported cases related to the number of cases in other source of data).

Concerning this issue, the need for national linked datasets of road accidents was recently strengthened in the European Union (ETSC, 2007).

In Sweden, since the end of 1990s, a national information system for traffic accidents called STRADA (Swedish Traffic Accident Data Acquisition) was established. The ultimate aim of STRADA was to reduce the amount of unreported accidents by gaining access to hospital-reported accidents, in addition to the police records. This especially concerned the unreported accidents with vulnerable road users. Based on the system's data, annual statistical reports on road traffic injury are produced. However, until now, only about 60 percent of all emergency hospitals participate in STRADA. Moreover, the medical services have their own systems and different classifications of injury, and are not particularly interested in STRADA's data (Forward and Samuelsson, 2007).

Another group of studies demonstrated that analysing the data from trauma databases enabled in-depth considerations of specific populations of road traffic injury.

For example, the Israeli study by Peleg et al (2005) used the ITR data to identify factors contributing to the risk of injury for motorcyclists as compared to drivers of other motor vehicles. The study group comprised 10,967 drivers, aged 16 and above, who were involved in traffic accidents and hospitalized between January 1, 1997 and June 30, 2003. A multiple logistic regression revealed that Tel Aviv, the busiest metropolitan city in Israel, has a high risk for motorcycle injury in comparison with other regions; males have an increased risk compared to females; and age is a protecting factor since the risk of injury as a motorcyclist decreases as age increases.

Another Israeli study (Soffer et al, 2006) sought to determine the incidence of alcohol-related trauma, and to specify the time of day, the cause of trauma, and the morbidity and mortality rates as compared to non-alcohol-associated trauma in the tertiary trauma unit of a large medical center in Tel Aviv. The data were obtained from the ITR, based on patient records from the Tel Aviv Sourasky Medical Center for the period January 2001 to December 2003. Of the 5,529 patient records reviewed, 170 had high alcohol blood levels (> 50 mg/ml). It was found that patients intoxicated with alcohol had higher rates of road accident injuries and stab wounds. The alcohol-intoxicated patients were more likely to be non-Jewish, young and male. Moreover, similar to usual findings on this topic, most of the alcohol-related injuries occurred during the weekend and during evening to late night hours.

Van Kampen (2008) studied cyclist hospital admissions in the Netherlands, based on data from the National Medical Registration system. In the analysis, a distinction was made between injured cyclists in crashes with a motorized vehicle and the non-motor vehicle crashes, where the latter comprised 70% of the total. Using the development in cyclist hospital admissions as a measure, it was found that, in total, road safety for cyclists has deteriorated over the years, mostly due to the trends observed in the second group (non-motor vehicle crashes). Although cyclists who are not hit by a motor vehicle have sustained less severe injury and there are fewer fatalities, their number increased over the years, as well as their crash rate. Furthermore, the injury severity for this group of cyclists has not decreased, as opposed to cyclists who are injured in motor vehicle crashes.

The analyses looked also at the most important injury of each cyclist who was admitted to hospital (Van Kampen, 2008). For cyclist in-patients from motor vehicle crashes, head/skull injury was found to be the most important injury (45%), where leg injury takes the second position with 25%, and injury to the torso comes third with 13%. For cyclist in-patients from non-motorized vehicle crashes, leg injury is the most frequent injury (40%), where head/skull injury takes the second place with 30%, followed by injury to the arms with 20%.

In addition, many studies were found in the literature, where trauma data served as a basis for the evaluation of various components of the trauma care system.

For example, an Israeli study based on the national trauma registry revealed a steady significant reduction in the inpatient death rate of severe trauma patients, which were hospitalized at all level I trauma centers between 1997 and 2001 (Peleg et al, 2004).

Additional examples of such studies are presented in the literature review included in the SafetyNet (2005) report.

Summing up the findings, we can indicate that once a trauma registry or a similar database is maintained in the country, many in-depth traffic injury studies are usually carried out (the examples were seen in Israel, France, the Netherlands). Moreover, the information system based on hospital records can assist in providing corrected figures of the scope and characteristics of traffic injury in the country and in assessing the performance of the trauma care system and its components.

At the same time, the national trauma registries are not common in the EU countries yet, leaving for the future the issues of application of trauma registries or similar databases for the estimation of TM SPIs.

3 Further development of a combined indicator

3.1 General

The set of TM SPIs recommended by the SPI Theory report (Hakkert et al, 2007) for characteristic and comparison of the TM system's performance in the EU countries is detailed in Sec 1.3. This set of TM SPIs includes fourteen basic indicators enabling to carry out a wide range of country comparisons (see Vis and Van Gent, 2007). In addition, a combined indicator was developed to measure a country's overall performance for trauma management, which was estimated by means of ranking the values of separate SPIs and weighting the results together (see Hakkert et al, 2007). The estimates of both separate TM SPIs and the combined indicators mentioned above were based on the data received from the countries for year 2003.

During the last project year, a new questionnaire survey was sent out to the countries asking for trauma management data for year 2006. The new data collection aimed to update the available database, to re-estimate the TM SPIs for the countries and to re-produce the country comparisons. Among other things, the new data collection and estimation intended to include the new Member States (Bulgaria and Romania) and to extend the list of countries participating in the comparisons (because in the previous survey only 17 countries supplied the data – see Vis and Van Gent, 2007).

Having received the countries' responses to the new survey, we found that, in total, fewer countries provided the information this time than in the first survey, where some of them stated that no major changes occurred in the TM data in 2006 versus 2003 or that recent information cannot be easily collected. At the same time, several additional countries (in comparison with the first survey) succeeded in collecting some TM data, this time.

A further detailed consideration of the data received revealed discrepancies in some data items reported for year 2006 in comparison with 2003, for some countries. Therefore, efforts were undertaken to verify the latest information reported on the countries, through a direct correspondence with the national experts. Due to obvious difficulties in the TM data collection and some inaccuracies revealed in the data reported in the past, we decided that the database available is not sufficient for performing comparisons of changes in the TM SPIs that have occurred over time. Instead, the estimation of the TM SPIs and the combined indicators should be performed using the latest available data for all the countries which supplied the information in the current and/or previous surveys.

The final dataset collected for the countries, including the TM SPIs estimated using these data, is presented in Appendix A. In total, the TM data are available for 21 countries, including 13 countries with data updates for 2006. Depending on SPIs, the countries have various levels of missing data (the highest level of missing data is observed for Portugal, for which only one TM data item was provided). The country comparisons using separate TM SPIs will appear in Vis and Eksler (2008).

In this chapter we provide the results of additional examinations of both basic and combined TM SPIs. The analysis includes three components: an additional examination of basic TM SPIs; a more extensive analysis of the combined indicator and a new way of combining basic indicators into a composite one using statistical weighting.

The additional examination of basic TM SPIs considers three new basic SPIs which were suggested during the meetings with national experts. They are:

- the percentage of EMS station with at least one physician (2b);

- the number of EMS stations per 1000 km^2 (3c);

- the number of EMS transportation units per 1000 km^2 (11c).

The SPIs *3c, 11c* were suggested as a substitute to the SPIs *3b* and *11*, respectively, accounting for the fact that some countries are not able to provide the figures of the total and/or rural road lengths. (Estimated values of these new indicators are also presented in Appendix A).

The extensive analysis of the combined indicator applies the method of combining separate indicators that was suggested in Hakkert et al (2007) but compares the results for various combinations of the basic indicators. The influence of separate SPIs, including the new ones, on the final country's ranking is considered as well as the sensitivity of the countries' ranking to different combinations of basic SPIs.

The results of examination of additional SPIs and the analysis of the combined indicator are given in Sec. 3.2.

In addition, a new way of combining basic indicators into a composite one, using statistical weighting by means of Principle Component Analysis and Common Factor Analysis, is explored. The findings of this analysis are given in Sec 3.3.

3.2 Examinations of additional basic indicators and of the combined indicator

3.2.1 Additional indicators

Figures 3.1, 3.2 provide the results of country comparisons using two groups of SPIs, where the availability of Emergency Medical Services for each country is estimated in terms of relative indices per area versus per road length. In particular, Fig. 3.1 compares the countries by the SPIs:

- the number of EMS stations per 100 km of rural road length (3b) – the old one;

- the number of EMS stations per 1000 km^2 (3c) – the suggested substitute;

where Fig. 3.2 compares the countries by the SPIs:

- the number of EMS transportation units per 100 km of road length (11) - the old one;

- the number of EMS transportation units per 1000 km^2 (11c) - the suggested substitute.

It can be seen from Fig 3.1 that the index per area is available for more countries than the index per road length. At the same time, the new index produces visible changes in the countries' ranking. For example, the countries with high values of both indices are Germany and the UK, whereas the new index adds three more countries to the high-level group (Austria, Portugal, Slovakia). Moreover, the new index tends "to improve" the position of smaller and more densely populated counties (e.g. Belgium, Denmark), and "to worsen" the position of larger and less populated countries (e.g. Sweden, Finland, Norway).

The second new index (the number of EMS transportation units per area – see Fig. 3.2) demonstrates a similar tendency: it "improves" the position of smaller and more densely populated counties (e.g. Belgium, Malta, the Netherlands), and "worsens" the position of larger and less populated countries (e.g. Austria, Slovakia, Lithuania, Czech Republic).

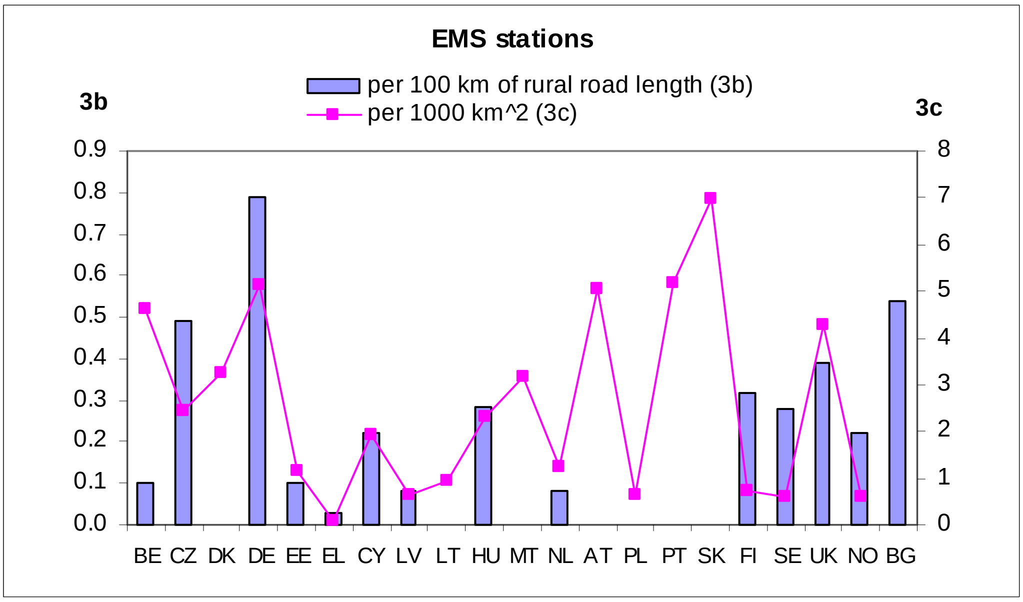

Figure 3.1 Comparison of countries by the TM SPIs on the availability of EMS stations.

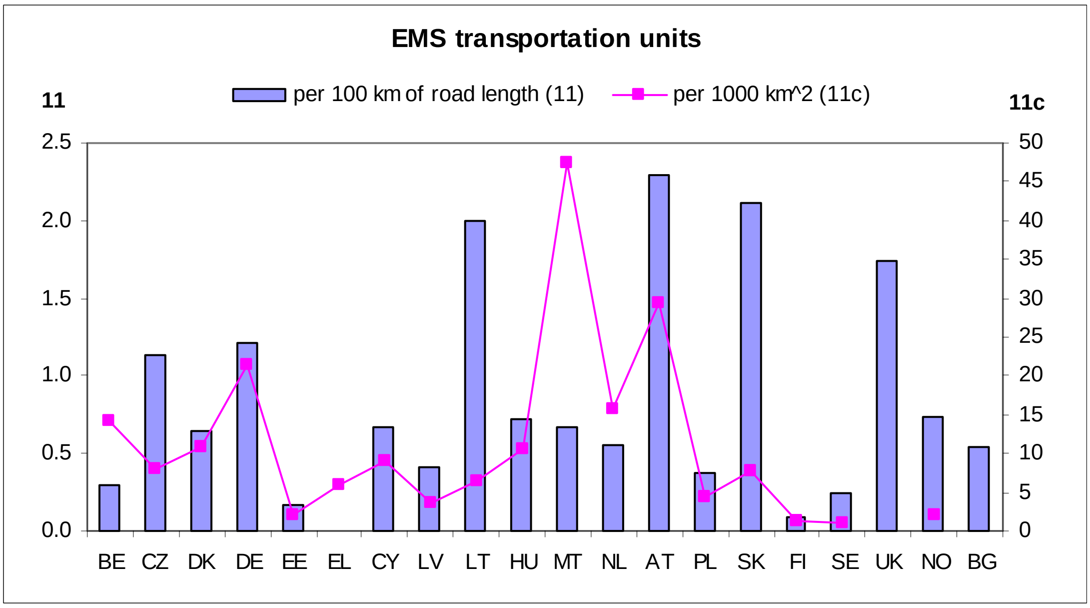

Figure 3.2 Comparison of countries by the TM SPIs on the availability of EMS transportation units.

In general, using the suggested substitute indices provides *rather different* results from the original SPIs, especially for countries not belonging to the best TM group. In addition, a concern on misleading consideration cannot be ignored as the new indicators disregard the differences in the population patterns of the countries.

More insight into the potential usefulness of the new SPIs, including "the percentage of EMS station with at least one physician (2b)", is given below, when different forms of the combined TM indicator are considered.

3.2.2 Combined indicator

A combined indicator was suggested by Hakkert et al (2007) for providing an overall characteristic of the TM system's performance. The combined indicator developed was limited to the following considerations: it would be based on the TM SPIs' values, which were available for a country, where the comparison by means of the combined indicator would provide an indication of "higher"/ "lower" level of the system's performance *relative* to other countries in the sample. In addition, according to the meanings of separate SPIs, the combined indicator would tell us something about the level of the EMS treatment *potential*, EMS response time and the treatment *potential* of permanent medical facilities, i.e. the message is limited mostly to the availability of these services and, to a lesser extent, to the shares of higher-quality resources.

The combined indicator is estimated by means of ranking the values of separate TM SPIs and weighting the results together. Two ways of ranking are applied: method A and method B. Following are the details of both methods.

Method A: according to the values of each SPI, a direct ranking of countries is performed, e.g. rank "1" corresponds to the best SPI value, rank "2" to the second best, etc. Using the ranks for all the SPIs, for each country, an average rank is estimated. The average ranks are considered as a final population which is subdivided into five groups. The groups indicate the levels of the system's performance: (1) high; (2) relatively high; (3) medium; (4) relatively low; (5) low, where level (1) includes the values (ranks) which are lower than the population mean minus standard deviation; level (3) – the values (ranks) between the percentiles 40% and 60%; level (5) – the values (ranks) over the population mean plus standard deviation; level (2) comprises all the values between (1) and (3), and level (4) – all the values between (3) and (5).

In mathematical terms, the procedure is as follows.

Let x_{ij} designate a rank of country i for SPI j, $i \in [1,N]$, $j \in [1,K]$, N – the number of countries compared, K – the number of indicators considered.

Then $X_i = \sum_j x_{ij}/n_i$ presents an average rank, where n_i – the number of SPI values available for country i (excluding missing values).

For the sample $\{X_i\}$ the statistical values are estimated: a mean MN(X), a standard deviation SD(X), a 40% percentile P40(X), a 60% percentile P60(X).

Then, belonging of country i (Y_i) to one of the five groups of the TM system's performance is defined as follows:

$Y_i \in (1)$ if $X_i \leq MN(X) - SD(X)$

$Y_i \in (2)$ if $MN(X) - SD(X) < X_i \leq P40(X)$

$Y_i \in (3)$ if $P40(X) < X_i \leq P60(X)$

$Y_i \in (4)$ if $P60(X) < X_i \leq MN(X) + SD(X)$

$Y_i \in (5)$ if $MN(X) + SD(X) < X_i$

Method B: according to the values of each SPI, the countries are ranked using five groups of performance level, where rank "1" (high level) includes the SPI values which are higher than the population mean plus standard deviation; rank "3" (medium level) – the SPI values between the percentiles 40% and 60%; level "5" (low level) – the SPI values which are lower than the population mean minus standard deviation; rank "2" (relatively high level) comprises the SPI values between "1" and "3", and rank "4" (relatively low level) – the SPI values between "3" and "5". Then, based on the ranks for all available SPIs, for each country, an average rank is estimated. The average ranks are considered as a final population which is subdivided into 5 groups using the aforementioned levels of the system's performance (1-5 as introduced for "method A").

Considering the values of each SPI, typically, a better (lower) rank is given to a higher value of the SPI. Exceptions to the rule stated for the other SPIs are applied for such SPIs as *2b* (percentage of EMS stations with at least one physician), *8* (percentage of specially-equipped EMS vehicles), *19-21* (characteristics of the response time) and *24* (percentage of beds in higher level medical facilities), where the ranking is more empirical. For example, for the SPI *20* (percentage of EMS responses meeting the demand) three ranks were defined: "1" for values 95%-100%; "2" for 80%-95%; "3" for values lower than 80%. (Missing values are ignored by all rankings.)

The combined indicators were estimated using both methods of ranking with different sets of basic SPIs. In total, 7 variants of the combined indicators were estimated, of which four - by method A and three – by method B. In each trial, a different set of basic TM SPIs was applied, as follows:

1) **Ranks A** – ranking by method A using the whole set of 14 SPIs (all the minimum set of basic TM SPIs as presented in Sec.1.3. This trial is similar to the main calculations performed in the previous country comparison survey – see Hakkert et al, 2007);
2) **Ranks A1** - ranking by method A using a reduced set of 11 SPIs (i.e. excluding *5a,8b,19* indicators as having lower weights for country comparisons. This trial is similar to the alternative calculations performed in the previous country comparison survey – see Hakkert et al, 2007);
3) **Ranks A2** - ranking by method A using an extended set of 15 SPIs (all the minimum set of basic TM SPIs as in Ranks A' trial plus a new *2b* SPI - "percentage of EMS stations with at least one physician");
4) **Ranks A3** - ranking by method A using a reduced set of 11 SPIs (i.e. excluding *5a,8b,19* indicators similar to Ranks A1' trial where instead of the old *3b,11* SPIs the new *3c,11c* indicators were used);
5) **Ranks B** – ranking by method B using the whole set of 14 SPIs (all the minimum set of basic TM SPIs as presented in Sec.1.3. This trial is similar to another way of calculations performed in the previous country comparison survey – see Hakkert et al, 2007);
6) **Ranks B1** - ranking by method B using a reduced set of 11 SPIs (i.e. excluding *5a,8b,19* indicators as having lower weights for county comparisons);
7) **Ranks B3** - ranking by method B using a reduced set of 11 SPIs (i.e. excluding *5a,8b,19* indicators similar to Ranks B1' trial, where instead of the old *3b,11* SPIs the new *3c,11c* indicators were used).

To sum up, trials Ranks A, Ranks A1 and Ranks B resemble those performed in the previous country comparison survey (now they are re-run based on the updated dataset), where trials Ranks A2, Ranks A3, Ranks B1 and Ranks B3 provide additional alternatives, to consider the influence of various sets of basic TM SPIs.

By each ranking procedure, each country is attributed to one of five levels of the TM system's performance, which are "high", "relatively high", "medium", "relatively low" or "low". Moreover, based on the results of seven trials, final ranking of the countries is defined.

The estimation results of the seven trials and the final country's ranking are presented in Table 3.1. In addition, Table 3.2 provides information on the availability of data for each trial, including the changes in the amount of missing values when the new indicators (*2b,3c,11c*) were included in the analysis.

Country	Ranks A	Ranks B	Ranks A2	Ranks A1	Ranks A3	Ranks B1	Ranks B3	Final estimate	
AT	1	1	1	1	1	1	1	**1**	High
DE	1	1	1	1	1	1	1	**1**	High
BG	2	2	2	2	2	2	2	**2**	Relatively high
SK	2	2	2	2	2	2	2	**2**	Relatively high
CZ	2	2	2	2	3	3	2	**2**	Relatively high
NO	2	3	2	1	3	2	3	**2**	Relatively high
UK	3	2	3	2	2	2	2	**2**	Relatively high
LT	3	2	3	2	4	2	3	**3**	Medium
DK	4	2	4	3	2	2	2	**3**	Medium
LV	2	3	2	3	3	4	4	**3**	Medium
BE	4	3	3	4	2	3	2	**3**	Medium
CY	2	4	2	3	3	4	4	**3**	Medium
EE	3	4	3	3	2	4	3	**3**	Medium
HU	3	3	3	4	4	3	3	**3**	Medium
MT	4	4	4	4	4	4	3	**4**	Relatively low
FI	4	4	4	4	4	3	4	**4**	Relatively low
SE	4	4	4	4	5	4	4	**4**	Relatively low
PL	4	4	4	5	5	4	5	**4**	Relatively low
EL	5	5	5	4	5	5	5	**5**	Low
NL	5	5	5	5	5	5	5	**5**	Low

Table 3.1. Combined estimates of the trauma management systems' performance in the countries considered: results of seven trials and the final estimate.

It can be seen from Tables 3.1, 3.2 that:

- In all the ranking trials the groups of countries with "high" and "low" levels of the TM systems' performance were stable, where the ranks of countries with intermediate levels of the systems' performance depended on the method of ranking. The countries which are especially sensitive to the method of ranking are: Norway, Cyprus, Latvia, Lithuania, Estonia, Denmark and Belgium.

- The addition of *2b* indicator ("percentage of EMS stations with at least one physician", trial Ranks A2) did not lead to a significant change in the countries' ranking in comparison with the trial without *2b* (Ranks A). On the other hand, the addition of this indicator increased the amount of missing values for the countries considered. Thus, this indicator should not be recommended for the inclusion in the basic set of the TM SPIs.

- Using "per area" indicators instead of "per road length" indicators (i.e. *3c,11c* instead of *3b,11* or the comparison of Ranks A3, Ranks B3 with Ranks A1, Ranks B1, respectively) does create differences in the definition of system's level for about half of countries. However, the countries which "suffered" from these changes belong to the intermediate levels of the system's performance, where in the majority of cases the change implied moving to a "neighbour" category of the performance level, i.e. was not drastic. The exception was observed in two cases only: for Lithuania and Belgium, which moved from "relatively high" to "relatively low" categories or vice versa, but in the bottom line both countries belong to the "medium"-level group.

On the other hand, using the "per area" indicators, as expected, provided some benefits from the viewpoint of basic SPIs' availability for the countries compared (see Table 3.2). However, using the new indicators instead of the old ones did not necessarily provide better consistency of the country's ranking received by a single method (e.g. Ranks A3, Ranks B3) versus the final results (see Table 3.1).

Country	No of missing values-Ranks A	No of missing values-Ranks B	No of missing values-Ranks A1	No of missing values-Ranks B1	No of missing values-Ranks A2	No of missing values-Ranks A3	No of missing values-Ranks B3	*Adding 2b*	*Using 3c,11c instead of 3b,11*
AT	2	2	2	2	2	1	1		*better*
BE	0	0	0	0	0	0	0		
BG	2	2	1	1	2	3	3		*worse*
CY	2	2	1	1	2	1	1		
CZ	0	0	0	0	1	0	0	*worse*	
DE	1	1	1	1	1	1	1		
DK	3	3	3	3	4	2	2	*worse*	*better*
EE	0	0	0	0	0	0	0		
EL	4	4	3	3	5	2	2	*worse*	*better*
FI	5	5	4	4	5	4	4		
HU	1	1	1	1	2	1	1	*worse*	
LT	5	5	5	5	5	4	4		*better*
LV	2	2	2	2	2	2	2		
MT	3	3	2	2	3	1	1		*better*
NL	4	4	4	4	5	4	4	*worse*	
NO	7	7	5	5	8	5	5	*worse*	
PL	4	4	3	3	4	2	2		*better*
SE	3	3	3	3	4	3	3	*worse*	
SK	3	3	3	3	3	2	2		*better*
UK	3	3	3	3	4	4	4	*worse*	*worse*

Table 3.2. Availability of countries' data in various trials for estimating the combined indicator.

In general, we did not receive strict evidence that the application of new indicators instead of the old ones provides clear benefits for the overall countries' ranking in accordance with the levels of the TM system's performance. Moreover, recognizing a concern of possible misleading results when the EMS availability in the countries is compared by means of the "per area" indices, we suggest to continue the application of the TM SPIs' set that was previously defined (with *3b* and *11* indicators).

- Neither single method of ranking was fully consistent with final estimates based on the results of all the trials performed. Therefore, it is advisable, when the countries are compared by the level of the TM system's performance, to apply several ways of ranking for the estimation of the combined TM SPI. Preferable methods of ranking in such trials would be: Ranks A, Ranks A1, Ranks B and Ranks B1, where Ranks A3 and Ranks B3 can be tried as well. Consistency of the results of different rankings will increase the reliability of findings.

3.3 Development of a composite indicator by means of statistical weighting

Besides the building of the combined indicator by means of multiple ranking as presented in Sec.3.2, at this stage a new and more rigorous way of combining basic TM SPIs into a composite indicator was explored, i.e. using statistical weighting techniques. The techniques examined were Principle Component Analysis (PCA) and Common Factor Analysis (FA).

The analysis had a number of purposes. First, it was important to explore a possibility of creating a composite indicator on the TM system's performance, based on the data available. Secondly, by applying several statistical techniques for the data analysis, we expected to recognize, among the list of basic SPIs, those items which are more essential for the characteristic of the TM system's performance. Thirdly, it was expected that the composite indicator would enable the ranking of countries in accordance with the TM system's performance or, at least, to identify several groups of countries with similar levels of such performance.

3.3.1 Data preparation

The data which were available for the analysis are presented in Table 3.3. They include basic TM SPIs estimated for 21 countries: in total, 17 SPIs, of which 14 belong to the original set of the TM SPIs and 3 SPIs (*2b,3c,11c*) are new. Among the original set of the TM SPIs, three indicators (*5a,8b,19*) have a lower weight for county comparisons than other indicators. Therefore, for the analysis, three groups of variables were defined: *ai* – eleven SPIs from the original TM SPI set having higher weight for the country comparisons; *bi* – three other TM SPIs from the original set, with lower weight; and *ci* – the three new SPIs. The variables introduced are shown in Table 3.3. (Further presentation of the results in this Section will be in terms of these variables).

Preparing the data for the analysis, a number of data transformations were carried out, to create a homogeneous dataset. For example, in the case when the data item included a range of values we took its average as a representing value; estimates of "the demand for response time" were brought to the values corresponding to 95% of responses; for the "percentage of EMS responses meeting the demand", a share below 15 min was produced when necessary, etc. In addition, data outliers were examined. As a result, variable *a4* for Austria was excluded from the combined indicator's building process (nevertheless, the value is included in the calculations of the final scores for Austria).

Furthermore, depending on the SPI, a wide range of missing data patterns was observed. As can be seen from Table 3.3, only two countries have values for the whole set of SPIs. Therefore, prior to the analysis, missing *data imputations* were performed. To impute the data, we used the MI procedure of SAS 9.2, with the MCMC method for imputation. At present only continuous variables can be included for the MCMC imputation, which assumes multivariate normality of variables. We used SAS macro *%bctrans* to find Box-Cox transformation in order to achieve marginal normality of each of the continuous variables. Due to relatively small number of observations with respect to the number of variables, the imputations were not straightforward but done separately for groups of variables. The final data set, with initial and imputed values of TM SPIs, is presented in Table 3.4.

3.3.2 Method of analysis

To combine the basic indicators into a composite one, weights based on statistical models are applied. We examined two methods: Principal Component Analysis (PCA) and Common Factor Analysis (FA) weighting. Both methods group together indices that are collinear to form a composite indicator that captures as much of common information among basic indicators as possible. The idea under PCA/FA is to account for the highest possible variation in the indicators set using the smallest possible number of factors (Nardo et al, 2005). If no correlation between basic indicators exists, then a composite indicator can not be obtained by these methods.

The first step in the FA is to check the correlation structure of the data, where the second step is the identification of a certain number of latent factors, smaller than the number of indicators, representing the data. In the PCA, we retain those factors that account for the largest amount of the variance.

Variables	*c1*	*a1*	*a2*	*b1*	*a3*	*a4*	*b2*	*a5*	*a6*	*a7*	*b3*	*a8*	*a9*	*a10*	*a11*	*c2*	*c3*
Country	(2b) % with at least one physician	(3a) EMS stations per 10000 citizens	(3b) EMS stations per 100 km of rural road length	(5a) physicians out of EMS staff	(5) physicians+ paramedics out of EMS staff	(6) EMS medical staff per 10000 citizens	(8b) MICU out of the total	(8) BLSU+MICU+ helicopters/ planes out of the total	(9) EMS transportation units per 10000 citizens	(11) EMS transportation units per 100 km of road length	(19) The demand for response time, min	(20) Percentage of EMS responses meeting the demand	(21) Average response time of EMS, min	(24a) % of beds in certified trauma centres and trauma departments of hospitals	(25) Number of trauma care beds per 10000 citizens	(3c) EMS stations per 1000 km^2	(11c) EMS transportation units per 1000 km^2
BE	26.5%	0.14	0.10	15.0%	15.0%	8.90	22%	100%	0.44	0.30	15 min	100%	6 min	100%	0.69	4.6	14.1
CZ	n/a	0.19	0.49	15.1%	15.1%	3.60	58%	100%	0.61	1.13	15 min	89.2%	7.83 min	100%	10.41	2.4	7.9
DK	n/a	0.26	n/a	5.0%	5.6%	3.60	3%	100%	0.87	0.65	5-10 min	100%	8.0 min	n/a	n/a	3.2	10.9
DE	39.4%	0.22	0.79	32.1%	73.6%	6.43	49%	85%	0.92	1.21	15 min	91.5%	8.1 min	n/a	61.96	5.1	21.3
EE	54.7%	0.39	0.10	14.5%	18.4%	9.94	7%	100%	0.68	0.16	15 min	64%	23 min	95%	2.31	1.2	2.0
EL	n/a	0.01	0.03	7.0%	n/a	1.93	3%	99%	0.69	n/a	n/a	n/a	15 min	0%	46.19	0.1	5.8
CY	100.0%	0.23	0.22	19.0%	19.0%	4.18	49%	100%	1.07	0.68	n/a	60% within 10 min	n/a	0%	1.28	1.9	8.9
LV	100.0%	0.18	0.08	17.2%	17.2%	7.34	99%	100%	1.06	0.41	25 min	88%	17 min	n/a	n/a	0.7	3.7
LT	100.0%	0.18	n/a	18.8%	18.8%	4.75	0%	100%	1.26	1.99	20 min	n/a	n/a	n/a	n/a	0.9	6.5
HU	n/a	0.21	0.28	13.1%	13.1%	0.96	13%	100%	0.96	0.72	15 min	72%	12-20 min	n/a	3.34	2.3	10.5
MT	100.0%	0.03	n/a	54.5%	54.5%	1.70	0%	100%	0.39	0.67	n/a	n/a	15-30 min	100%	0.41	3.2	47.5
NL	n/a	0.03	0.08	0.0%	0.0%	1.62	0%	100%	0.40	0.56	15 min	n/a	n/a	n/a	n/a	1.2	15.7
AT	29.0%	0.51	n/a	5.9%	29.4%	51.32	5%	100%	2.97	2.30	15 min	95%	n/a	7%	78.53	5.1	29.3
PL	100.0%	0.06	n/a	n/a	n/a	2.10	35%	100%	0.37	0.37	15 min	90%	n/a	100%	0.56	0.7	4.4
PT	n/a	0.46	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	5.2	n/a
SK	100.0%	0.63	n/a	21.4%	21.4%	7.09	1%	53%	0.70	2.11	15 min	n/a	n/a	100%	1.68	7.0	7.7
FI	2.4%	0.47	0.32	1.1%	28.1%	1.05	25%	100%	0.77	0.09	n/a	n/a	n/a	n/a	n/a	0.7	1.2
SE	n/a	0.30	0.28	0.2%	0.2%	4.41	89%	100%	0.56	0.24	15 min for 90%	n/a	10-15 min	n/a	n/a	0.6	1.1
UK	n/a	0.17	0.39	0.0%	64.2%	4.65	0%	21%	3.20	1.74	8 min for 75%	100%	n/a	n/a	n/a	4.3	n/a
NO	n/a	0.44	0.22	n/a	n/a	n/a	0%	93%	1.47	0.73	n/a	app. 90%	n/a	n/a	n/a	0.6	2.1
BG	100.0%	0.29	0.54	22.4%	22.4%	9.55	54%	87%	0.72	0.54	n/a	n/a	15 min	100%	1.09	n/a	n/a

Table 3.3. Basic trauma management SPIs available for the analysis.

Variables	*c1*	*a1*	*a2*	*b1*	*a3*	*a4*	*b2*	*a5*	*a6*	*a7*	*b3*	*a8*	*a9*	*a10*	*a11*	*c2*	*c3*
Country	(2b) % with at least one physician	(3a) EMS stations per 10000 citizens	(3b) EMS stations per 100 km of rural road length	(5a) physicians out of EMS staff	(5) physicians+ paramedics out of EMS staff	(6) EMS medical staff per 10000 citizens	(8b) MICU out of the total	(8) BLSU+MICU + helicopters/planes out of the total	(9) EMS transportation units per 10000 citizens	(11) EMS transportation units per 100 km of road length	(19) The demand for response time, min	(20) Percentage of EMS responses meeting the demand	(21) Average response time of EMS, min	(24a) % of beds in certified trauma centres and trauma departments of hospitals	(25) Number of trauma care beds per 10000 citizens	(3c) EMS stations per 1000 km^2	(11c) EMS transportation units per 1000 km^2
AT	0.290	0.512	0.462	0.059	0.294	51.316	0.054	1.000	2.968	2.298	15.000	0.950	9.283	0.071	78.526	5.054	29.297
BE	0.265	0.144	0.101	0.150	0.150	8.895	0.218	1.000	0.437	0.301	15.000	1.000	6.000	1.000	0.687	4.640	14.104
BG	1.000	0.286	0.540	0.224	0.224	9.553	0.542	0.866	0.721	0.545	15.169	0.773	15.000	1.000	1.093	2.204	9.089
CY	1.000	0.231	0.222	0.190	0.190	4.185	0.494	1.000	1.065	0.676	14.360	1.000	10.168	0.000	1.284	1.935	8.925
CZ	0.787	0.186	0.493	0.151	0.151	3.595	0.582	1.000	0.611	1.130	15.000	0.892	7.830	1.000	10.415	2.421	7.947
DK	0.555	0.260	0.231	0.050	0.056	3.600	0.034	1.000	0.871	0.651	7.500	1.000	8.000	0.465	28.331	3.248	10.882
EE	0.547	0.394	0.099	0.145	0.184	9.935	0.065	1.000	0.684	0.162	15.000	0.640	23.000	0.955	2.305	1.173	2.035
FI	0.024	0.472	0.320	0.011	0.281	1.049	0.246	1.000	0.766	0.090	11.467	0.958	9.466	0.434	40.910	0.739	1.201
DE	0.394	0.222	0.791	0.321	0.736	6.429	0.488	0.852	0.922	1.212	15.000	0.915	8.100	0.219	61.958	5.131	21.286
EL	0.741	0.011	0.029	0.070	0.134	1.928	0.026	0.991	0.686	0.422	17.509	0.921	15.000	0.000	46.192	0.091	5.800
HU	0.381	0.213	0.282	0.131	0.131	0.961	0.131	1.002	0.964	0.721	15.000	0.720	16.000	0.623	3.344	2.322	10.512
LV	1.000	0.184	0.081	0.172	0.172	7.342	0.992	1.000	1.056	0.407	25.000	0.880	17.000	0.220	-13.962	0.650	3.731
LT	1.000	0.181	0.326	0.188	0.188	4.746	0.000	1.000	1.261	1.991	20.000	0.741	19.612	0.199	-7.677	0.936	6.518
MT	1.000	0.026	0.211	0.545	0.545	1.697	0.000	1.000	0.386	0.674	16.539	0.805	22.500	1.000	0.411	3.165	47.468
NO	0.455	0.437	0.221	0.159	0.286	5.277	0.000	0.927	1.468	0.732	13.060	0.900	10.047	0.398	27.987	0.618	2.075
PL	1.000	0.055	0.104	0.181	0.127	2.104	0.352	1.000	0.373	0.371	15.000	0.900	11.978	1.000	0.561	0.654	4.405
PT	0.229	0.458	0.313	0.069	0.178	3.487	0.217	0.925	0.805	0.962	18.204	0.735	10.840	1.345	29.289	5.182	11.616
SK	1.000	0.633	1.541	0.214	0.214	7.089	0.011	0.532	0.697	2.108	15.000	0.780	17.000	1.000	1.677	6.988	7.705
SE	0.210	0.302	0.281	0.002	0.002	4.407	0.886	1.000	0.558	0.242	15.480	0.839	12.550	0.223	16.527	0.611	1.129
NL	0.493	0.031	0.081	0.000	0.000	1.620	0.000	1.000	0.401	0.557	15.000	0.801	11.636	0.251	33.305	1.228	15.748
UK	0.390	0.169	0.392	0.000	0.642	4.650	0.000	0.214	3.200	1.740	8.730	1.000	8.788	0.487	60.163	4.258	21.125

Table 3.4. Final dataset for analysis, with initial and imputed values of basic trauma management SPIs.

We used Kaiser-Meyer-Olkin (KMO) statistics to predict and demonstrate if the data are likely to factor well, based on their correlations and partial correlations. There is a KMO statistic for each individual variable, and an overall KMO statistic. It is customary that KMO overall should be 0.60 or higher, to proceed with the factor analysis. If this condition is not satisfied, one should drop the indicator variables with the lowest individual KMO statistic values, until KMO overall rises above 0.60.

In both methods (PCA/FA), the combination of factors into a combined index is done by their weighted sum, where the weights are taken in accordance with the variance explained by each factor.

Using the two types of analysis defined (PCA/ FA), three trials of creating a composite indicator were performed. They are:

1) **PCA_15** – a PCA which started with all the 17 variables. "Eigenvalue>1" criterion was applied for choosing the initial number of factors. Further, variables *b2* (percentage of MICU out of the total transportation units) and *a10* (percentage of beds in certified trauma centres and trauma departments of hospitals) were eliminated due to statistical reasons. Based on the remaining fifteen variables, three factors were fitted, which are responsible for 64.4% of the cumulative variance.
2) **FA_11** – a common factor analysis started with all the 17 variables. Based on estimates of the KMO statistics, variables *a1,a2,a4,a10,b1,c1* were excluded from building the factors. Further analysis of the factors using the variables remained showed that we can get a four factors' solution based on eleven variables, with 95% cumulative variance explained.
3) **FA_9** – further exploration of results of the previous trial revealed that we can get a two factors' solution based on nine variables (i.e. additionally excluding *b2* and *c3* variables), with 90% cumulative variance explained.

The results of each analysis (three trials) enabled to produce, for each country, the values of the factors created (three, four and two factors, respectively), a combined safety indicator (called WF – weighted factor), and clusters of countries with similar values of the factors created. Besides, the factors created provided an insight into the similarities and dissimilarities in behaviours of basic SPIs. Detailed results of the analyses are given in Appendix B. A brief summary of findings is presented below.

3.3.3 Results

1) In the **PCA_15** analysis, three factors were fitted to the data, where:

Factor 1 reflects mostly the basic SPIs such as *a9* (average response time of EMS) and *b3* (the demand for response time), for which lower values are associated with better system's performance, as well as *c1* (percentage of EMS stations with at least one physician), *a6* (EMS transportation units per citizens), *a8* (percentage of EMS responses meeting the demand), and *a11* (number of trauma care beds per citizens), for which higher values are associated with better system's performance;

Factor 2 reflects mostly the basic SPIs *a2* (EMS stations per road length), *c2* (EMS stations per area), *a7* (EMS transportation units per road length), *a1* (EMS stations per citizens), *a4* (EMS medical staff per citizens) and *a5* (percentage of highly-equipped transportation units out of the total). For all these SPIs, higher values are associated with better system's performance;

Factor 3 reflects mostly *c3* (EMS transportation units per area), *a3* (share of physicians and paramedics out of EMS staff), and *b1* (share of physicians out of EMS staff), for which higher values are preferable.

Accounting for the SPI coefficients (see App.B), the desirable behaviour of the factors (i.e. that associated with better TM system's performance) will be as follows:

Factor 1 $\rightarrow$ min; Factor 2 $\rightarrow$ max; Factor 3 $\rightarrow$ max.

The weights assigned to the factors in this trial were: 0.38, 0.36 and 0.26, respectively, meaning that in the combined estimate factors 1 and 2 may offset each other.

Considering the country scores estimated for each factor and the combined estimates (see App.B), we noted that countries with the best values of each factor, i.e. the lowest values of factor 1 and the highest values of factors 2 and 3 (Germany and the United Kingdom), did not arrive to a remarkable (very high or very low) combined value. In addition, similar values of the combined estimate can be received in rather different cases: when one or even several factors demonstrated "opposite to the desired" behaviour. Moreover, the highest values of the combined indicator do not necessarily belong to countries having a good position in accordance with each of the factors. Based on these considerations, it was decided not to rank or group the countries in accordance with the value of the combined estimate. Instead, *groups of countries with similar TM system's performance are defined comparing the values of the three factors separately*.

Using a WARD clustering procedure, which works with the factor values, the countries were classified into similar groups as presented in Figure 3.3. Countries belonging to the same group have similar values of factors, where certain differences are measured between the groups.

Using the classification results, in general, different numbers of groups can be defined, depending on the level of distances between the countries in the same group, which is selected as a threshold. For example, with a threshold value of about 0.03, we can identify six groups of countries (see a vertical dashed line in Fig.3.3). In order to interpret properly the TM system's performance in each group, we need to examine the countries' positions plotted versus each pair of the factors. For example, Figure 3.4 illustrates the countries' positions plotted against the factor 1' and factor 2' values.

Based on the combined analysis of the results, the groups of countries were defined as follows:

1 – DE and UK, with best characteristics of the TM systems' performance, according to all factors;

2 – AT and SK, with good characteristics of the TM systems' performance, especially according to factor 2' values;

3 – FI, DK, NO, BE, SE, CY, CZ, PT, HU;

4 – BG, EE, LT, LV, where groups 3 and 4 are with a medium level of the TM systems' performance but due to different factors;

5 – NL, EL and PL, with a relatively low level of the TM systems' performance; and

6 – MT, which is different from other countries by the factor values, mostly by a very high value of factor 3, where the combined estimate located this country close to group 2. Therefore, we assumed that this country probably belongs to a good-medium level of the TM system's performance (between the groups 2 and 3).

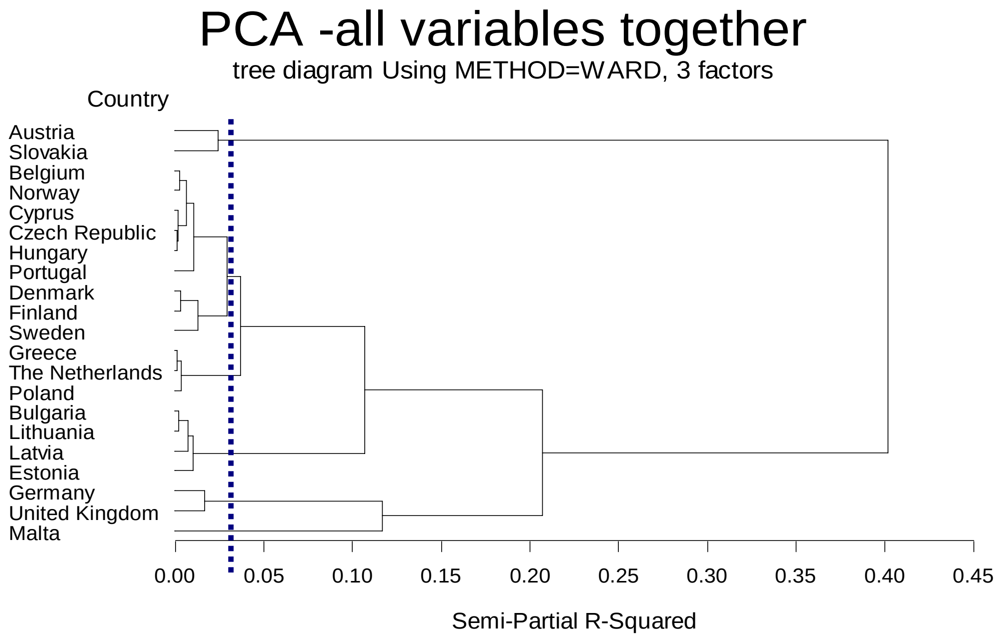

Figure 3.3 Countries' classification into similar groups (PCA_15' analysis). Note: dashed line indicates a threshold for groups' definition.

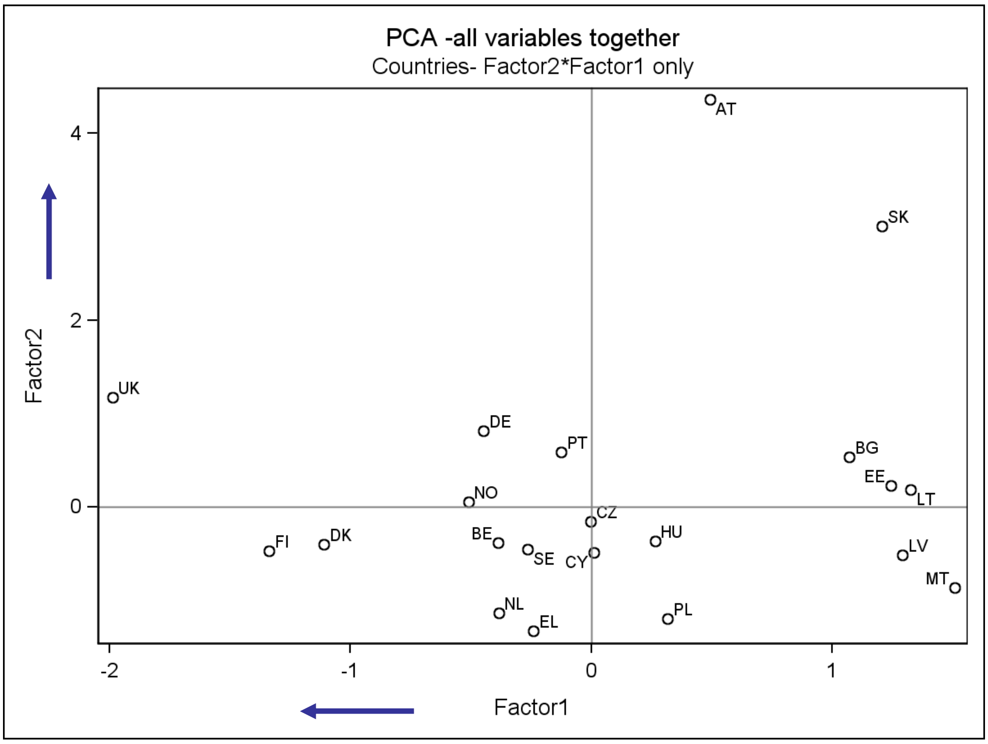

Figure 3.4. Countries plotted versus factor 1' and factor 2' values (PCA_15' analysis). Note: arrows indicate preferable values of factors.

2) In the **FA_11** analysis, four factors were fitted to the data (see App. B), where:

Factor 1 reflects mostly the basic SPI *a9* (average response time of EMS), for which lower values are associated with better system's performance, and *a11* (number of trauma care beds per citizens) and *a8* (percentage of EMS responses meeting the demand), for which higher values are associated with better system's performance;

Factor 2 reflects mostly the basic SPIs *a7* (EMS transportation units per road length), *a6* (EMS transportation units per citizens) and *a5* (percentage of highly-equipped transportation units out of the total). For all these SPIs, higher values are associated with better system's performance;

Factor 3 reflects mostly *c3* (EMS transportation units per area), *a3* (share of physicians and paramedics out of EMS staff), and *c2* (EMS stations per area), for which higher values are preferable;

Factor 4 reflects mostly *b2* (share of MICU out of the total transportation units) and *b3* (the demand for response time), where for the first item a higher value and for the second – a lower value is preferable.

Accounting for the SPI coefficients (see App.B), the desirable behaviour of the factors (i.e. that associated with better TM system's performance) will be as follows:

Factor 1 $\rightarrow$ min; Factor 2 $\rightarrow$ max; Factor 3 $\rightarrow$ max; where for Factor 4, due to opposite contributions of the variables, the final "preferable" behaviour is unclear.

The weights assigned to the factors in this trial were: 0.32, 0.31, 0.22 and 0.15, respectively, meaning that in the combined estimate factors 1 and 2 may offset each other, where in total a positive value of the combined estimate is desirable.

Considering the country scores estimated for each factor and the combined values (see App.B), we found, similar to the previous trial, that countries with best values of each factor, i.e. negative values of factor 1 and positive values of factors 2 and 3 (Germany, the United Kingdom and Austria), arrived to a positive but not high combined estimate. In addition, similar values of the combined estimate were also received by countries with "opposite to the desired" behaviour of one or more factors. Therefore, like in the previous trial, grouping of countries with similar TM system's performance was made using the values of factors in separate and not based on the combined estimate.

Using the results of a WARD clustering procedure and the countries' positions plotted against the factor values (see App.B), the groups of countries were defined as follows:

1 – DE, UK and AT, with best characteristics of the TM systems' performance, according to most factors;

2 – SK, BG, LV, HU, LT, PT, EE; and

3 – FI, DK, NO, BE, SE, CY, CZ, where groups 2 and 3 are with a medium level of the TM systems' performance but due to different factors;

4 – NL, EL, PL and SE, with a relatively low level of the TM systems' performance;

5 – MT, which is different from other countries, mostly by a low value of factor 2 and a high value of factor 3, where the combined estimate located this country close to group 2.

3) In the **FA_9** analysis, two factors were fitted to the data (see App. B), where:

Factor 1 reflects mostly the basic SPIs *a7* (EMS transportation units per road length), *a6* (EMS transportation units per citizens), *c2* (EMS stations per area), *a3* (share of physicians and paramedics out of EMS staff) and *a5* (percentage of highly-equipped transportation units out of the total). For all these SPIs, higher values are associated with better system's performance;

Factor 2 reflects mostly the basic SPIs *a9* (average response time of EMS) and *b3* (the demand for response time), for which lower values are associated with better system's performance, as well as *a11* (number of trauma care beds per citizens) and *a8* (percentage of EMS responses meeting the demand), for which higher values are associated with better system's performance.

Accounting for the SPI coefficients (see App.B), the desirable behaviour of the factors (that associated with better TM system's performance) will be as follows:

Factor 1 $\rightarrow$ max; Factor 2 $\rightarrow$ min.

The weights assigned to the factors in this trial were: 0.55 and 0.45, respectively, meaning that in the combined estimate factors 1 and 2 may offset each other.

Considering the country scores estimated for each factor and the combined values (see App.B), we found, similar to the previous trials, that countries with best values of each factor, i.e. positive values of factor 1 and negative values of factor 2 (Germany, the United Kingdom and Austria), arrived to a positive but not very high combined estimate. Besides, similar values of the combined estimate were also received by countries with "opposite to the desired" behaviour of one or both factors. Therefore, like in the previous trials, grouping of countries with similar TM system's performance was made using the values of factors separately and not based on the combined estimate.

Using the results of a WARD clustering procedure (see App.B) and the countries' positions plotted against the factor values (Figure 3.5), the groups of countries were defined as follows:

1 – DE, UK, AT, with high characteristics of the TM systems' performance, according to both factors;

2a – FI, BE, CY, DK, CZ, NO, and

2b – SK, where for groups 2a and 2b the desired behaviour was observed for one of the factors;

3 – BG, HU, LV, PT, with a medium level of the TM systems' performance;

4 – MT, LT, EE, and

5 – SE, PL, NL, EL, where groups 4 and 5 are with relatively low level of the TM systems' performance but due to different reasons.

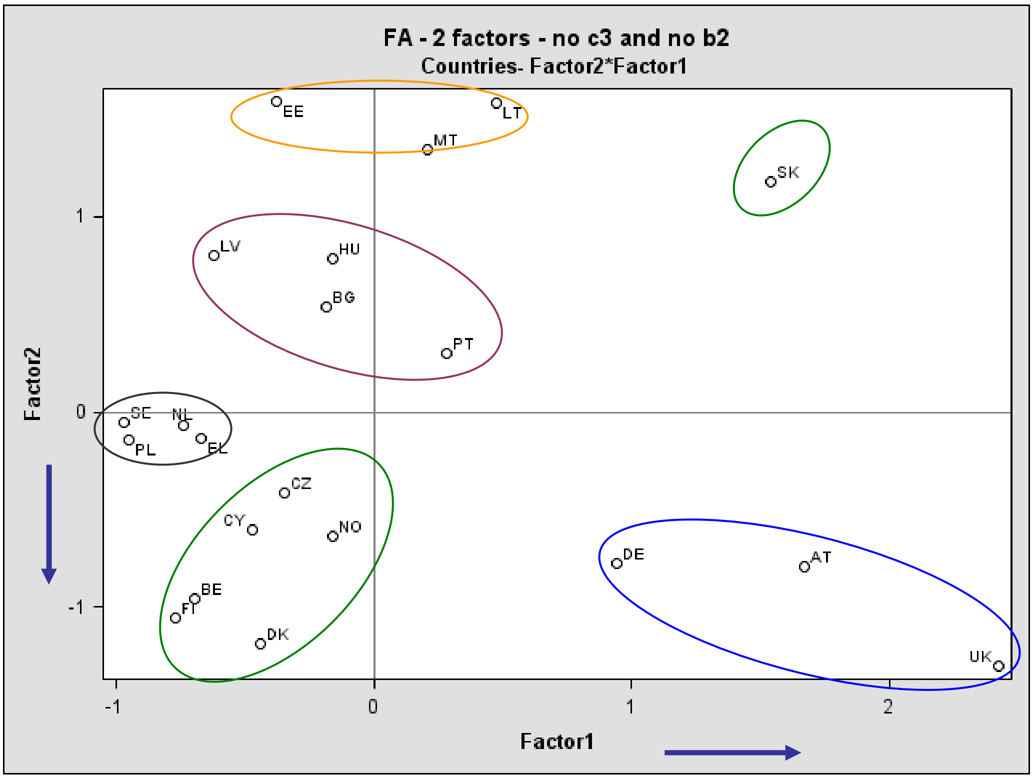

Figure 3.5. Countries plotted versus factor 1' and factor 2' values (FA_9' analysis). Note: arrows indicate preferable values of factors.

3.3.4 Discussion

The country groups received by the three analyses and final country's ranking based on these results are presented in Table 3.5.

It can be seen from Table 3.5 that the results of different analyses are consistent as to the recognition of countries with high or low level of the TM systems' performance, where grouping of countries with intermediate levels of the system's performance changes among the trials. This means that the definition of intermediate levels of the system's performance is sensitive to the set of basic SPIs, which are involved in countries' estimation and grouping.

Comparing the results of current analyses, which used statistical weighting techniques, with those received by means of multiple ranking (see Table 3.1), we can note that, in general, current results look more favourable. For example, in the current results, a number of countries, e.g. MT, FI, UK, significantly improved their final positions, where a few countries (e.g. BG, CZ, NO) moved from a "relatively high" to "medium" level group but still belong to the intermediate level of the system's performance (i.e. the change is not drastic). These positive changes may be associated with the data imputations performed prior to the analyses, where missing data for the countries were accomplished accounting for the available indicator values and the indicator interrelations observed in the whole set. Therefore, for countries having good values of some indicators similarly good values of missing indicators were restored.

Such a positive change is especially evident in the case of United Kingdom, where missing values of five SPIs were accomplished in such a manner that the country clearly moved to the top position in terms of the TM system's performance. Another case to be mentioned is the case of Portugal, for which 15 out of 17 basic SPIs were missing and, consequently, were restored based on typical relationships between the indicators. As a result, the country received a stable position in the middle of the list.

Country	Groups based on PCA_15	Groups based on FA_11	Groups based on FA_9	Final groups	Level of the TM system's performance
UK	1	1	1	1	High
DE	1	1	1	1	High
AT	2	1	1	1	High
SK	2	2	2a	2	Relatively high
MT	2a	2	4	3	Medium
FI	3	3	2	3	Medium
DK	3	3	2	3	Medium
SE	3	5	5	4	Relatively low
BE	3	3	2	3	Medium
NO	3	3	2	3	Medium
CY	3	3	2	3	Medium
HU	3	2	3	3	Medium
CZ	3	3	2	3	Medium
PT	3	2	3	3	Medium
LV	4	2	3	3	Medium
EE	4	2	4	3	Medium
BG	4	2	3	3	Medium
LT	4	2	4	3	Medium
NL	5	5	5	5	Low
EL	5	5	5	5	Low
PL	5	5	5	5	Low

Table 3.5. Country groups in accordance with the trauma management systems' performance: results of three analyses and final ranking.

Examining the results we can conclude that the statistical analysis enabled us to identify several groups of countries with similar levels of the TM system's performance. At the same time, contrary to the expectations, we did not arrive at a composite indicator which would be applicable for a meaningful classification of countries in accordance with the level of the TM system's performance. Applying the tools developed by each analysis we preferred to deal with separate factors created and not to weight them together because such weighting would bring us to a less clear picture of the results. Nevertheless, the factors created were useful both for recognizing similarities in basic indicators' behaviour and for defining each country's position in comparison with other countries.

Another important finding of the current step is that the analyses performed enable the recognition, among the list of basic SPIs, of those items which are more essential for the characteristic of the TM system's performance. According to the results of several analyses, the least consistent basic SPIs are "percentage of MICU out of the total transportation units" and "percentage of beds in certified trauma centres and trauma departments of hospitals". An additional list of basic SPIs, which behave differently from the rest of TM SPIs, includes: "EMS stations per 10000 citizens", "EMS stations per 100 km of rural road length", "percentage of EMS stations with at least one physician", "EMS medical staff per 10000 citizens", "share of physicians out of EMS staff" and "EMS transportation units per 1000 km^2". However, it should be mentioned that the specific behaviours of these indicators was critical for one type of analysis only (factor analysis) but did not prevent their participation in another type of analysis (principle component analysis).

Finally, we can name a list of nine TM SPIs which played an essential role in all the analyses performed and can, therefore, be considered as a core set of the TM SPIs. They are:

- The number of EMS stations per area,
- The number of EMS transportation units per road length,
- The number of EMS transportation units per citizens,
- Percentage of physicians and paramedics out of the total EMS staff,
- Percentage of highly-equipped transportation units out of the total,
- The demand for response time,
- Average response time of EMS,
- Percentage of EMS responses meeting the demand,
- The number of trauma care beds per citizens.

It is suggested that the nine remaining indicators may provide a concise but reasonable characteristic of the TM system in the country as they reflect both the availability and quality issues of the emergency medical services along with the characteristics of response time and the availability of permanent medical facilities.

4 Case-studies with trauma management SPIs

4.1 General

This chapter provides the results of two case-studies which considered additional applications of the TM SPIs developed. In the first case-study, safety performance indicators of regional trauma management systems were considered. The TM questionnaire was distributed in the federal states of Germany, where the minimum dataset for estimating TM SPIs (as introduced in Sec 1.3) was requested. The data collected enabled the consideration of the SPIs of regional trauma management systems, including a valuable comparison of the range of values in densely populated versus scarcely populated areas.

In the second case-study, the set of TM SPIs developed was applied for estimating the TM system's performance in a new country - Israel. Based on the trauma management questionnaire, a minimum set of TM data was collected and basic TM SPIs were, consequently, estimated. The level of TM system's performance in Israel was compared with other countries using the results of two approaches developed for providing a combined estimate, i.e. multiple ranking (as presented in Sec.3.2) and statistical weighting (as presented in Sec.3.3).

4.2 Consideration of trauma management SPIs on the regional level: federal states of Germany

4.2.1 The data collected and SPIs estimated

In January 2008 a questionnaire survey was started in the 16 federal states of Germany. The objective of the survey was to collect the minimum set of data for the characteristic of TM system's performance in differently populated areas. The 16 state ministries (Ministries of the interior, Ministries for social affairs) which are responsible for the EMS were contacted and asked to fill in a one-page questionnaire by the end of February 2008. (The questionnaire was identical to that distributed to national experts of countries, i.e. included all the items as presented in Table 1.1 plus item *2a* "of EMS stations those with at least one physician".)

The questionnaire was translated into German. The original questionnaire (English version) was created using international definitions. Some of these definitions (e.g. “trauma center”, “BLSU”, “MICU”) are not prevalent in Germany. Therefore, adequate German translations had to be found. This might have caused slight differences in the original and translated version of the questionnaire.

Of the 16 federal states, 13 states are regional ones, i.e. these states comprise urban and rural regions and differ in size between 2570 km^2 and 70553 km^2. Three states are city states, i.e. these states are represented by one big city and its surrounding; the area of the city states is between 404 km^2 and 889 km^2.

By mid-March 13 federal states had responded. One of the responses was not applicable as the questionnaire supplied contained the information on air rescue (helicopters) only, with regard to items *2a*-*7e*, where all other questions were not answered.

The data of the 12 federal states showed some deficiencies with regard to their availability and comparability as detailed below.

a. ***The availability of data**:* In most federal states the data are not available as a state statistic. In each federal state (regional states), the EMS is divided into several areas/regions (Rettungsdienstbereiche), where each region is more or less autonomous for the implementation, management, and performance of the EMS. Therefore, representative data are available on a regional level only. To gain an overview on a state level, the ministries had to contact the responsible persons in the EMS regions. This process was time consuming and did not always lead to success. In some federal states the different EMS regions differ very much in regard of size, population density, landscape etc. Therefore, comparisons between these regions are problematic. In some federal states these differences become evident, e.g. in graduated legal demands for response time (different demands for urban and rural areas). It was stated by some ministries, that they do not favour the aggregation of regional data to a state statistic. In consequence, the responded data revealed many missing values.

b. ***Comparability of data:*** It became apparent that some of the questions are not precise enough to get comparable data. For example, concerning the *number of EMS staff in service* (items *4a-4f),* some of the responders commented that their data refers only to full-time (main job) personal; others stated that the information includes persons working in an honorary capacity, aside job and main job. Most of the responders did not comment on this, so it is unclear which reference is used. Furthermore, there is a difference between the “availability” of physicians and permanent posts, because there are many more (accessible) emergency doctors than permanent EMS posts, where the reference is seldom specified in the responses received.

Another example concerns the *number of trauma beds in permanent medical facilities* (items *22a-22d*). As mentioned before, the term “trauma center” is not prevalent in Germany. Therefore the term “trauma center” was translated into “Krankenhäuser der Maximalversorgung” (i.e. hospitals with maximal care, level 4 hospitals), a common German term which is almost identically defined in all federal states. In regard to the level 1-3 hospitals (level 1 hospitals = “Grundversorgung”, level 2 hospitals = “Regelversorgung”, level 3 hospitals = “Schwerpunktversorgung”) there are slight differences in the definitions between the federal states. One major problem is that some federal states do not distinguish between “department of surgery” and “department of accident surgery” (=“trauma department”). Therefore, the responded values of item *22b* are not comparable.

The aforementioned restrictions in the data collected limited the possibilities of comparison between federal states. Moreover, BASt was not authorized to forward the data of single states to the SafetyNet team. Therefore, it was decided to present the estimation results synoptically. Furthermore, to be able to draw comparisons between densely and scarcely populated federal states, the data and estimates of regional states and city states are presented separately.

Considering the estimation results it has to be taken into account that the data of the regional states includes rural and urban areas and that density of population differs in and between federal states significantly. Furthermore, the size of the regional states differs considerably and that resulted in wide ranges of both TM data and SPIs estimated.

The TM data collected for federal states are presented in Table 4.1. Based on these primary data trauma management SPIs were calculated as presented in Table 4.2. Comments to Tables 4.1-4.2:

1) Regional states are: Baden-Württemberg, Freistaat Bayern, Brandenburg, Hessen, Niedersachsen, Rheinland-Pfalz, Saarland, Sachsen-Anhalt, Schleswig-Holstein, Freistaat Thüringen.

2) City states: Bremen, Hamburg.

Data items	Regional states	City states
Population (A)	1,043,167 – 12,443,893	663,979 – 1,743,627
Area	2570 – 70,553 km²	404 – 755 km²
Density of Population	87 – 406 persons/km²	1,644 – 2,309 persons/km²
Road length - total (B)	6,612 – 219,500 km *	1,785 – 3,956 km
Road length - public, outside build-up areas (C)	2,041 – 146,200 km **	0 km
No of dispatching centers (1)	1 – 46	1 – 2
No of EMS stations (2a)	29 – 394	22 – 31
Of EMS stations those with at least one physician	14 – 217 ***	6 – 8
No of physicians (4a)	640 – 2,379 ****	224 ***
No of paramedics (4b)	215 – 2,858 **	456 – 1733
No of nurses (4c)	0 – 9 *****	0
No of medical technicians (4d)	25 – 2,660 **	114 – 201
Total (including others) (4f)	240 – 6,553 *****	657 – 2071
No of BLSU (7a)	0 – 224 *	0 – 8
No of MICU (7b)	8 – 448 **	28 – 100
No of helicopters/planes (7d)	1 – 12	1 – 2
Total (including others) (7e)	118 – 924 *	37 – 120
The demand for EMS time (19)	10 – 15 min. (sparsely populated areas: 17)	8 – 10 min.
Percentage of EMS responses meeting the demand (20)	85 – 95,4 % **	84,2 – 87 %
Average response time of EMS (21)	8,1 – 9,5 min.******	6 – 6,4 min.
Number of trauma beds in certified trauma centers (22a)	298 – 15,263 ***	*
Number of trauma beds in trauma departments of hospitals (22b)	30 – 31,746 ***	218 ***
Total (including others) (22d)	5.969 – 74,968 ***	5,648 ***

* Data from two federal states is missing.
** Data from three federal states is missing.
*** Data from one federal state is missing.
**** Data from five federal states is missing.
***** Data from four federal states is missing.
****** Data from six federal states is missing.

Table 4.1. Data on trauma management collected for federal states.

SPI	Regional states	City states	Regional states' SPI versus the EU countries' SPI *(ranks[#])*
EMS stations per 10,000 citizens (3a)	0.27-0.72	0.18-0.33	High *(1-2)*
EMS stations per 100 km of rural road length (3b)	0.23 – 1.91 *	not relevant	High-medium *(1-3)*
Percentage of physicians out of EMS staff (5a)	22.1% – 40.1% ***	10.8% ****	High *(1-2)*
Percentage of physicians + paramedics out of EMS staff (5)	69.4% – 84.1% ***	94.5% ****	High *(1)*
EMS medical staff per 10,000 citizens (6)	2.30 – 11.27 *****	9.89 – 11.88	Wide range, from high to medium-low *(1-4)*
Percentage of MICU out of the total EMS units (8b)	3.0% – 98.9% *	75.7% – 83.3%	Wide range, from high to low *(1-4)*
Percentage of BLSU + MICU + Helicopters/ planes out of the total EMS units (8)	40.3% – 100% *****	85.0% – 100%	Wide range, from high to low *(1-3)*
EMS transportation units per 10,000 citizens (9)	0.75-1.20 **	0.56-0.69	High-medium *(2-3)*
EMS transportation units per 100 km of road length (11)	1.59 – 4.14 *	2.07 – 3.03	High *(1)*
The demand for EMS response time (19)	10 – 15 min. (sparsely populated areas: 17)	8 – 10 min.	High *(1)*
Percentage of EMS responses meeting the demand (20)	85% – 95.4% **	84.2% – 87%	Relatively high *(2)*
Average response time of EMS (21)	8.1 – 9.5 min. ******	6 – 6,4 min.	High *(1)*
Percentage of beds in certified trauma centres and trauma departments of hospitals out of the total number of trauma beds (24a)	8.0% – 98.3% ****	n/a **	Wide range, from high to low *(1-3)*
Number of the total trauma care beds per 10000 citizens (25)	23.5-70.3	85.1 ****	High *(about 1)*
Percentage of EMS stations with at least one physician (2b)	28.4%-65.8% ****	25.8%-27.3%	Medium *(3-4)*
EMS stations per 1000 km^2 of area (3c)	4.68-11.32	41.1-54.5	High *(1)*
EMS transportation units per 1000 km^2 of area (11c)	10.5-45.9 **	91.6-158.9	High *(1-2)*

* Data from three federal states is missing.
** Data from two federal states is missing.
*** Data from five federal states is missing.
**** Data from one federal state is missing.
***** Data from four federal states is missing.
[#]Federal states are characterized by the SPI level which is similar to the ranks which were defined when the EU countries were ranked in accordance with values of this SPI. – see Sec.4.2.2.

Table 4.2. Trauma management SPIs estimated for federal states.

4.2.2 Discussion of results

The estimation of the TM SPIs revealed that the medical health care (the availability and quality of EMS and permanent medical facilities) differs between regional states, and between regional and city states. The differences observed between the regional states may stem from various reasons such as population density, economic situation of a state, political aspects and others.

Comparing the regional and city states, the SPI values showed slightly better results for the city states. A better medical health care in city states (and urban areas) is not surprising because:

- In urban areas, there are shorter access routes from the EMS stations to the scene of accident and from the scene of accident to the hospital.
- Most trauma centers and hospitals are located in (big) cities. The same holds true for emergency physicians (who are often employed in hospitals).

In addition, in Germany, over the last years changes in the financing of the health care system (e.g. implementation of Diagnosis Related Groups) took place. These changes initiated a process of restructuring hospital care, among others by closing smaller hospitals in favour of higher level hospitals. In consequence, the hospital density is reduced in some areas, especially in rural areas.

The results illustrate that the acquisition of data with regard to the quality of the EMS and the health care in permanent medical facilities in Germany is closely related to the particular conditions in the federal states. Differences in definitions of major medical and infrastructural terms, legislation, population density, organizational and political characteristics and so on, render it difficult to compare the quality of the EMS between federal states. Even within one federal state there are varying conditions that prevent direct comparison between two or more regions. Therefore, detailed quality assessment has always to take into account the particularities of a state or region.

Finally, it was interesting to compare the TM SPI values estimated for federal states with corresponding values estimated for the EU countries. The comparison was made by each SPI, where the range of values obtained for the regional states was compared with the ranges of values attributed to various ranks of this SPI, when the combined indicators were produced for the countries (see Sec.3.2.2, Method B of ranking). For example, during the countries' ranking by *3a*-values ("EMS stations per 10,000 citizens"), the following ranks were defined: "1" (high) when the country value is over 0.42; "2" (relatively high) when the country value lies between 0.24-0.42; "3" (medium) when the country value lies between 0.18-0.24; "4" (relatively low") when the country value lies between 0.08-0.18; and "5" (low) when the country value is below 0.08. The range of values for this SPI, estimated for the regional states was 0.27-0.72. Therefore, the regional states belong to "1-2" ranks of this SPI and, in general, the number of EMS stations per 10,000 citizens, in the regional states, can be considered as "high".

Following this line, the TM SPIs of the regional states were characterized in terms of belonging to a certain rank/ ranks defined for the EU countries – see right column in Table 4.2. One can note that in the majority of cases (10 out of 17 SPIs), the federal states are characterized by a high level of the TM SPIs in comparison with the ranges observed for the EU countries. The regional SPIs were found to be high for: the number of EMS stations per citizens and per area; the percentage of physicians and paramedics out of the EMS staff; the number of EMS transportation units per road length and per area; and the characteristics of the EMS response time.

4.3 Estimating trauma management SPIs for an additional country: Israel

In this case-study we dealt with the task of estimating trauma management SPIs for a new country - Israel, which was not previously involved in country comparisons. The task included TM data collection by means of the pre-defined form, estimating TM SPIs and judging the country TM system's performance in comparison with other countries.

The questionnaire used for data collection was similar to that distributed to national experts of countries, i.e. included all the items as presented in Table 1.1. The data were collected by means of direct contacts with representatives of EMS, Ministry of Health, National Trauma Council, etc. The data collected on trauma management in Israel, for year 2007, are presented in Table 4.3.

General information

A	Population, thousands	7116.7
B	Road length - total, km	17686
C	Road length - public, outside built-up areas, km	6260+1594

Data on TM

1	No of dispatching centers	11
2	No of EMS stations	108
4a	Number of EMS staff in service: No of physicians	70
4b	No of paramedics	437
4c	No of nurses	0
4d	No of medical technicians	650
4f	Total (including others)	1439
7a	Number of EMS transportation units in service: No of BLSU	400
7b	No of MICU	170
7d	No of helicopters/ planes	2
7e	Total (including others)	572
19	The demand for EMS response time, min	10-15
20	Percentage of EMS responses meeting the demand	n/a
21	Average response time of EMS, min	n/a*
22a	Number of trauma beds in permanent medical facilities: In certified trauma centres	n/a
22b	In trauma department of hospitals	n/a
22d	Total (including others)	n/a
	Comments	* There are differences among regions

Table 4.3. Data on trauma management collected for Israel, year 2007.

Based on the data collected, the TM SPIs were estimated as presented in Table 4.4. Following, the level of the TM system's performance in Israel was compared with other countries. The comparison was done in two ways. First, for each SPI, the value estimated for Israel was compared with the ranges of values attributed to various ranks of this SPI (which were received when the combined indicators were produced for the countries - see Method B in Sec.3.2.2; this approach is similar to that used for judging the SPI values of German regional states in the previous Section). Results of this consideration are given in the right column of Table 4.4.

SPI	**Value**	**Israeli value versus the EU countries' SPIs** *(rank#)*
(3a) EMS stations per 10000 citizens	0.15	Relatively low *(4)*
(3b) EMS stations per 100 km of rural road length	1.38	High *(1)*
(5a) Percentage of physicians out of EMS staff	4.9%	Relatively low *(4)*
(5) Percentage of physicians + paramedics out of EMS staff	35.2%	Relatively high *(2)*
(6) EMS medical staff per 10000 citizens	2.02	Relatively low *(4)*
(8b) Percentage of MICU out of the total EMS units	29.7%	Relatively high *(2)*
(8) Percentage of BLSU + MICU + Helicopters/ planes out of the total EMS units	100%	High *(1)*
(9) EMS transportation units per 10000 citizens	0.80	Medium *(3)*
(11) EMS transportation units per 100 km of road length	3.23	High *(1)*
(19) The demand for EMS response time, min	10-15 min	High *(1)*
(20) Percentage of EMS responses meeting the demand	n/a	--
(21) Average response time of EMS, min	n/a	--
(24a) Percentage of beds in certified trauma centres and trauma departments of hospitals out of the total number of trauma beds	n/a	--
(25) Number of the total trauma care beds per 10000 citizens	n/a	--
(3c) EMS stations per 1000 km^2	4.99	High *(1)*
(11c) EMS transportation units per 1000 km^2	26.43	High *(1)*

#SPI value for Israel belongs to this rank which was defined in the EU countries' ranking in accordance with the values of this SPI.

Table 4.4. Trauma management SPIs estimated for Israel, year 2007, and results of their comparisons with other countries.

As can be seen from Table 4.4, the majority of Israeli TM SPIs are "high" or "relatively high" in terms of ranks defined based on the SPI values for the European countries. Israeli SPIs are especially high in comparison with the values observed for the EU countries, when the number of EMS stations and the number of EMS transportation units are considered *per road length*. One of the reasons for this can be in relatively short length of Israeli road network in comparison with other countries. At the same time, the number of EMS stations and the number of EMS transportation units *per area* are also high in Israel and comparable with the best values of the EU countries. Therefore, in general, a high level of coverage by the EMS stations and transportation units can be stated for Israel (although, it is an average figure only).

Moreover, Israeli EMS are characterized by relatively high share of higher-qualified staff (physicians and paramedics) and by high share of properly-equipped EMS transportation units. At the same time, the number of EMS stations and EMS staff per 10,000 citizens are relatively low in comparison with other countries, whereas the number of EMS transportation units per citizens is medium.

The demand for the EMS response time in Israel is high; however, no information is available concerning the actual time values of the initial treatment by EMS.

In general, the EMS level (EMS availability and quality) in Israel can be classified as *relatively high*, in terms of the groups which were defined for the EU countries.

The second method of comparison of Israeli SPIs with other countries used the results of statistical weighting technique – the two factors' solution fitted to the data when a factor analysis of TM SPIs was performed (results of FA_9 trial, see Sec. 3.3.3). In this case, first, data imputations of missing Israeli data were performed and, then, using the tools produced by the factor analysis (FA_9 trial), the factor scores were estimated for Israel. The values estimated for Israel were: factor 1= 1.306; factor 2 = -0.498.

A comparison of factor scores for Israel with scores of other countries (see App.B) reveals that both factor scores (positive value of factor 1 and negative value of factor 2) ascribe Israel to the group of countries with the best characteristics of the TM systems' performance. This can be seen easily when the countries' position are plotted against the factor values – Figure 4.1.

One can note that the result of the second method of comparison of Israeli SPIs with other countries (using factor scores) is better than that of the first method (using attributed ranks). A reason for this "improvement" probably lies in the data imputations performed: based on relatively high values of the SPIs reported, similarly good values were restored for the missing SPIs.

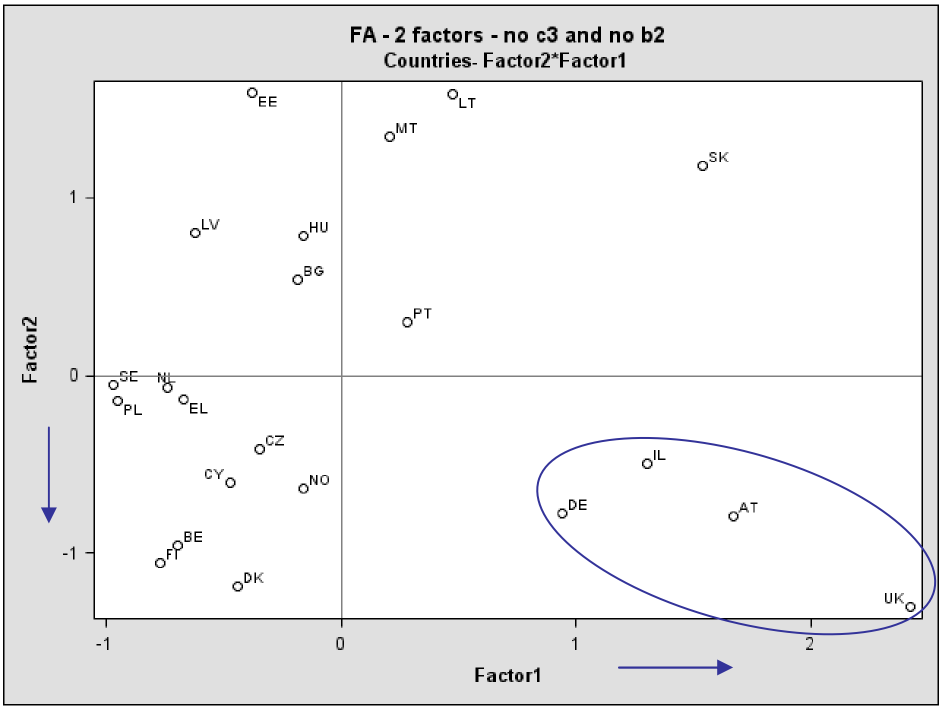

Figure 4.1. Israel and other countries plotted versus factor 1' and factor 2' values (FA_9 analysis). Note: arrows indicate preferable values of factors.

5 Summary and conclusions

The report published in 2007 (Hakkert et al, 2007) provided details about the theory behind the development of safety performance indicators (SPIs) in seven predefined road safety domains, including trauma management. The current report presents an update to the basic SPIs Theory report: it provides the findings of the research activities which were undertaken for further development of the trauma management SPIs, during the last period of the SafetyNet project.

Trauma Management (TM) covers two types of medical treatment: the initial medical treatment provided by Emergency Medical Services (EMS), at the scene of accident and during the transportation to a permanent medical facility, and further medical treatment provided by permanent medical facilities (hospitals, trauma centres). To reduce the severity and the number of road crash victims, the TM system should provide rapid and adequate initial care of injury, combined with sufficient further treatment at a hospital or trauma centre. Thus, trauma management SPIs should estimate the speed and the quality of the post-crash care, both initial and further, in the country.

Accounting for the limitations of data available in the countries, a minimum set of TM SPIs was introduced for the characteristic of the TM system's performance. The set of TM SPIs includes:

Availability of EMS stations

- the number of EMS stations per 10,000 population and per 100 km length of rural public roads

Availability and composition of EMS medical staff

- percentage of physicians and paramedics out of the total number of EMS staff
- the number of EMS staff per 10,000 population

Availability and composition of EMS transportation units

- percentage of Basic Life Support Units, Mobile Intensive Care Units and helicopters/planes out of the total number of EMS transportation units
- the number of EMS transportation units per 10,000 population
- the number of EMS transportation units per 100 km of total public road length

Characteristics of the EMS response time

- the demand for an EMS response time (min)
- percentage of EMS responses meeting the demand
- average response time of the EMS (min)

Availability of trauma beds in permanent medical facilities

- percentage of beds in trauma centres and trauma departments of hospitals out of the total trauma care beds
- the number of total trauma care beds per 10,000 citizens

Furthermore, a combined indicator was suggested which is built by means of multiple ranking of separate SPIs (Hakkert et al, 2007).

To estimate the TM SPIs, a data set is requested for each country, which includes: total number of EMS stations; number of EMS staff in service, according to categories; number of EMS transportation units in service, according to categories; the demand for a response time, min; percentage of EMS responses which meet the demands for response time; average response time of EMS, min; total number of beds in permanent medical facilities, according to categories. In addition, the estimation of TM SPIs requires for general information for the country, on population size, total road length and road length outside built-up areas.

In the process of the development of TM SPIs (Hakkert et al ,2007), the potential of trauma registries and other medical databases for providing better insight into the actual TM system's performance was indicated. In the last step of the project, a literature study was undertaken to check recent publications on issues concerning application of trauma registry and other medical databases for exploring road safety injury. Studies of road safety injuries using medical databases were found for France, the Netherlands, Israel, Italy and Sweden.

Summing up the findings, it was concluded that once a trauma registry or a similar database is maintained in the country, many in-depth traffic injury studies are usually carried out. Moreover, the information system based on hospital records can assist in providing corrected figures of the scope and characteristics of traffic injury in the country and in assessing the performance of the trauma care system and its components. At the same time, the national trauma registries are not common in the EU countries yet, leaving for the future the issues of application of trauma registries or similar databases for the estimation of TM SPIs.

During the last project year, a new questionnaire survey was arranged among the countries, which resulted in creating a dataset with TM SPIs for 21 countries. A number of analyses were carried out on this dataset: examination of new basic SPIs; an extensive analysis of the combined indicator built by multiple ranking (old form) and creating a composite indicator by means of statistical weighting (new form).

The new basic SPIs considered were: the percentage of EMS stations with at least one physician; the number of EMS stations per country's area and the number of EMS transportation units per country's area, where both "per area" indicators could serve as substitutes of relevant "per road length" indicators. However, the analysis of influence of the new indicators on country comparison results, both in separate and in the process of building combined SPIs, did not support their inclusion in the basic set of TM SPIs.

The analysis of the old form of combined TM indicator considered seven variants of building a combined estimate, which differed by ranking methods and by the sets of basic SPIs involved. The final estimates based on the seven trials enabled the countries to be attributed to five levels of the TM system's performance, which are: "high", "relatively high", "medium", "relatively low" or "low".

Neither single method of ranking was fully consistent with the final estimates based on the results of all the trials performed. Therefore, it is advisable, when the countries are compared by the level of the TM system's performance, to apply several ways of ranking for the estimation of the combined TM SPI.

A new way of creating a composite TM indicator, by means of statistical weighting - principle component analysis and common factor analysis, was explored. Three trials of creating the factors were performed. The results of trials were consistent as to the recognition of countries with high or low level of the TM systems' performance, where grouping of countries with intermediate levels of the system's performance changed among the trials. This means that the definition of intermediate levels of the system's performance is sensitive to the set of basic SPIs, which are involved in countries' estimation and grouping.

In general, the statistical weighting enabled us to identify several groups of countries with similar levels of the TM system's performance. At the same time, contrary to expectations, we did not arrive at a composite indicator which could be applicable for a meaningful classification of countries in accordance with the level of the TM system's performance. Applying the tools developed by each analysis we preferred to deal with separate factors created and not to weight them together because such weighting would bring us to a less clear picture of the results. Nevertheless, the factors created were useful both for recognizing similarities in basic indicators' behaviour and for definition of each country's position in comparison with other countries.

Another important finding of the statistical weighting was recognizing, among the list of basic SPIs, those items which are more essential for the characteristic of the TM system's performance. This core set of the TM SPIs includes:

- The number of EMS stations per area,
- The number of EMS transportation units per road length,
- The number of EMS transportation units per citizens,
- Percent of physicians and paramedics out of the total EMS staff,
- Percentage of highly-equipped transportation units out of the total,
- The demand for response time,
- Average response time of EMS,
- Percentage of EMS responses meeting the demand,
- The number of trauma care beds per citizens.

The core set of the TM SPIs provides a concise but reasonable characteristic of the TM system in the country as it reflects both the availability and quality issues of the emergency medical services along with the characteristics of response time and the availability of permanent medical facilities.

Two case studies demonstrated additional applications of the TM SPIs developed: for comparison of regional trauma management systems (in federal states in Germany) and for estimating the TM system's performance for a new country (on the example of Israel). To properly judge the TM SPI values estimated for federal states and for Israel, they were compared with corresponding values estimated for the EU countries. It was found that in the majority of cases (10 out of 17 SPIs), the federal states are characterized by high level of the TM SPIs in comparison with the ranges observed for the EU countries. Similarly, the SPI estimates obtained for Israel ascribe it to the group of countries with high level of the TM system's performance.

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Abridged Glossary

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 transportation 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.

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.

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.

Mobile intensive care unit (MICU): a unit with a medical doctor or paramedic 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.

EMS 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).

Trauma beds:

No common definition is available. Typically are considered

1) all beds in trauma centres/ trauma departments of hospitals;

2) beds in surgery departments of regular hospitals.

Trauma Centre:

No common definition is available. The minimum threshold of basic clinical capabilities to be provided by a trauma centre is as follows[1]:

[1] According to ETSC (1999)

In-house 24 hours a day:
Emergency Medicine
Anaesthesiology
General Surgery and any life saving surgery (such as urgent external fixation for pelvic fractures, vascular surgery)
Radiology: a mobile X-ray apparatus should be located in the resuscitation room and the other X-ray facilities such as CT-scan should located near the emergency department

On call promptly available:
ESSENTIAL:
Anesthesiology (2nd team)
General Surgery (2nd team)
Neurosurgery (2nd team)
Orthopaedic Surgery
Maxillo facial Surgery
Interventional Radiology

DESIRABLE :
Pediatric Surgery
Vascular Surgery
Urologic Surgery
Plastic Surgery
Thoracic surgery

Facilities and resources: available in-house 24 hours a day:
X-ray and Ultrasonography
CT-scan
Trauma operating room with staffed personnel
Clinical laboratory service
Blood bank with adequate storage facilities
Rehabilitation team for the acute trauma phase

The facilities and medical instruments for every clinical procedure must be recorded on dedicated checklists which are monitored every day by trained nursing staff overseen by the trauma coordinator.

Acknowledgement

The authors would like to thank the National Experts of the 29 cooperating countries (27 member states, Norway and Switzerland) for providing the data, multiple fruitful discussions and giving feedback on concept versions of the trauma management SPIs.

Appendix A Trauma management data collected for the countries and SPIs estimated

	Year	(1) No of dispatching centers	(2) No of EMS stations	(2a) with at least one physician	(2b) % with at least one physician	(3a) EMS stations per 10000 citizens	(3b) EMS stations per 100 km of rural road length	(4a) No of physicians	(4b) No of paramedics	(4c) No of nurses	(4d) No of medical technicians	(4f) Total
BE	2006	11	151	40	26.5%	0.14	0.10	1400	0	450	7500	9350
CZ	2006	14	191	n/a	n/a	0.19	0.49	558	0	1150	1983	3691
DK	2003	8	140	n/a	n/a	0.26	n/a	96	12	30	1800	1938
DE	2006	270	1832	n/a	39.4%	0.22	0.79	17000	22000	0	8800	53000
EE	2006	6	53	29	54.7%	0.39	0.10	194	52	685	405	1336
EL	2006	10	12	n/a	n/a	0.01	0.03	150	2000	0	0	2150
CY	2006	8	18	18	100.0%	0.23	0.22	62	0	180	0	326
LV	2006	40	42	42	100.0%	0.18	0.08	288	0	465	0	1675
LT	2006	1	61	61	100.0%	0.18	n/a	300	0	1300	0	1600
HU	2003	25	216	n/a	n/a	0.21	0.28	128	0	0	847	975
MT	2003	1	1	1	100.0%	0.03	n/a	36	0	30	0	66
NL	2003	24	51	n/a	n/a	0.03	0.08	0	0	1400	1240	2640
AT	2006	60	424	123	29.0%	0.51	n/a	2500	10000	0	30000	42500
PL	2006	130	211	211	100.0%	0.06	n/a	n/a	n/a	n/a	8021	8021
PT	2003	4	480	n/a	n/a	0.46	n/a	n/a	n/a	n/a	n/a	n/a
SK	2006	49	341	341	100.0%	0.63	n/a	818	0	1216	0	3822
FI	2006	15	250	6	2.4%	0.47	0.32	6	150	0	400	556
SE	2006	18	275	n/a	n/a	0.30	0.28	10	0	2000	2000	4010
UK	2003	37	979	n/a	n/a	0.17	0.39	0	17272	0	9630	26902
NO	2003	44	200	n/a	n/a	0.44	0.22	n/a	n/a	n/a	n/a	n/a
BG	2006	28	220	220	100.0%	0.29	0.54	1643	0	2585	0	7336

	(5a) physicians out of EMS staff	(5) physicians+ paramedics out of EMS staff	(6) EMS medical staff per 10000 citizens	(7a) No of BLSU	(7b) No of MICU	(7d) No of helicopter s/ planes	(7e) Total	Comments
BE	15.0%	15.0%	8.90	357	100	2	459	4a-4f of 2003
CZ	15.1%	15.1%	3.60	251	365	11	627	all TM data for 2003
DK	5.0%	5.6%	3.60	450	16	3	469	
DE	32.1%	73.6%	6.43	2673	3709	91	7600	TM data for 2003; 2b estimated as average btw states
EE	14.5%	18.4%	9.94	84	6	2	92	
EL	7.0%	n/a*	1.93	735	20	3	765	TM data for 2003; *for (5) 100% does not seem reliable
CY	19.0%	19.0%	4.18	41	41	1	83	
LV	17.2%	17.2%	7.34	0	239	2	241	(2a) assumed
LT	18.8%	18.8%	4.75	425	0	0	425	
HU	13.1%	13.1%	0.96	847	128	5	978	* (4a) physicians and paramedics together
MT	54.5%	54.5%	1.70	15	0	?	15	(2a) assumed;(7e) at least
NL	0.0%	0.0%	1.62	650	0	4	654	drivers
AT	5.9%	29.4%	51.32	2300	133	25	2458	
PL	n/a	n/a	2.10	900	500	21	1421	*(4f) at least
PT	n/a	n/a	n/a	n/a	31	2	n/a	
SK	21.4%	21.4%	7.09	190	4	6	376	(2a) assumed
FI	1.1%	28.1%	1.05	300	100	6	406	(7) is probably higher as each municipality (of 400) has EMS transport
SE	0.2%	0.2%	4.41	50	450	8	508	
UK	0.0%	64.2%	4.65	123	0	14	640	*(4d) ambulance support staff; EMS transport for West Yorkshire
NO	n/a	n/a	n/a	604	0	19	672	
BG	22.4%	22.4%	9.55	177	300	3	554	(2a) assumed

	Year	(8b) MICU out of the total	(8) BLSU+MICU+ helicopters/ planes out of the total	(9) EMS transportation units per 10000 citizens	(11) EMS transportation units per 100 km of road length	Population, mln	Road length - total, km	Road length- public, outside built-up areas, km	Comments
BE	2006	22%	100%	0.44	0.30	10.5	152256	149028	
CZ	2006	58%	100%	0.61	1.13	10.3	55510	38768	TM data of 2003
DK	2003	3%	100%	0.87	0.65	5.4	72074	n/a	
DE	2006	49%	85%	0.92	1.21	82.4	626981	231480	TM data of 2003
EE	2006	7%	100%	0.68	0.16	1.3	56850	53640	
EL	2006	3%	99%	0.69	n/a	11.1	n/a	41100	TM data of 2003
CY	2006	49%	100%	1.07	0.68	0.8	12280	8101	
LV	2006	99%	100%	1.06	0.41	2.3	59180	51599	
LT	2006	0%	100%	1.26	1.99	3.4	21345	n/a	
HU	2003	13%	100%	0.96	0.72	10.1	135555	76588	
MT	2003	0%	100%	0.39	0.67	0.4	2227	n/a	
NL	2003	0%	100%	0.40	0.56	16.3	117430	63280	
AT	2006	5%	100%	2.97	2.30	8.3	106962	n/a	
PL	2006	35%	100%	0.37	0.37	38.1	382615	n/a	
PT	2003	n/a	n/a	n/a	n/a	10.5	n/a	n/a	
SK	2006	1%	53%	0.70	2.11	5.4	17833	n/a	
FI	2006	25%	100%	0.77	0.09	5.3	453161	78161	In rural roads not included: 375000 km of private roads
SE	2006	89%	100%	0.56	0.24	9.1	210000	98000	
UK	2003	0%	21%	3.20	1.74	57.9	392321	249649	data for GB; *EMS transport data for West Yorkshire
NO	2003	0%	93%	1.47	0.73	4.6	91825	90663	
BG	2006	54%	87%	0.72	0.54	7.7	101659	40725	

	Year	(19) The demand for response time, min	(20) Percentage of EMS responses meeting the demand	(21) Average response time of EMS, min	Comments
BE	2006	15 min	100%*	6 min*	*based on local EMS service, region Antwerp; data of 2003
CZ	2006	15 min	89.2%	7.83 min*	* in Prague (1.2 mio); data of 2003
DK	2003	5-10 min*	100%	8.0 min**	*varies in counties; ** outside Copenhagen; in: 3-4 min
DE	2006	15 min*	91.5%**	8.1 min	* to be met in 95% of all cases; **est'd based on: p95:16.3 min
EE	2006	15 min*	64%	23 min	*30 minutes for 70% of responses to low priority calls; 15 minutes for 90% of responses to high priority calls; 10 minutes for 55% of responses to high priority calls
EL	2003	n/a	n/a (no demand)	15 min	
CY	2006	n/a	60% within 10 min	n/a	
LV	2006	25 min*	88%**	17 min***	*25 min ouside and 15 min inside built-up area; **96% inside built-up areas; ***6 min inside
LT	2006	20 min*	n/a	n/a	*20 min in rural, 10 min in urban areas
HU	2003	15 min*	72%**	12-20 min***	* no official demand ** range 61%-82%; *** in rural areas (8 min in capital)
MT	2003	n/a	n/a (no demand)	15-30 min	
NL	2003	15 min*	n/a	n/a	*internal standard: up to 15 min in 95% of cases
AT	2006	15 min	95%	n/a	*internal standard: up to 15 min in 95% of cases
PL	2006	15 min*	90%	n/a	*8 min in urban areas, 15 min in rural areas
PT	2003	n/a	n/a	n/a	
SK	2006	15 min	n/a	n/a	
FI	2006	n/a	n/a	n/a	
SE	2006	90%	n/a	10-15 min	different rules for northern vs southern regions
UK	2003	8 min for 75%*	100%**	n/a	*of Cat A; 14/19 min for 95% of Cat B, C; because 75.7% of Cat A get a response within 8 min
NO	2003	n/a*	app. 90%	n/a	*Standards defined for urban areas and non-urban areas
BG	2006	n/a	n/a	15 min	

	Year	(22a) In certified trauma centres	(22b) In trauma department of hospitals	(22d) Total	(24a) % of beds in certified trauma centres and trauma departments of hospitals	(25) Number of trauma care beds per 10000 citizens	Population, mln	Comments
BE	2006	0	722	722	100%	0.69	10.5	
CZ	2006	850	9842	10692	100%	10.41	10.3	TM data are for 2003
DK	2003	n/a	n/a	n/a	n/a	n/a	5.4	
DE	2006	n/a	n/a	510767	n/a	61.96	82.4	
EE	2006	0	296	310	95%	2.31	1.3	*85 beds for trauma; 211 beds for orthopedics; 14 beds for children trauma and orthopedics
EL	2003	0	0	51500	0%	46.19	11.1	TM data are for 2003
CY	2006	0	0	100	0%	1.28	0.8	
LV	2006	n/a	n/a	n/a	n/a	n/a	2.3	
LT	2006	n/a	n/a	n/a	n/a	n/a	3.4	
HU	2003	n/a	n/a	3391	n/a	3.34	10.1	
MT	2003	0	16	16	100%	0.41	0.4	
NL	2003	n/a	n/a	n/a	n/a	n/a	16.3	
AT	2006	771	3874	65035	7%	78.53	8.3	
PL	2006	0	2140	2140	100%	0.56	38.1	
PT	2003	n/a	n/a	n/a	n/a	n/a	10.5	
SK	2006	0	904	904	100%	1.68	5.4	
FI	2006	n/a	n/a	n/a	n/a	n/a	5.3	
SE	2006	0	n/a	n/a	n/a	n/a	9.1	*emergency care is integrated with other e.g. surgery departments; no trauma dep's are defined
UK	2003	n/a	n/a	n/a	n/a	n/a	57.9	data for GB
NO	2003	n/a	n/a	n/a	n/a	n/a	4.6	
BG	2006	728	111	839	100%	1.09	7.7	*(22d) at least

Appendix B Development of a composite indicator by means of statistical weighting: detailed results

B.1 PCA_15 analysis

Rotated Factor Pattern

variable	*Factor1*	*Factor2*	*Factor3*
a9	**0.80936**	-0.00565	0.07632
c1	**0.71332**	-0.02495	0.26280
b3	**0.66267**	-0.13432	-0.03541
a6	**-0.53361**	0.44569	0.24807
a8	**-0.68955**	-0.14580	0.22829
a11	**-0.81180**	0.19117	0.23120
a2	0.11234	**0.85708**	0.06127
c2	-0.15178	**0.74990**	0.32386
a7	-0.09848	**0.73649**	0.32246
a1	-0.10390	**0.72598**	-0.44725
a4	0.33138	**0.48496**	-0.21550
a5	0.24952	**-0.66059**	-0.24285
c3	-0.05695	0.08477	**0.88119**
a3	-0.16490	0.36710	**0.74842**
b1	0.63652	0.03870	**0.64791**

Country Scores

Obs	*Country*	*Code*	*Factor1*	*Factor2*	*Factor3*	*WF*
1	Austria	AT	0.49132	4.36118	-1.65113	1.31761
2	Belgium	BE	-0.38843	-0.38478	-0.16823	-0.32973
3	Bulgaria	BG	1.06948	0.53499	-0.28323	0.52568
4	Cyprus	CY	0.01060	-0.49004	0.17793	-0.12492
5	Czech Republic	CZ	-0.00427	-0.15922	-0.09390	-0.08307
6	Denmark	DK	-1.11092	-0.39901	-0.34875	-0.65755
7	Estonia	EE	1.24178	0.23045	-1.19757	0.24416
8	Finland	FI	-1.33669	-0.46931	-0.96402	-0.92920
9	Germany	DE	-0.44961	0.81534	1.55297	0.52492
10	Greece	EL	-0.24060	-1.32994	0.07749	-0.54747
11	Hungary	HU	0.26399	-0.36510	-0.25688	-0.09685
12	Latvia	LV	1.29017	-0.51620	-0.30934	0.22696
13	Lithuania	LT	1.32288	0.18439	0.02127	0.57628
14	Malta	MT	1.50786	-0.86194	3.07492	1.06834
15	Norway	NO	-0.50945	0.05420	-0.54260	-0.31641
16	Poland	PL	0.31628	-1.19335	0.07330	-0.28720
17	Portugal	PT	-0.12501	0.58383	-0.65248	-0.00885
18	Slovakia	SK	1.20598	3.00225	-0.50467	1.40286
19	Sweden	SE	-0.26420	-0.45927	-1.41061	-0.63278
20	The Netherlands	NL	-0.38177	-1.13836	-0.21363	-0.60866
21	United Kingdom	UK	-1.98669	1.17448	1.36812	0.01875

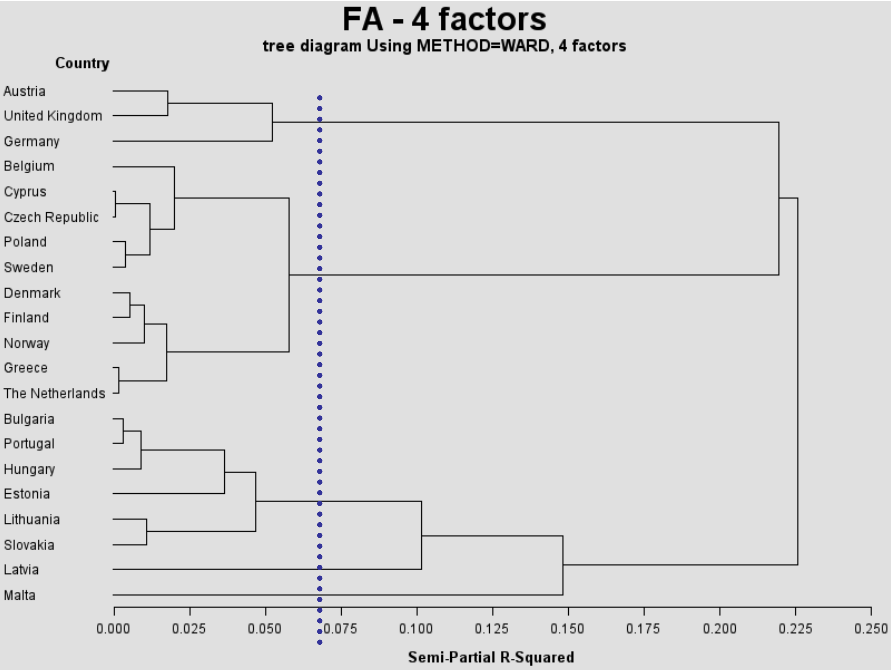
B.2 FA_11 analysis

Rotated Factor Pattern

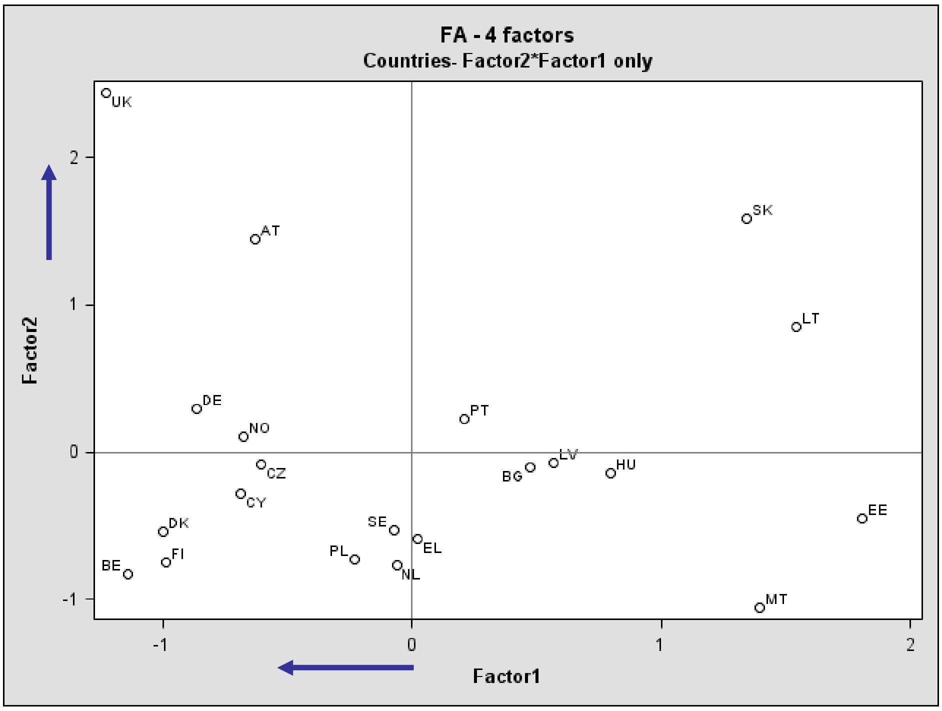
variable	*Factor1*	*Factor2*	*Factor3*	*Factor4*
a9	**0.89943**	-0.08401	0.04695	-0.01389
a11	**-0.54289**	0.33843	0.26063	-0.29857
a8	**-0.82380**	0.05022	0.09221	0.04234
a7	0.07091	**0.77790**	0.28054	-0.08111
a6	-0.29268	**0.71967**	0.14998	-0.12519
a5	0.11213	**-0.69820**	-0.14290	0.18922
c3	0.01197	0.11726	**0.80108**	-0.15228
a3	-0.13989	0.38298	**0.62804**	-0.04692
c2	-0.09637	0.48164	**0.51634**	-0.09980
b2	-0.11707	-0.19946	-0.18986	**0.69428**
b3	0.51347	-0.10912	-0.01131	**0.60021**

Country Scores

Obs	*Country*	*Code*	*Factor1*	*Factor2*	*Factor3*	*Factor4*	*WF*
1	Austria	AT	-0.63089	1.44450	1.09520	-0.20104	0.46760
2	Belgium	BE	-1.13805	-0.82491	0.34673	0.38827	-0.48431
3	Bulgaria	BG	0.47609	-0.10213	-0.23733	0.32238	0.11343
4	Cyprus	CY	-0.68618	-0.27974	-0.22310	0.58909	-0.26700
5	Czech Republic	CZ	-0.60266	-0.08589	-0.37359	0.70858	-0.19543
6	Denmark	DK	-0.99860	-0.54376	-0.25804	-1.25905	-0.72997
7	Estonia	EE	1.80851	-0.44872	-0.54865	-0.88367	0.17800
8	Finland	FI	-0.98624	-0.74709	-0.49894	-0.49705	-0.73059
9	Germany	DE	-0.86189	0.29728	1.67458	0.62157	0.28459
10	Greece	EL	0.02138	-0.58690	-0.38299	-0.36814	-0.31706
11	Hungary	HU	0.79930	-0.14611	-0.30488	-0.40859	0.07855
12	Latvia	LV	0.56864	-0.07828	-0.38665	2.49364	0.43843
13	Lithuania	LT	1.54248	0.84614	-0.55949	0.22367	0.66215
14	Malta	MT	1.39836	-1.05738	2.60714	-0.40453	0.62839
15	Norway	NO	-0.67257	0.10137	-0.76971	-0.50473	-0.42619
16	Poland	PL	-0.23186	-0.73054	-0.64188	0.17556	-0.41916
17	Portugal	PT	0.21033	0.21983	0.22075	0.27598	0.22534
18	Slovakia	SK	1.34367	1.58430	0.08085	-0.38364	0.88336
19	Sweden	SE	-0.07016	-0.53134	-0.97856	0.72501	-0.29887
20	The Netherlands	NL	-0.06226	-0.76865	-0.29670	-0.76023	-0.43947
21	United Kingdom	UK	-1.22740	2.43800	0.43528	-0.85308	0.34820



Countries' classification into similar groups (FA_11' analysis). Note: dashed line indicates a threshold for groups' definition.



Countries plotted versus factor 1' and factor 2' values (FA_11' analysis). Note: arrows indicate preferable values of factors.

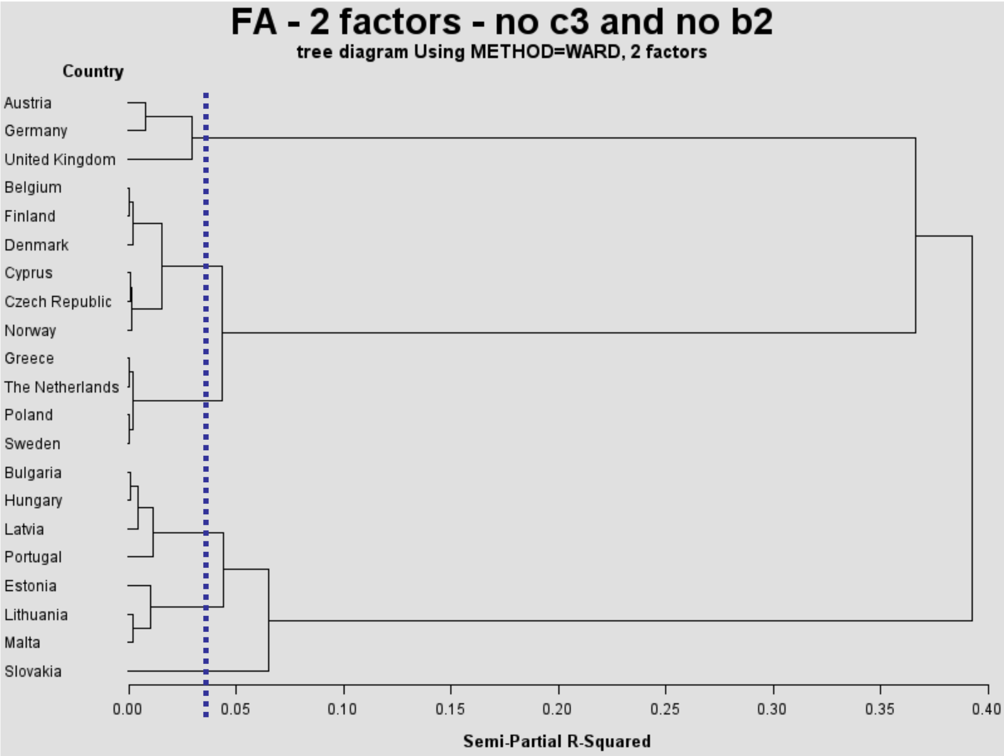
B.3 FA_9 analysis

Rotated Factor Pattern

variable	*Factor1*	*Factor2*
a7	**0.80680**	0.04428
a6	**0.69894**	-0.32385
c2	**0.65734**	-0.11268
a3	**0.61548**	-0.14528
a5	**-0.70809**	0.13983
a9	-0.03122	**0.86145**
b3	-0.18715	**0.57276**
a11	0.43949	**-0.59210**
a8	0.04348	**-0.80646**

Country scores

Obs	*Country*	*Code*	*Factor1*	*Factor2*	*WF*
1	Austria	AT	1.67019	-0.79186	0.55227
2	Belgium	BE	-0.69555	-0.95458	-0.81316
3	Bulgaria	BG	-0.18494	0.53500	0.14196
4	Cyprus	CY	-0.46898	-0.59938	-0.52819
5	Czech Republic	CZ	-0.34757	-0.41647	-0.37885
6	Denmark	DK	-0.43942	-1.18283	-0.77697
7	Estonia	EE	-0.37527	1.59038	0.51726
8	Finland	FI	-0.76845	-1.05454	-0.89835
9	Germany	DE	0.94430	-0.77620	0.16309
10	Greece	EL	-0.66730	-0.13548	-0.42582
11	Hungary	HU	-0.15810	0.78714	0.27110
12	Latvia	LV	-0.62258	0.79777	0.02235
13	Lithuania	LT	0.47496	1.57753	0.97559
14	Malta	MT	0.20615	1.34203	0.72191
15	Norway	NO	-0.15717	-0.63170	-0.37264
16	Poland	PL	-0.95096	-0.14324	-0.58420
17	Portugal	PT	0.28211	0.29829	0.28946
18	Slovakia	SK	1.53815	1.17807	1.37465
19	Sweden	SE	-0.96670	-0.05211	-0.55142
20	The Netherlands	NL	-0.73816	-0.06590	-0.43291
21	United Kingdom	UK	2.42526	-1.30191	0.73289



Countries' classification into similar groups (FA_9' analysis). Note: dashed line indicates a threshold for groups' definition.