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AN APPLICATION OF A ROAD NETWORK SAFETY PERFORMANCE INDICATOR

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Abstract: Safety Performance Indicators (SPI) are used for measuring operational conditions of the road system that affect safety performance. Although several SPIs related to road users are commonly used (speeds, drinking and driving, seat belt and helmet use, etc.), SPIs for roads are rarely calculated. In this paper, the significance of a road network SPI is discussed and a methodology for its calculation is proposed. Based on this methodology, the road network SPI assesses whether the 'right road' is in the 'right place'. Specifically, the existing road network connections between urban centers are compared to the theoretically required ones which are defined as the ones meeting some minimum requirements with respect to road safety. The application of this methodology in Greece is also presented. Specifically, the Road Network SPI is calculated for the area of Peloponnese, the southern part of the Greek mainland. The Peloponnese was chosen because it is a large geographical area with numerous cities and towns of various sizes and populations, it includes all types of roads in a relatively “closed” road network and finally it has a mountainous mainland, which is interesting to study. The application concluded that the overall SPI is the result of putting together an increased number of lower level theoretical connections presenting a very satisfactory SPI, with a small number of higher level theoretical connections presenting a poor SPI. A great unbalance of the road network in the study area is thereby revealed and the road links requiring upgrade are identified.

Keywords: safety performance indicators, assessment, road, application, Greece.

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1. INTRODUCTION

Fundamental road safety assessment is based on the numbers of accidents, fatalities and injuries. However, such data do not provide all the necessary information. The assessment of current safety conditions of a road system and the monitoring of their progress is achieved with the use of additional safety indicators such as seat belt use rates, speeds, drinking and driving rates, etc. Moreover, in their efforts to improve road safety, relevant policymakers and analysts need to take into account as many factors influencing safety as possible or, at least, those factors they are able to affect or control (ETSC, 2001). Additional Safety Performance Indicators (SPI) (rather than accident/ injury numbers) might provide a means for monitoring the effectiveness of safety actions applied and information about underlying causes of crashes.

Safety Performance Indicators are defined as the measures (indicators), reflecting those operational conditions of the road traffic system, which influence the system's safety performance (SafetyNet, 2005). The purpose of SPIs is (SafetyNet, 2005):

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

SPIs may concern particular groups of road users e.g. children, new drivers or professional drivers, or compliance with important safety rules e.g. seat belt use, or cover specific areas such as the urban road network or the trans-European network (CEC, 2003)**.** They provide a more complete picture of the level of road safety and may point to the emergence of developing problems at an early stage, before these problems result to accidents (ETSC, 2001; Luukkanen, 2003).

Moreover, SPIs can be used for monitoring, assessing and evaluating the processes and operations of road safety programs concerning their potential to solve the problems they aim to. Qualitative and quantitative information is used to help determine a program's success in achieving its objectives. So as to achieve their purpose, SPIs need to be relevant to the objectives and the expected outcomes of the program, and to be quantifiable, verifiable and unbiased. A set of indicators should reflect all relevant objectives and be limited to those really needed as the use of a large number of indicators can result in a lack of focus and consequently little influence on the decision making process (Hakkert et al, 2007).

Ideally, the developed SPIs should (Hakkert et al, 2007):

a) Be sensitive to significant changes in the system's conditions and over time, particularly in response to focused interventions such as policy changes.

b) Be invariant and independent from changes of non-focused circumstances.

c) Cover a meaningful range of changes in the systems' conditions.

d) Be sensitive to the influence of external factors like changes in population structure, in legal conditions of road traffic, traffic volumes or mobility behaviour in time or between countries.

e) Be estimated in a statistically reliable and valid manner and be of good and homogeneous quality.

f) Be comprehensible, because visualization of results is important.

The quality of SPIs can be tested at three different levels (SafetyNet, 2005):

- Direct measurement of the identified insecure operational conditions is possible. This means that the indicator will cover the complete scope of the problem, which means the indicator will react on all possible interventions.
- Direct measurement of the identified problem is not possible. The identified problem can be seen as a latent variable. Describing the latent variable by several indirect variables as indicators will bridge this gap.
- Considering the expected availability of data and assessing the reasonable effort for data acquisition, in some cases it would be difficult or even impossible to do that. In this case one would have to cross the dividing line between operational conditions of road traffic and interventions, which are intended to improve the operational conditions. Doing this means to give up independence from interventions and to bridge the gap by reducing or splitting the problem.

Apart from the benefits gained from the development and application of SPIs there are also some limitations that should be taken into consideration. More specifically (Hakkert et al, 2007):

a) More general SPIs play mostly descriptive and not explanatory roles for "final outcomes" (accidents/ casualties).

b) A comparison of SPI values is applicable for similar conditions only. Moreover, the conditions for which SPIs are estimated should be defined explicitly, where the remaining differences between the compared entities should be underlined.

c) Interrelations among different SPIs are possible.

Before the elaboration of SPIs for specific problems, a uniform vision and common methodology for their development should be defined. The common approach should ensure the reliability and validity of SPIs, increase the acceptance and application of SPIs and at last get transparency for the potential users of SPIs (Hakkert et al, 2007). Such an approach was developed within a 6th FP European Integrated Project called SafetyNet and applied for the development of SPIs concerning alcohol and drug-use, speeds, protection systems, daytime running lights, vehicles (passive safety), roads, and trauma management (Hakkert and Gitelman, 2007).

The objective of this paper is to discuss the significance of a road network SPI and to present the calculation of such an SPI in Greece, as performed for the purposes of the ROSEE (ROad safety in South-East European regions) EU co-funded project.

2. ROAD NETWORK SPI

During the last years, SPIs have been the subject of extended research and emphasis has been given to methodological and data issues (Wegman et al., 2008; Assum and Sørensen, 2010). Furthermore, composite indicators e.g. indexes which are a combination of individual indicators are rapidly developed (De Leur and Sayed, 2002; Hermans et al., 2008; Gitelman et al., 2010), in order to meet the need for examining the various factors that have an influence on road safety (Yannis et al, 2013).

A large number of factors which contribute to road accidents and injuries and therefore, might be potentially relevant for SPIs, has been identified by ETSC (2001). Specifically, aspects of road user behaviour that could be used as SPIs include:

• speeding, comparison to mean speed, speed variance, speed limit violations;
• percentage of seat belts' and child restraints' use;
• percentage use of crash helmets;
• incidence of drinking and driving;
• failure to stop or yield at junctions or at pedestrian crossings;
• inadequate headways – close following;
• use of daytime running lights;
• use of reflective devices for cyclists and pedestrians;
• use of pedestrian crossing facilities by pedestrians.

Concerning road and vehicles, potential SPIs are (ETSC, 2001):

1. pavement friction mostly in winter and on wet road surfaces;
2. percentage of new cars with the top star rating according to EuroNCAP;
3. percentage of technically defective vehicles;
4. percentage of road network not satisfying safety design standards.

Indicators of the quality of the post-crash care can be added to this list.

In the EU, the most commonly used SPIs for road transport are speed measurements, surveys on the use of seat belts and crash helmets, and surveys on the incidence of drinking and driving (ETSC, 2001). An exhaustive literature review on SPIs (SafetyNet, 2005) revealed that there were no SPIs for road networks in use. However, infrastructure layout and design has a strong impact on the safety performance of the road transport system. Many ongoing practices in infrastructure research use casualty data for safety assessment. In addition, crash prevention can be improved by early assessments of safety hazards e.g. by monitoring the physical appearance of the road environment and the operational conditions of traffic. The safety performance of the road transport system is the result of the right combination of the functionality, homogeneity, and predictability of the network, the road environment, and the traffic involved. In order to develop suitable SPIs, quantitative relations between road network, road design elements, road characteristics and road safety have to be known sufficiently well (SafetyNet, 2005). From this perspective, it is important to assess the safety of a road network at two levels (Yannis et al, 2013):

- The road design level: individual roads should be designed in a safe way.
- The road network level; the right road should be located at the right place from a functional point of view, i.e. the road category of a road should be appropriate given its function in the road network.

Concerning road design, there are no direct SPIs in use at the moment. Indirect SPIs could be formulated based on two methods: The Dutch Sustainably Safe Indicator (SSI) and the Road Protection Score (RPS) of EuroRAP. Both methods pay attention to homogeneity of the road traffic and forgiving road environments and score specific road design elements. This score can be used to formulate SPIs for road design. Even though there is some overlap in the road elements considered in the two methods, these elements are scaled in a different way. The SSI has strong roots in the Dutch Sustainable Safety vision, and therefore pays more attention than the RPS to the predictability of the road environment and the function in the network of the distinguished sustainably safe road categories (Hakkert et al, 2007). The RPS is a measure for the protection that is provided in relation to three main accident types: run-off road, head-on impacts and severe impacts at intersections.

At the network level, an SPI that assesses whether the 'right road' is in the 'right place' was developed in the framework of the SafetyNet project. The concept is based on the German guidelines for road categories (FGSV, 1988). Dijkstra (2003) converted this concept into a method that he applied in Limburg. The method developed by Dijkstra (2003) was adapted to the European situation within SafetyNet. The 'right road' is in the 'right place' in case the actual road category of a road is appropriate (from a safety point of view) given the (urban or rural) centres that are connected by that road. The idea behind this concept is that the function and traffic volume of a road determine the minimal requirements that have to be met by that road in order to guarantee an acceptable level of safety. The function and traffic volume of a road depend on the sizes of the (urban or rural) centres that are connected by that road. Hereby we assume that higher traffic volumes puts higher requirements to a road and that traffic volumes are higher between larger centres. The minimal requirements that have to be met by a road are related to (preventing) different types of conflicts. The SPI is defined as the percentage of appropriate current road category length per road category (Weijermars, 2008).

3. DEVELOPMENT OF A ROAD NETWORK SPI

In order to obtain a road network SPI that will be suitable for international comparisons, it is necessary to use an internationally harmonized road categorization. Based on the functional road classification proposed in SafetyNet, roads are classified into six categories ranging from AAA down to C as shown in Table 1. This classification is restricted to rural roads and motorways (Weijermars, 2008).

Table 1. *SafetyNet functional road classification (Source: Weijermars, 2007)*

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

Urban centres are categorized in five different based on their population. The population is used as a measure for the importance of a city, or for the amount of traffic that is generated / attracted by a city. Type 1 refers to a large city, type 5 to a village, and 2-4 are in-between. The population for each urban centre type is shown in Table 2 This classification can be enhanced with other information such as industrial areas, shopping areas and recreational sites. In that case the attraction of traffic is determined by more variables than only inhabitants.

Road categories that should be present between different types of urban areas are also shown in Table 2. Centre types 1 and 4, 1 and 5 and 2 and 5 are not directly connected but only via other centre types (indirectly). In addition, the A road category (single carriageway) is not considered for any connection because the AA road category is preferred for its dual carriageway.

Table 2. *Connections between diferrent types of urban areas*

Urban area (population)	Type 1	Type 2	Type 3	Type 4	Type 5
Type 1 (>200,000)	AAA	AAA	AA	Indirectly	indirectly
Type 2 (100,000-200,000)		AA	AA	BB	indirectly
Type 3 (30,000-100,000)			BB	BB	B
Type 4 (10,000-30,000)				B	B
Type 5 (<10,000)					C

The first step for the calculation of the SPI is to determine a specific study area, like a region of a country or a certain sample size. The second step is to make a list of all urban centres in the study area and to determine its types on the basis of the number of inhabitants. The third step is to search for the needed connections between these centres. The basis for defining these connections relies on so called search circles around all cities and towns within the study area. For each centre a search circle is drawn. This search circle is determined by the distance to the closest centre of the same type: the centre for which the circle is drawn is the centre of the circle and the radius of the circle is described by the shortest distance to the closest centre of the same type. The area within each circle can be seen as the area of influence of that specific city or town. Within this area, connections to other cities are assumed. Table 3 shows which types of centres are searched for within the search areas.

Table 3. *Overview of the search for centres*

Start centre	Search for the centre of the same type (radius)	Centres in search areas	Assessment of the connections between
1	The nearest 1	2 and 3	1 and 1, 1 and 2, 1 and 3
2	The nearest 2	3 and 4	2 and 2, 2 and 3, 2 and 4
3	The nearest 3	4	3 and 3, 3 and 4
3	The nearest 4	5	3 and 5
4	The nearest 4	5	4 and 4, 4 and 5

Applying this procedure to all the urban centres within the study area provides a list of the connections that need to be assessed. For all these connections, first of all, it should be evaluated whether there is an actual connection. Hakkert and Gitelman (2007) proposed a detour factor of 1.6 to investigate whether there is an actual connection.

This implies that there should be a connection of which the length is less than 1.6 times the direct distance between two cities. In case there is an actual connection, it needs to be determined which road categories it is composed of. Next, the current road category is compared to the theoretically desired road category derived from Table 2. When the current road category is higher than or equal to the road category that should be present according to Table 2, the current road is considered to be appropriate from a safety point of view. If the current road category is lower than the road category that should be present, the current road is considered to be inappropriate. When the appropriate and existing road categories are compared for all connections, the proportion of appropriate road category length can be calculated for each road category. The road network SPI is defined as the percentage of appropriate current road category length per road category.

In summary, the data needed for the calculation of the road network SPI include:

- Location of urban centres;
- Population per urban centre;
- Location of roads that connect centres;
- Road categories of actual roads (expressed in AAA to C);
- Length of roads.

The location of urban centres and the population of these centres are used to produce a list of connections that are assessed. To be able to determine whether the road category is appropriate, the actual road category should be known. Road classifications differ by country and the present classes have to be converted to the road categories specified in Table 1 using the criteria from this table. Finally, the lengths of roads of different categories must be measured to calculate the percentage of roads that are of an appropriate category.

4. APPLICATION OF A ROAD NETWORK SPI IN GREECE

4.1 Introduction

In the framework of the ROSEE (ROad safety in South-East European regions) EU co-funded project the road network SPI was calculated for a specific area of Greece, using the approach developed within the SafetyNet project. The area of the Peloponnese, situated in the south of Greece (Figure 1) was selected for the calculation of the Road Network SPI in Greece. The specific area was selected because it covers a large geographical area and it includes numerous cities and towns of various sizes and populations. Moreover, it shows a relatively “closed” road network and has a mountainous mainland.

Figure 1. *Map of the Peloponnese in South Greece*

4.2 Definition and categorization of urban centres

Due to the large size of the study area, there are a few hundreds of urban centres to be examined leading to too many theoretical connections. Nevertheless, the majority of these centres are small villages with very low population (sometimes less than 100 inhabitants), for which the examination of the road connections is not of high interest, at least within the framework of this study. Therefore, an assumption was made to include only centres with a population higher than 2,000 inhabitants. Still, the list of the remaining urban centres with low permanent population (less than 2,000 inhabitants) was also examined, in order to identify additional centres which attract a significant amount of interurban traffic due to their administrative or economic role. Thus, 13 additional urban centres were selected:

- three centres corresponding to harbour areas (Killini in the northwest, being the main gateway to the islands of the Ionian Sea, and Galatas and Methana in the east, being main gateways to the islands of the Saronic Gulf)
- five centres corresponding to important tourist destinations, as summer (Monemvasia in the southeast, Epidavros, Tolo and Porto Heli in the east) or winter (Kalavryta in the north) resorts.
- five centres corresponding to important administrative centres, situated mainly close to major urban areas.

This resulted in 70 urban centres to be examined in total. These were classified according to their population only. Finally, there was no type 1 centre and only one type 2 centre (Patra with 168,000 inhabitants).

However, before the final classification, a couple of adjustments were made, in order to better account for the role of several small urban centres. More specifically, some of the type 5 centres should rather be considered as type 4 centres, as the amount of traffic they attract cannot be reflected by their small population. For example, Kalavryta (one of the major winter resorts in Greece), Killini (main harbour to the Ionian Sea), Epidavros (important centre with major archaeological sites and many cultural events around the year) and Porto Heli (popular summer resort) were upgraded into type 4 centres. The final classification is shown in Table 5.

4.3 Theoretically desired connections

As the city of Patra is the only type 2 centre in the Peloponnese, the radius for the determination of the connections with Patra is considered to cover the whole study area (connections with all type 3 and type 4 centres in Peloponnese are assessed).

Theoretical road connections were determined using the presented common methodology. Each search area was determined as a circular area with a radius equal to the distance between each centre and the closest centre of the same type. Exceptionally, for the establishment of the connections between type 3 and type 5 centres the radius is defined by the distance between the type 3 and the closest type 4 centre. It is noted that theoretical connections between type 5 centres were not taken into account, given that these are expected to have the minimum road category standards anyway and are therefore not interesting for this study. In total, 102 theoretical connections were determined.

4.4 Actual connections

Since there are no official national digital map and related GIS tools available, the actual connections were determined using a free route planner available on the internet in combination with the personal experience of the study team. This allowed for great flexibility in the estimation of alternative routes (e.g. fastest vs. shortest route) and accuracy on the length and type of the road segments of each route. The road classification of the route planner needed to be transformed into the SafetyNet road classification, as shown in Table 4.

Table 4. *Transforming the local road categories into SafetyNet road categories*

SafetyNet category	Route planner category
AAA	Highway toll, Highway no toll
AA	National Road toll, National Road no toll (separation)
A	National Road toll, National Road no toll (no separation)
BB	Main paved road (separation)
B	Main paved road (no separation)
C	Paved road, road

__Table 5.__ Urban centres in the Peloponnese

	Centre type				
	1	**2**	**3**	**4**	**5**
Urban areas	-	Patra	Korinthos Kalamata Tripoli	Loutrakion Nafplion Argos Sparti Pirgos Amaliadha Eghio Palea Epidavros Porto Heli Killini Kalavrita	Arhea Korinthos Eksamilia Agioi Theodoroi Assos-Leheon Velon Zevgolateion Vraxation Isthmia Nemea Xylokastron Athikia Kiato Ligourion Ermioni Kranidion Nea Kios Astros Leonidion Megalopoli Neapoli Voion Githeion Vlahiotis Molaoi Skala Gargalianoi Kiparissia Messini Hora Pilos Filiatra Andravida Vartholomio Varda Gastouni Zaharo Lehena Krestena Traganon Vrahneika Diakopton Kato Ahaia Ovria Demenika Paralia Rio - Agios Vasileios Rododafni Dherveni Tolo Monemvasia Koroni Methoni Meligalas Akrata Galatas Methana

Type 5 centres of <2000 inhabitants but of special interest
Centres upgraded from type 5 to type 4 due to high importance

Generally, it was found that the SafetyNet road categorization is too strict for the specific setting. Specifically, in Greece there is seldom a dual carriageway for lower-level roads (e.g. for other than major National roads). Consequently, in the present study, SafetyNet road categories AA and BB were rarely encountered.

Several adjustments of the common methodology were required when matching the theoretical connections with actual ones. First of all, the fastest route criterion was applied for all actual connections. Due to the mountainous landscape of a large part of the study area, preliminary analysis indicated that the examination of "safest" routes (as those of higher road categories) would lead to unacceptable detours and thus would not be meaningful.

Depending on the search area centre in each case, several connections were examined in both directions (i.e. from centre A to centre B, and from B to A). Moreover, in each connection, the small proportion of the roads included in the urban area (i.e. the "urban" part of the connection), not exceeding a few kilometres in each case, and was classified as road type B or C.

The detour factor was calculated for each one of the connections, as the ratio of the actual connection length and the respective celestial latitude. The following remarks can be made:

- If a maximum detour factor equal to 1.6 was to be considered, as suggested by Hakkert and Gitelman (2007), almost 38% of all actual connections would be omitted, due to the increased number of geographical barriers in the study area.
- If a higher maximum detour factor would be accepted (e.g. equal to 2 or 3) the respective percentage would be much lower (12.6% and almost 2% respectively).

Considering a maximum detour factor higher than 1.6, is quite realistic for the study area and for the whole Greece in general, because of its mountainous mainland. A maximum detour factor of around 2 would exclude a few theoretical connections with limited practical meaning (e.g. Porto Heli - Leonidio), but would also exclude several other important connections, therefore an even higher detour factor could be considered. A maximum detour factor of 3 seems more appropriate. For instance, the Kalavryta area, which is a major winter resort, is located in the centre of a large mountainous area at a high altitude, and therefore most of its actual connections, which are important ones in the study area, have a detour factor of around 3. Other important connections crossing through mountains (such as Kalamata - Sparti) also require detour factors higher than 2. In any case, each connection needs to be examined separately in terms of detour factor.

4.5 Calculation of the SPI

Following the above, the road network SPI for the study area was calculated as shown in Table 6 and Figure 2. In total, 6,020.3 kilometres of road were examined, out of which 4,598.8 were of appropriate or higher actual road category than the theoretical one, resulting in a total road SPI equal to 76.4% in this study area.

This finding is not very satisfactory overall; however a more detailed consideration of the SPI reveals an interesting picture. As shown in Table 6, theoretical connections of type AA are met only by 23% of the total length of the actual connections.

Respectively, around 82% of the total road length meets BB or higher standards. One should take into account, though, that no actual BB connections exist in the study area (dual carriageway is very rare for lower level connections in Greece). If BB and B road categories were merged, the SPI for this connection type would be extremely high in the study area. As regards lower level connections, the SPI is equal to 81.5% for type B connections.

Table 6. *SPI scores per road category*

Theoretically desired road category	Current road category					
	AAA	AA	A	BB	B	C
AAA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AA	17.1%	6.1%	70.2%	0,0%	6.1%	0.6%
A	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BB	30.6%	2.9%	48.7%	0,0%	14.0%	3.9%
B	6.7%	0.0%	33.8%	0,0%	41.0%	18.5%
C	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Overall, it is indicated that the total SPI score (aggregated over the road categories) is the result of putting together an increased number of lower level theoretical connections presenting a very satisfactory SPI, with a small number of higher level theoretical connections presenting a poor SPI. A great unbalance of the road network in the study area is thereby revealed.

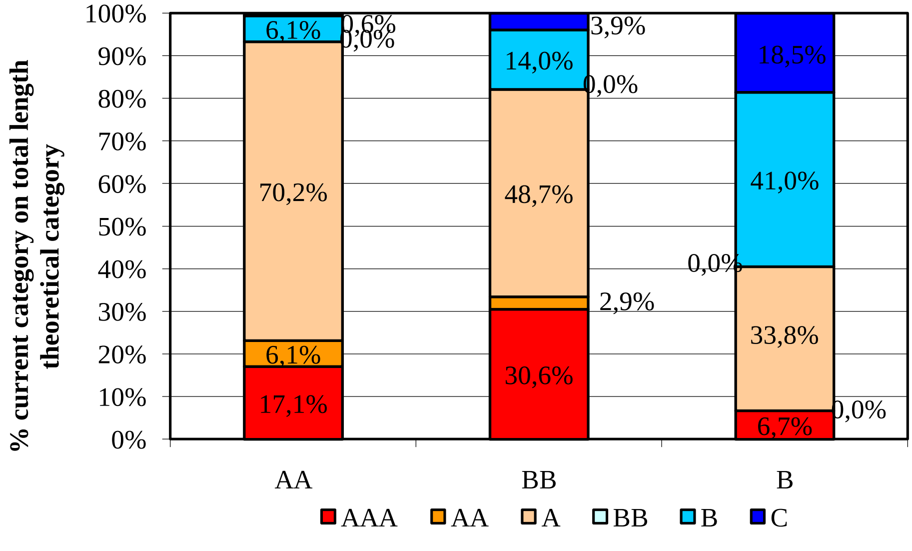

Figure 2. *SPI scores per road category*

5. DISCUSSION

Road safety can be assessed in terms of the social costs of crashes and injuries. However, simply counting crashes or injuries is an imperfect indicator of the level of road safety. A Safety Performance Indicator (SPI) is any variable, which is used in addition to the figures of crashes or injuries to measure changes in the operational conditions of road traffic. SPIs provide a more complete picture of the level of road safety and can detect the emergence of problems at an early stage, before these problems result in crashes. They use qualitative and quantitative information to help determine a road safety programmes' success in achieving its objectives.

Although several SPIs have been proposed for different road safety issues, mainly in relation to driver behaviour (e.g. seat belt use, alcohol, drugs, etc.) and vehicles (e.g. passive safety), SPIs for the road network and design are rarely used. In this paper, the significance of a road network SPI was discussed and the calculation of such an SPI in Greece was presented. This SPI was calculated within the ROSEE (ROad safety in South-East European regions) EU co-funded project using the approach developed within the SafetyNet project. Through this SPI, the existing road network is compared to the theoretically required one, defined as one which meets some minimum requirements with respect to road safety.

The calculation of the road network SPI in Greece revealed a number of issues that could further improve the relevant methodology and its efficiency on future applications. Specifically, according to the real conditions and the particularities of each study area, the methodology should be adapted by implementing small changes.

Concerning the definition and classification of the centres, it was anticipated that population as a unique measure is not an optimal indicator. The list of urban centres that followed from the method was evaluated and 13 additional centres were added to the list of centres. These include harbours, tourist destinations and administrative centres. Moreover, some type 5 centres were upgraded into type 4 centres. The final list of urban centres represents the actual situation more adequately.

As far as the circular areas for the determination of the theoretical connections are concerned, the implementation of the methodology could result in theoretical connections that normally should not be assessed. If the distance between two centres of the same type is long, the radius of the respective circular search area would be very long resulting in connections that are not meaningful. In that case, either a smaller circular area could be assigned based on a different criterion or the resulting theoretical connections should be logically assessed before any connection is assigned. In the case of Greece, the nearest type 4 centre to the type 4 centre of Eghio was Amaliada, which was too far, resulting in type 4-type 5 connections within this area that were not meaningful. The initial idea was to drop this circular area. However, the upgrade of Kalavryta (which is much closer to Eghio) into type 4 centre solved this problem as the circular area was realistic.

A route planner proved to be a useful tool for the identification of actual connections. In general, it appeared to be possible to translate the road categories from the route planner to the SafetyNet road categories. However, the SafetyNet road categorization seems too strict for Greece, since there is seldom a dual carriageway for lower-level roads. This results in a medium SPI score, especially for the AA (23% of the roads that should be AA are in fact AA or higher).

A detour factor of 1.6 was concluded not to be realistic for the Greek study area. Detour factors of two and three were tested. For some connections a detour factor of 2 appeared to be realistic, for other connections a detour factor of 3 appeared to be better. Therefore, we conclude that each connection with a detour higher than 1.6 should be analysed separately and it should be decided on the basis of local knowledge whether a connection is theoretically needed and whether the actual connection has an acceptable detour factor. Summarized, the methodology consists of a number of steps that will need to be adapted to each specific study area. In any case the methodology should be implemented by persons familiar with the area and the road network under examination in order to be able to make all reasonable assumptions (i.e. upgrading a centre into a greater type) and amendments (i.e. adopting a higher detour factor). Moreover, all changes to the method should be clearly described and motivated.

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