Deliverable D3.10c:

Safety Performance indicators for Roads: Pilots in the Netherlands, Greece, Israel and Portugal

Please refer to this report as follows:

Weijermars, W.A.M. (ed.) Safety Performance indicators for Roads: Pilots in the Netherlands, Greece, Israel and Portugal. Deliverable D3.10c of the EU FP6 project SafetyNet.

Contract No: **TREN-04-FP6TR-S12.395465/506723**
Acronym: **SafetyNet**
Title: **Building the European Road Safety Observatory**

Integrated Project, Thematic Priority 6.2 "Sustainable Surface Transport"

Project Co-ordinator:
Professor Pete Thomas
Vehicle Safety Research Centre
Ergonomics and Safety Research Institute
Loughborough University
Holywell Building
Holywell Way
Loughborough
LE11 3UZ

Organisation name of lead contractor for this deliverable:
SWOV

Editor:
Dr. Wendy A.M. Weijermars (SWOV)

Report Author(s): Elisabete Arsénio, João Cardoso, Carlos Lima Azevedo **(LNEC);** Antonis Chaziris, Eleonora Papadimitriou, George Yannis **(NTUA);** Victoria Gitelman **(TECHNION);** Kirsten Duivenvoorden, Govert Schermers, Wendy Weijermars **(SWOV)**

Due Date of Deliverable: 31/10/2008 **Submission Date: 31/10/2008**

Project Start Date: 1st May 2004 **Duration: 4.5 years**

Project co-funded by the European Commission within the Sixth Framework Programme (2002 -2006)		
Dissemination Level		
PU	**Public**	

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

Executive Summary

This report discusses the results of pilot projects in which the road network SPI was applied. The road network SPI assesses whether the 'right road' is in the 'right place', i.e. it investigates whether the actual road category meets the road category that should be present given the sizes of the urban areas that it connects. The SPI can be calculated following a number of steps. First of all, the urban and rural centres in the area under study are listed and classified into groups on the basis of the number of inhabitants. Second, it is determined which centres should be connected to each other and by what type of road (road category). These theoretically desired connections are compared to the actual connections. The SPI is defined as the percentage of appropriate current road category length per road category.

In order to obtain more insight into the limitations and the applicability of the SPI, it was applied in the following pilot countries: Greece, Israel, Portugal, and the Netherlands. From these pilot projects we conclude that it is possible to calculate the SPI scores. The data necessary for calculating the SPI scores was available in the pilot countries and the different steps of the method could be completed. Moreover, we defined some limitations of the method and some directions for further research in order to further develop the SPI.

First of all, the definition and classification of the centres need attention. Ideally, each urban area that is surrounded by rural area is defined as a centre. In practice, data is not always available on this level. In some cases, a centre consists of separate sub-centres with rural area in between. In other cases, two centres are so close to each other that there is no rural area in between them. Moreover, the centres were classified using the number of inhabitants, whereas in reality other facilities may also generate traffic. From the pilot projects it was concluded that some important existing centres may be excluded or classified to a lower category than they should be in case only the number of inhabitants is taken into account. We recommend to deal with these problems in a pragmatic way; centres can be classified on the basis of inhabitants, using the available data and the resulting classification should be evaluated and adapted by somebody with knowledge of the local situation. All changes should be reported and explained. Another issue is that the limits of the classes are chosen quite arbitrarily. Further research is necessary in order to obtain a theoretically sound classification system.

In general, the lists of connections that were determined for the pilot countries appeared to be realistic. In Portugal however, some connections were not found by the method due to small search areas. In other cases, theoretically desired connections were determined that are not found in practice, due to natural barriers.

Regarding the identification and matching of actual connections, the guidelines were very brief. Each pilot country executed this step in its own way, using a route planner or a GIS tool. In general, it appeared to be possible to select one actual connection and to categorise the roads on the basis of the SafetyNet road categorization. The detour factor of 1.6 that was suggested in the Manual (Hakkert & Gitelman, 2007) was concluded not to be appropriate for all pilot areas, yet it was found to be difficult to define one detour factor that is appropriate in all cases. Therefore, we propose to deal with it in a pragmatic way and to examine connection with a detour factor higher than 1.6 on a case-specific basis. In the pilot projects, we did not take into account the suggestion from the manual to upgrade the theoretically desired road category in certain cases that a road is used by several connections. This issue should be analysed further when improving the method.

The calculation of the SPI is quite straightforward if the preceding steps are applied. In general, the resulting scores seem quite realistic, although the scores of Greece seem low compared to the other pilot areas. One overall score may give a biased view, since it depends on the theoretically desired road network that differs greatly between the case study areas. Therefore, we recommend not to combine the results into one overall score. When the

results are analysed in more detail, there appear to be some road categories that have lower scores. The SN requirements for the different road categories possibly should be interpreted less strictly and the theoretically desired road categories between different types of centres possibly need revision. More research is needed concerning this issue. Moreover, in some cases relatively short sections of connections (connecting freeways to urban areas) failed. Maybe one should allow a certain percentage of the route to be of a lower category and only assess the primary part of the connection.

The experiences of the pilot countries were used to update the guidelines for calculating the SPI scores. In our opinion, the current method provides insight into the strengths and weaknesses in a road network. However, especially the classification of urban centres and the SafetyNet road categorization need further research to improve the method for calculating the SPI. Moreover, the relationship between the SPI scores and traffic safety should be analyzed in order to obtain more insight into the validity of the road network SPI.

Contents

1 Introduction

Road safety can be assessed in terms of the social costs of crashes and injuries. However, the numbers of crashes and people killed or seriously injured are small and do not provide all the necessary information about the level of road safety. Indicators like seat belt usage rates, speeds, and alcohol usage rates provide information about underlying causes of crashes. These indicators can assist in assessing the current safety conditions of a road traffic system and in monitoring their progress. Furthermore, they can be used to compare the safety performance of countries or regions and to measure the impact of various safety interventions. Within WP3 of SafetyNet, Safety Performance Indicators (SPIs) are developed for the following areas: alcohol and drug-use, speeds, protection systems, daytime running lights, vehicles (passive safety), roads, and trauma management. The SPIs are presented and described in Hakkert et al (2007). Furthermore, Hakkert and Gitelman (2007) discuss best practice that can be used as examples for countries that are willing to apply the SPIs.

For the area roads, two SPIs for roads were proposed, namely the road network SPI and the road design SPI (Hakkert et al, 2007). As these were new SPIs developed for the SafetyNet project, no examples were available. Therefore, an example case study was executed that was reported in Hakkert & Gitelman (2007). The purpose of this Dutch case study was twofold. First, it illustrated the rather theoretical concept of the SPIs. Second it provided more insight into the practical applicability and strengths and weaknesses of the method. From the case study reported in the Manual, it was concluded that the process of calculating the network SPI was quite complex and that a large amount of data is needed (also in case of a sample). Moreover, although the results of the case study seemed reasonable, a further evaluation of the results was concluded to be necessary to obtain more insight into the meaning of the estimated values. Finally, the method that was proposed for the calculation of the network SPI had some limitations that needed further research. Therefore, it was recommended to repeat the analysis for the Dutch case study manually and to apply the method in a number of countries.

Pilot projects were executed in Greece, Israel, Portugal, Spain and the Netherlands. This report discusses the results of these pilot projects. *Chapter 2* briefly discusses the method for calculating the SPIs, *Chapters 3* to *6* discuss the results of the various pilots and in *Chapter 7* the conclusions from the various pilots are combined into general conclusions.

2 Theory and guidelines

KIRSTEN DUIVENVOORDEN[A]

[A]SWOV

The road network SPI assesses whether the 'right road' is in the 'right place'. The concept is based on the German guidelines for road categories (FGSV, 1988). Dijkstra (2003) converted this concept into a method that he applied in Limburg. The method that is developed by Dijkstra (2003) is adapted to the European situation.

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.

This Chapter explains how the road network SPI can be calculated. To obtain a road network SPI that allows for international comparison, we propose an internationally harmonized road categorisation. This categorization is discussed in *Section 2.1*. The road category that should be present between cities (the appropriate road category) is dependent on the sizes of the cities that the road connects. For that purpose, different centre types are defined. *Section 2.2* discusses these centre types and the road categories that should be present between these centre types. *Section 2.3* subsequently shows how the road network SPI can be calculated. Finally, in *Section 2.4* we summarize which data is needed as input for the road network SPI. In *Appendix A*, detailed guidelines are provided for the calculation of the road network SPI. These guidelines were followed for the pilot projects.

2.1 Road categorization

To obtain a road network SPI that allows for international comparison, an internationally harmonized road categorization is proposed. *Table 2.1* presents the functional road classification that is proposed for SafetyNet together with the preferred characteristics. Roads are classified into six categories ranging from AAA down to C. This classification is restricted to rural roads and motorways.

	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, preferable with lane separation	Dual carriageway	Single carriageway, preferable 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	Preferable grade-separated	Preferable grade-separated	Preferable roundabout	Preferable roundabout	

Table 2.1 SafetyNet Functional road classification (Source: Hakkert et al. 2007).

2.2 Centre type definition

Within SafetyNet, five types of centres are distinguished, on the basis of the number of inhabitants. The number of inhabitants is used as a measure for the importance of a city, or for the amount of traffic that is generated (or attracted) by a city. Type 1 is a big city, type 5 is a village, and 2-4 are in-between. The number of inhabitants for each centre type is shown in *Table 2.2*. 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.

Table 2.2 also shows the road categories that should be present between different types of urban areas, i.e. for different types of connections. Note that there are no direct connections required between centre types 1 and 4, between 1 and 5 and between 2 and 5. These connections will go via other centre types (indirect). Also note that none of the connections requires road category A. The A road category (single carriageway) is not considered for any type of relation because the AA road category is preferred for its dual carriageway.

Urban area (number of inhabitants)	Type 1	Type 2	Type 3	Type 4	Type 5
Type 1 (>200,000)	AAA	AAA	AA	indirectly	indirectly
Type 2 (100,000 to 200,000)		AA	AA	BB	indirectly
Type 3 (30,000 to 100,000)			BB	BB	B
Type 4 (10,000 to 30,000)				B	B
Type 5 (<10,000)					C

Table 2.2 Connections between different types of urban areas.

2.3 Calculation of the road network SPI

Appendix A provides detailed guidelines for the calculation of the road network SPI. This Section gives a short explanation of these guidelines.

The first step is to determine a specific study area, like a region of a country or a certain sample size. A sample size can be chosen in order to obtain a representative result for the country or a specific area. The second step is to make a list of all centres in the pilot 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 midpoint 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 2.3* shows which types of centres are searched for within the search areas. The appropriate road categories between different types of centres are specified in *Table 2.2*.

Start centre	Search for the centre of the same type (radius)	Centres in search area	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

Table 2.3 Overview of the search for centres.

Applying this procedure to all centres within the pilot area results in a list with all connections that need to be assessed. For all these connections, first of all, it should be evaluated whether there is an actual connection. In the Manual (Hakkert and Gitelman, 2007) a detour factor of 1.6 was introduced in order 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 (as the crow flies) distance between two cities. Second, 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 that follows from *Table 2.2*. When the current road category is higher than or equal to the road category that should be present according to *Table 2.2*, the current road is considered to be appropriate from a safety point of view. In case 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.

An example: the current road category between centre X of type 3 and centre Y of type 4 is B. From *Table 2.2* however it follows that road category BB is needed between type 3 and type 4 centres. The current road category is thus lower than the theoretically required category which means that the current road category is not appropriate. In case the current type was higher (e.g. AA) or similar (BB), the current road category would have been appropriate.

The road network SPI is defined as the percentage of appropriate current road category length per road category.

2.4 Data needed as input

For the calculation of the road network SPI, the following information is needed:

– Location of urban centres;
– Number of inhabitants per urban centre;
– Location of roads that connect centres;

- Road categories of actual roads (expressed in AAA to C);
- Length of roads.

The locations of urban centres and roads are displayed on (digital) maps. The location of urban centres and the number of inhabitants 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 translated to the road categories specified in *Table 2.1* using the criteria from this table. Finally, the lengths of roads of different categories have to be known in order to calculate the percentage of roads that are of an appropriate category.

3 Dutch pilot

GOVERT SCHERMERS[A], KIRSTEN DUIVENVOORDEN[A], WENDY WEIJERMARS[A]

[A]SWOV

3.1 Introduction

For the Netherlands, The Province of South Holland was chosen as the pilot area for the calculation of the road network SPI. An earlier case study in this area was discussed in the Manual (Hakkert and Gitelman, 2007). For the first case study, the process of calculating the SPIs was automated and some changes were made to the basic method. As a result of the automated process, we did not have enough insight into the meaning of the results and the influence of adaptations to the basic method. Therefore, it was decided to repeat the case study manually, using the basic method.

The Province of South Holland is situated on the Southwest coast of Holland and comprises an area of 2818 square kilometres of land and some 600 square kilometres of water (CBS, 2006). The province has 3 455,097 inhabitants and 1,530,781 houses (CBS, 2007). The provincial capital is The Hague which is one of the 82 local authorities in the province. The province has a road network of 15,884 kilometres (CBS, 2007) made up of 740 kilometres of State roads (freeways with speed limits of 100 and 120km/h); 694 kilometres of provincial road (distributor roads with speed limits of typically 80km/h and sometimes 100km/h); 2,025 kilometres of Water Board roads (rural access roads with speed limits of 60km/h and 12,425 kilometres of local authority roads (80km/h rural distributors, 50km/h urban distributors and access roads with 30km/h limits). The province has a vehicle population of 1,384,971 vehicles.

3.2 Definition and classification of urban centres

For the pilot it was decided to define urban centres on the basis of inhabitants per local authority area. Population data are kept by Statistics Netherlands (CBS) and are available by municipal region. In many cases a municipal region incorporates a number of small towns/settlements. The Netherlands comprises some 800 urban areas/towns/settlements which have been amalgamated into some 443 municipal areas. Data at a more disaggregated level than municipal region are not available from CBS. Therefore, it was decided to define urban centres on the basis of population per local authority/municipal region. The CBS data on population are also used in the accident recording system BRON and for the SafetyNet pilot it was decided to use 2006 population data from BRON.

The province of South Holland has a total of 82 municipalities with a total of 111 towns (with more than 4000 inhabitants, source www.nl.wikipedia.org). Of these 2 have populations greater than 200,000 persons and 11 have populations below 10,000 persons. The urban centres are shown in Table 3.1.

Using the guidelines provided by the SafetyNet Manual one notices that the provided population limits result in most of the centres being classified as type 3 and 4 whereas there are surprisingly few type 5 centres. This means that the resulting theoretical road network will comprise of many type BB and B roads with relatively few type C roads.

Centre type				
1	2	3	4	5
Rotterdam	Dordrecht	Alphen aan den Rijn	Alblasserdam	Bergambacht
The Hague	Leiden	Barendrecht	Albrandswaard	Dirksland
	Zoetermeer	Capelle aan den IJssel	Alkemade	Graafstroom
		Delft	Bergschenhoek	Liesveld
		Gorinchem	Berkel en Rodenrijs	Moordrecht
		Gouda	Bernisse	Nieuw-Lekkerland
		Hellevoetsluis	Binnenmaas	Ouderkerk
		Katwijk	Bleiswijk	‘sGravendeel
		Leidschendam-Voorburg	Bodegraven	Strijen
		Maassluis	Boskoop	Vlist
		Papendrecht	Brielle	Zoeterwoude
		Pijnacker-Nootdorp	Cromstrijen	
		Ridderkerk	Giessenlanden	
		Rijswijk	Goedereede	
		Schiedam	Hardinxveld-Giessendam	
		Spijkenisse	Hendrik-Ido-Ambacht	
		Teylingen	Hillegom	
		Vlaardingen	Jacobswoude	
		Westland	Korendijk	
		Zwijndrecht	Krimpen aan den IJssel	
			Leerdam	
			Leiderdorp	
			Lisse	
			Middelharnis	
			Midden-Delfland	
			Nederlek	
			Nieuwerkerk ad IJssel	
			Nieuwkoop	
			Noordwijk	
			Noordwijkerhout	
			Oegstgeest	
			Oostflakkee	
			Oud-Beijerland	
			Reeuwijk	
			Rijnwoude	
			Rozenburg	
			Schoonhoven	
			Sliedrecht	
			Voorschoten	
			Waddinxveen	
			Wassenaar	
			Westvoorne	
			Zederik	
			Zevenhuizen-Moerkapelle	

Table 3.1 Centres in the Province of South Holland by population

A problem with the current definition of a centre (based on the municipal areas) is that in some cases a centre consists of several subcentres. Since the subcentres (villages) are combined into one larger centre (the municipality) the traffic between the subcentres is not considered when calculating the SPI.

On the other hand, in some cases two or more towns are that close to each other that there is no rural area between the towns. Theoretically, they could be considered as one centre, since the traffic between them is urban. In the pilot however, they were treated as separate centres.

Evaluating the list of centres, we noticed that there are some centres missing. The most important ones being the port of Rotterdam, the agricultural area Westland and flower auction. This is due to the fact that only inhabitants are taken into account when defining the centres.

3.3 Determination of theoretically desired connections

The next step is to determine the theoretically desired connections, using the search circles described in Chapter 2. *Figure 3.1* shows an example of the search area for the city of Rotterdam.

An immediate problem encountered when defining the search circles was the location of the actual centre of the search circle. In most cases the Central Business District (CBD) of a town or city would suffice but in some instances a centre comprised more than one urban area/town. In these cases an approximate geographic midpoint was selected as the centre although in some cases this resulted in the midpoint of the search circle being in an uninhabited/sparsely populated area of the municipality.

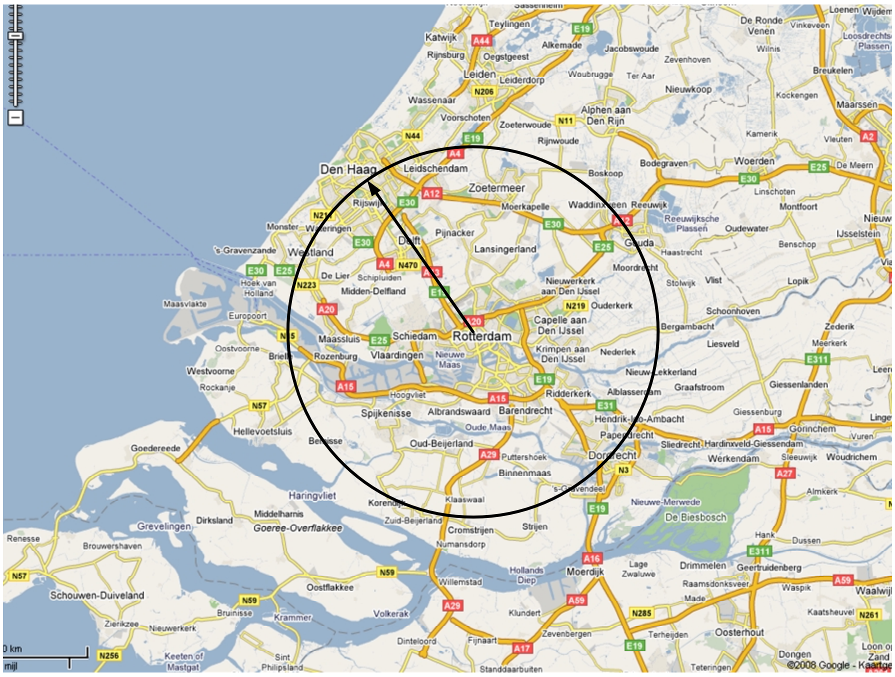


Figure 3.1 Search area for the city of Rotterdam: The nearest city of the same type (type 1) is The Hague, so the radius of the search circle is equal to the distance (as the crow flies) between Rotterdam and The Hague.

Once the search area is defined, the theoretical connections to the relevant centres can be established. *Figure 3.2* and *Table 3.2* show for example which connections are theoretically desired from Rotterdam (as explained in Chapter 2, type 4 and 5 centres are connected to type 1 centres via smaller centres). These connections are based on the "as the crow flies" principle and do not take account of actual geographic or other constraints. These theoretical connections are no more than lines reflecting the shortest possible connection between centres with an assumed relation to each other. The Netherlands, and especially the Province of South Holland, has many rivers and canals which form natural barriers between centres. In situations where these occurred, these were specifically noted. This information was used when evaluating the actual road network.

In cases where the search area encroached neighbouring provinces, centres in these provinces (and their subsequent connections) were not included in the evaluation.

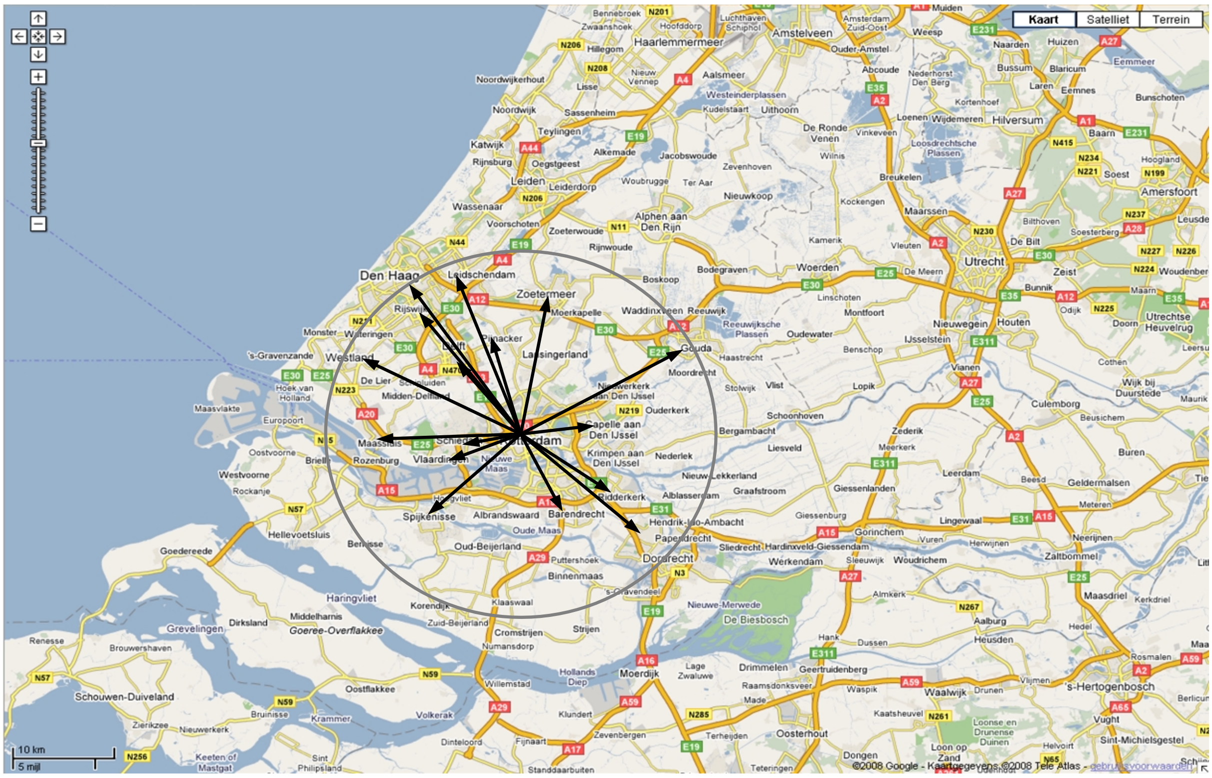


Figure 3.2 Theoretical connections between the city of Rotterdam and selected centres in the search area.

Starting centre:	Rotterdam	Theoretically desired connection
Nearest centre	The Hague	AAA
Type 2 within search area	Zoetermeer	AAA
Type 3 within search area	Barendrecht	AA
	Capelle a/d IJssel	AA
	Delft	AA
	Gouda	AA
	Leidschendam-Voorburg	AA
	Maassluis	AA
	Pijnacker-Nootdorp	AA
	Ridderkerk	AA
	Rijswijk	AA
	Schiedam	AA
	Spijkenisse	AA
	Vlaardingen	AA
	Westland	AA
	Zwijndrecht	AA

Table 3.2 Required connections (Search area Rotterdam - The Hague, Type 1 centres)

Figure 3.3 shows the theoretically desired road network according to the SafetyNet classification superimposed on the existing road network. Although these are not the direct (as the crow flies) connections, they reflect the desired road network based on the centres as defined in this pilot. It is evident that the primary rural road network desired by the SafetyNet approach is significantly less dense than the actual network that has been provided. This is expected since the SafetyNet methodology does not take into account actual Origin-Destination (O-D) patterns nor does it consider access to rural smallholdings and farms.

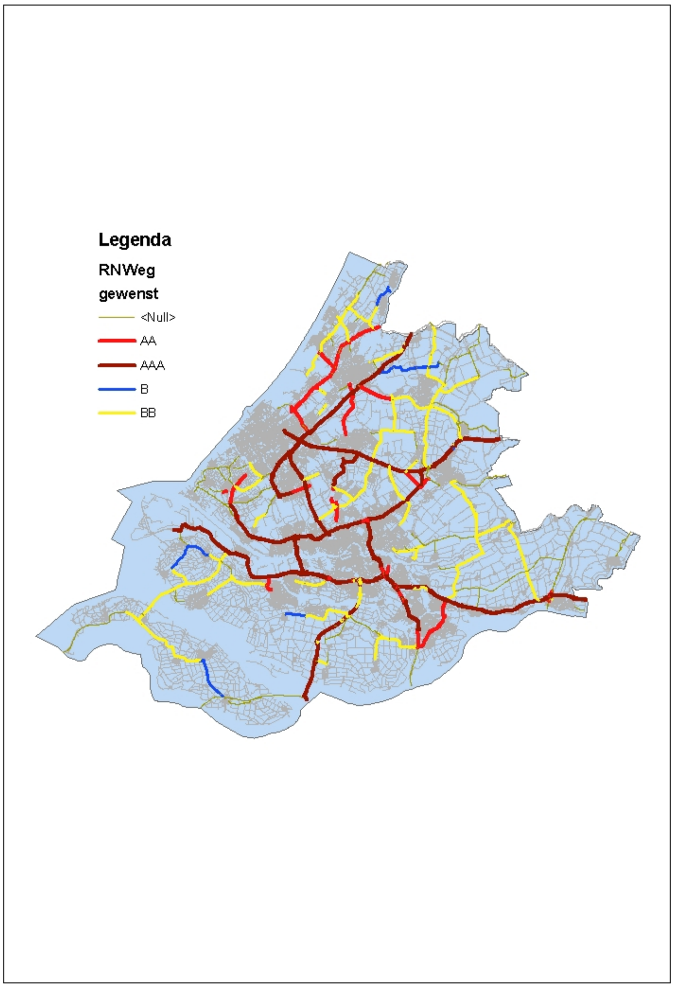


Figure 3.3: Safetynet connections based on existing roads in South Holland

According to the SafetyNet classification systems and based on connections between centres 1, 2, 3 and 4 as analysed in this pilot, the Province should have a road network comprising:

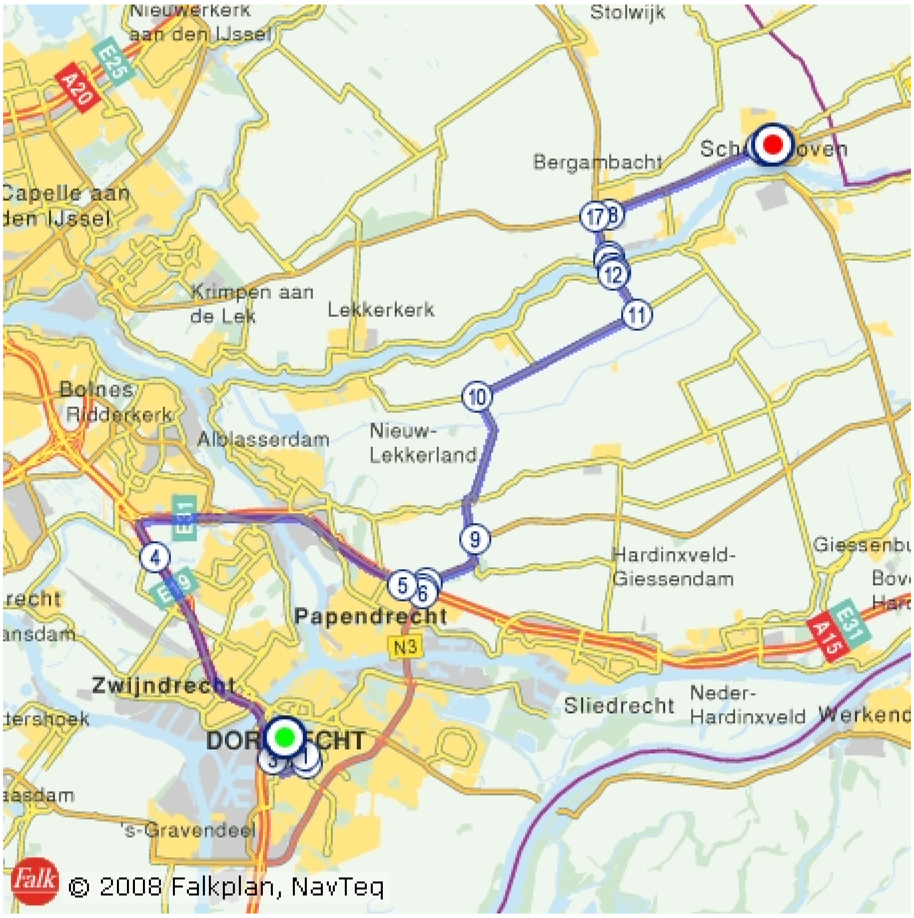
- 132 kms of AAA roads;
- 378 kms of AA roads;
- 1,763 kms of BB roads; and
- 435 kms of B roads.

Evaluating the resulting connections we noticed that there are some connections missing, i.e. some connections that are expected on the basis of knowledge of the local situation, are not found by the method as theoretically desired connections. Some connections are missing as a consequence of the missing centres in step 1 (connections to the port of Rotterdam, etc.). Other connections that are missing are connections to centres outside the case study area. These were not taken into account in the pilot project. Finally, connections between villages that are part of one municipality are not taken into account since centres are defined as municipalities instead of villages.

3.4 Identification and matching of actual connections

The next step in the evaluation was to categorise the actual roads according to the SafetyNet classification. In the Netherlands, the roads are categorised according to the three tier Sustainable Safety (Wegman et al, 2005) classification comprising freeways (through roads); distributor roads and access roads. Since the introduction of Sustainable Safety, road authorities have deemed it prudent to split each primary type into two sub-types. This differs from the SafetyNet classification which has three freeway (Type AAA, AA and A) classes, two distributor classes (Type BB and B) and one access road (Type C) class. SafetyNet does not appear to make any use of the Type A class and therefore its relevance must be questioned. Comparing the functional specifications of the relevant Sustainable Safety and SafetyNet road categories, these are essentially the same.

The road network in The Netherlands is very dense. Between most cities, several routes can be chosen from. When determining the actual road categories for a certain connection, one of the routes must be selected. For the Dutch pilot, existing connections between the centres were obtained using a route planner (ANWB routeplanner, www.anwb.nl). Central Business Districts (CBDs) or geographical centres (municipalities that consist of several villages) were used as start and end points for the connections. Moreover, the fastest route was selected[1].



Fastest route: 38.1 km
Travel time: 42 minutes

From: Dordrecht

To: Schoonhoven

Figure 3.4 Example of output from the navigation software. The numbers are explained in the text.

Figure 3.4 shows the actual route that is selected by the route planner (fastest route was selected and the CBDs were selected as begin and end point) from Dordrecht to Schoonhoven as an example. As can be seen from Figure 3.4 a route consists of various

[1] Using the ANWB route planner, one can select the shortest route or the fastest route or an alternative route.

roads. The navigation software provides a list of roads that are part of the route and the distances travelled on these roads. The route from Dordrecht to Schoonhoven (that is shown in Figure 3.4) starts on the urban network in Eindhoven (points 1 to 3), then it follows the A16 freeway (points 3 to 4), the A15 freeway (points 4-6), a short section (<400m) of the N3 A level road (points 6-8), a short section (2km) of the N214 (a type 2 rural distributor, points 8-9), a 4.2km section of the N481 (points 9 – 10), 4.9km of the N480 (points 10-11), 1.3km of the N479 (points 11-12), crosses the water by ferry (points 12-16), follows the N478 for 1.3km (points 16-17) and continues for some 4.8km on the N210 (points 17 – 19) before entering the urban roads in Schoonhoven. These roads often have different layouts and therefore possibly are from different categories.

Each connection could be split into urban and rural road sections, of which only the latter were included in the evaluation. The rural sections of the selected route were classified according to the SafetyNet classification using essentially existing information of the road network and through collaboration with the Provincial road authority. No physical inspection of the network was carried out to verify the carriageway and lane configurations.

Since a route consists of several roads, it is possible that a selected route (actual connection) is composed of several road categories. In that case, the length of each road category is determined. The connection between Dordrecht and Schoonhoven from Figure 3.4 for example is made up of two rural road classes (motorway and rural distributor road type 2). Some 44% of the total route is Motorway and some 50% is rural distributor road. The remaining approximately 6% of the route is considered urban.

Since SafetyNet deals with rural roads it would generally be adequate to consider connections between city/town (municipal) boundaries. However, not all land within municipal boundaries is developed and there may be large tracts resembling rural environments where roads may well still be classified on the basis of rural roads. In these cases one may need to define the connections from the edges of the development. In most cases this information can be taken from existing maps showing reasonable detail of the urban and rural road networks with some indication of municipal and/or provincial boundaries. For the Dutch case study we selected that part of the route that used rural roads. The edges of development were selected using the route planner.

For the purposes of SafetyNet we notice three issues with regard to the actual connection between Dordrecht and Schoonhoven, that serves as an example for other connections. Firstly, the fastest route is via the freeways and not via the seemingly shorter and more direct route via the N3. Although the faster route is longer, the freeway is more quickly accessible from Dordrecht centre. Question remains whether one should use the CBD as starting point.

Second, the connection comprises no less than two freeway sections, one (short) section of A level road and SIX sections on different distributor roads (possibly all with different functional characteristics. In such cases each road section should be separately listed and classified and ultimately compared to the theoretically required connection.

Third, data on the actual road layout and the lane configuration is not always readily available and hence it is not always easy developing the actual classification. In the Netherlands, rural distributor roads are predominantly single carriageways (therefore Type B SafetyNet roads) with here and there short sections of dual carriageway (type BB). For the purpose of the SafetyNet pilot the class of the existing connections and their lengths were determined from available data sources (including discussions with the provincial road authority). *Figure 3.5* shows the actual road network of South Holland.

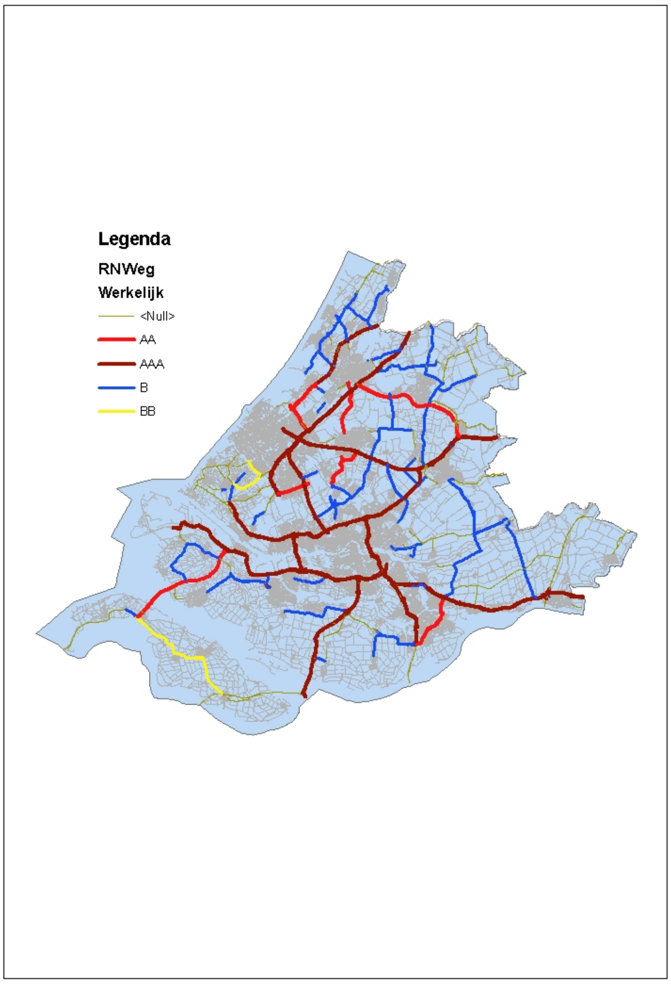


Figure 3.5 The actual road network of South Holland

3.5 Calculation of the SPI

The final step of the method is to compare the actual road categories to the theoretically desired one and to calculate the SPI score. Table 3.3 shows an example of the comparison between actual and theoretically desired road categories using Rotterdam as starting centre.

		Connection type Current	Theoretical	Length (km)	% not urban	Current vs theoretical
Starting centre:	Rotterdam					
Nearest centre:	S Gravenhage	AAA	AAA	24.6	61.8	Meets
Type 2 within search area	Zoetermeer	BB/B	AAA	19.9	71.9	Fails
Type 3 within search area	Barendrecht	AAA	AA	13.9	43.9	Exceeds
	Capelle a/d IJssel	*IU*	AA	9.0		
	Delft	AAA	AA	17.4	68.9	Exceeds
	Gouda	AAA/B	AA	24.9	58.6/24.5	Fails
	Leidschendam-Voorburg	AAA	AA	26.1	75.9	Exceeds
	Maassluis	AAA	AA	18.7	72.7	Exceeds
	Pijnacker-Nootdorp	BB/B	AA	15.0	48.7	Fails
	Ridderkerk	AAA	AA	14.8	51.4	Exceeds
	Rijswijk	AAA	AA	23.2	81.9	Exceeds
	Schiedam	AAA	AA	9.4	47.9	Exceeds
	Spijkenisse	AAA/B	AA	22.7	55.5/13.7	Fails
	Vlaardingen	AAA	AA	14.8	64.2	Exceeds
	Westland	AAA/B	AA	27.7	87.0	Fails
	Zwijndrecht	AAA	AA	17.4	70.3	Fails

IU means an inter urban connection

Table 3.3 Compliance of existing connections with theoretical requirements (Results showing Rotterdam as the type 1 starting centre).

A number of connections shown in the table do not fully meet with the requirements and contain sections of road of a lower class than required by SafetyNet. In most cases these are relatively short sections connecting the freeways to the urban area. Again the question arises as to how to define the start and end points of the connections. If a freeway passes in the vicinity of a town is this adequate or must the, often relatively short, section of road connecting the urban network to the freeway also be of the standard required by SafetyNet.

Two links (Rotterdam - Zoetermeer and Rotterdam - Pijnacker-Nootdorp) do not meet the functional requirements of SafetyNet at all and theoretically one would need to consider upgrading these to a suitable standard since they score poorly on this SPI. However, the road network in the Netherlands is extremely dense and distances are relatively short. In both these cases higher order roads (freeways) are available although they result in marginally longer travel times. Bearing this in mind it would not seem feasible to reconstruct existing links or to introduce new direct links between Rotterdam and Zoetermeer and between Rotterdam and Pijnacker-Nootdorp. In this manner all connections were evaluated.

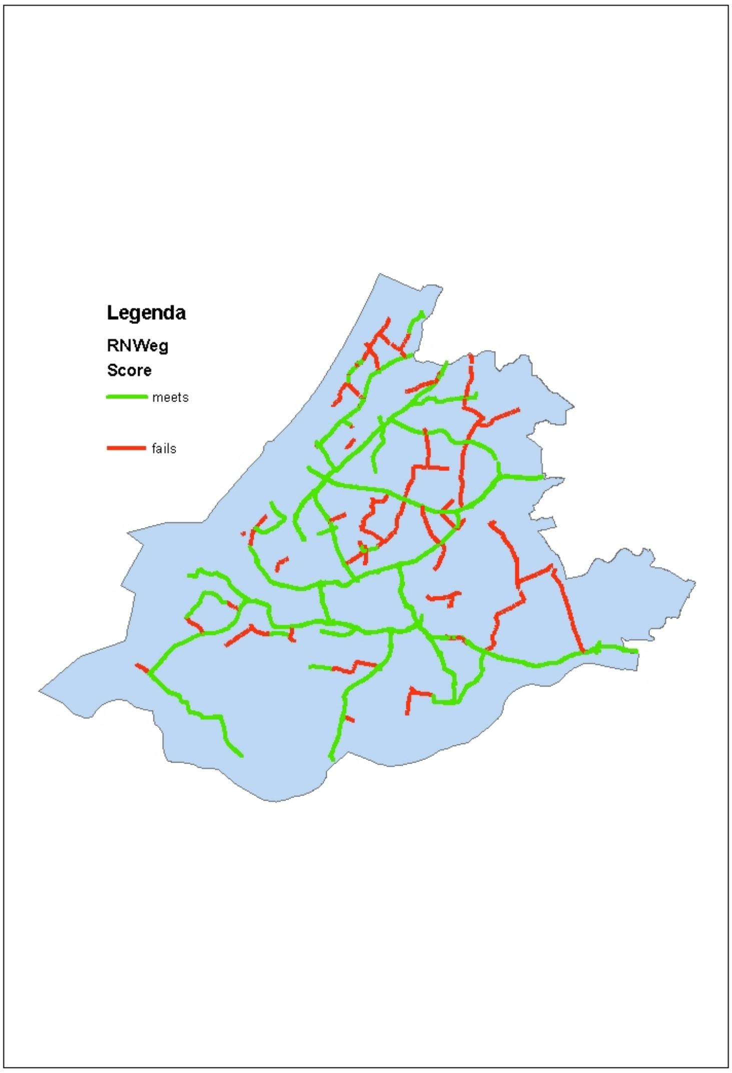


Figure 3.6 Evaluation of existing road network in terms of SafetyNet requirements.

Figure 3.6 shows which roads meet the theoretically desired road category and which roads do not. Here it is evident that a proportion of the existing road links do not meet the desired road category. The primary reason for this is that the Netherlands makes extensive use of single carriageway 2 lane rural distributors whereas SafetyNet desires the use of BB roads (dual carriageway with single or double lanes per direction). The Dutch distributors conform to the type B but most of which without any physical form of directional separation. Most of these roads do not permit overtaking and are not accessible to slow traffic (factors not considered in the SafetyNet classification). Furthermore, a number of these roads form links between the freeway and the urban road networks.

Subsequently the SPI score can be calculated. For each road category, the percentage of appropriate current road category is calculated. The scores are shown in *Figure 3.7*. From the figure it can be seen that for most road categories, the actual road categories comply quite well with the theoretically desired road category: 87% of the required AAA roads are in fact AAA roads, 87% of the roads that need to be AA are in reality AA or higher, and 91% of the required B roads are in fact B or higher. However, the requirements for BB road are less often met, with about 22% of the roads being of a lower category. Overall, about 82% of the road network in South Holland meets or exceeds the SafetyNet classification requirements.

Theoretically desired road category	Current road category					
	AAA	AA	A	BB	B	C
AAA	87.5%	0.0%	0.0%	0.0%	12.5%	0.0%
AA	72.3%	15.0%	0.0%	4.1%	8.6%	0.0%
A	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BB	58.2%	9.5%	1.5%	8.5%	21.4%	0.9%
B	31.3%	3.4%	0.0%	0.0%	56.0%	9.4%
C	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 3.4 SPI scores per road category (table).

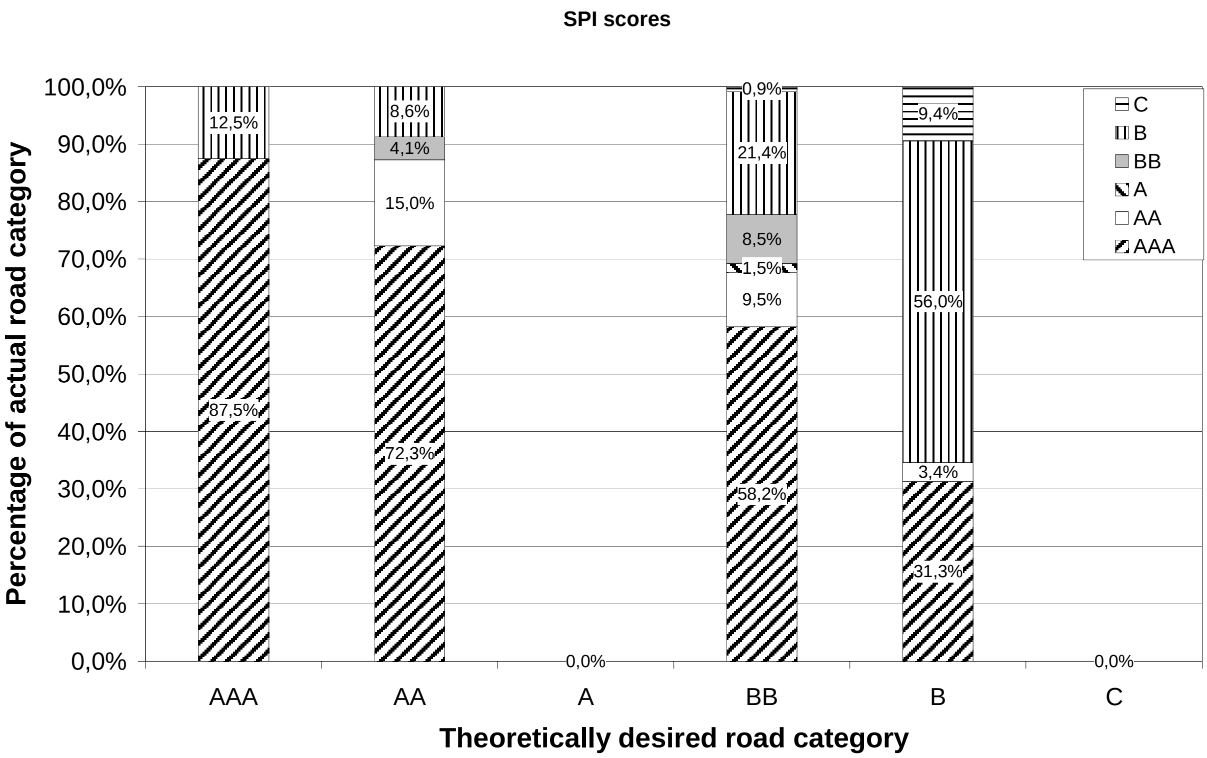


Figure 3.7 SPI scores per road category.

3.6 Conclusions and discussion

The road network SPI as proposed by the SafetyNet Manual proved a relatively easy and effective method to evaluate the existing road network in the Province of South Holland. However, some problems were encountered and the method and guidelines have some issues that need further refinement. In this section, the main issues are summarized for each step of the method.

3.6.1 Definition of urban centres

With regard to the first step of the pilot, several problems occurred. First of all, in the Dutch pilot, a centre was defined by a municipal area. This means that in some cases, several villages or settlements are combined into one geographic area, representing a centre. In such cases, one of the smaller towns is designated the CBD or the geographic midpoint can represent the CBD.

However, these smaller centres can be relatively far apart and are then connected by low order rural roads which should therefore be taken into account as part of the road network evaluation. Also the opposite occurs; in some cases centres share borders and there is no or very little undeveloped land separating the centres. The connection between such centres is mostly via existing intra-urban roads, and therefore a separate rural connection seems irrelevant.

It seems most logical to define each village or urban area that is surrounded by rural areas as one. However, in reality this is not possible, since data are not readily available on a village level. Therefore, we analysed the data on a municipal level and removed intra-urban connections from the analysis.

Centres were classified on the basis of the number of inhabitants. The size of a centre represents the importance of that centre or the amount of traffic that is generated (or attracted) by the centre. The amount of traffic generated by a centre also depends on other factors such as the amount of industry, governmental agencies and recreational facilities. The definition of the centre types is based on population data and quite arbitrary. By changing the limits of the different classes one changes the distribution of centres across types and the theoretically desired network.

If one would want to improve the classification procedure, the first issue would be to determine which factors influence the importance of a city and which measurable variables represent these factors. Secondly, data on these variables should be collected for the entire case study area. These data often are not available and difficult to collect. Then the limits of the various classes of centres should be set. At the moment, these limits are set in a quite arbitrary way. Another option would be to use the (estimated) traffic generated (or attracted) by a city as a measure for the importance of a city. Also these data are often not available. Besides, also in this case, limits of different centre types should be defined. Also these limits will be quite arbitrary. Further research is needed to improve the classification of centres.

The list of centres and the theoretically desired network that were obtained for South Holland appear to be quite realistic, although there are some missing centres like the port of Rotterdam and the flower auction. Overall, it is concluded that the methodology applied to the Dutch pilot is appropriate and relevant for the Dutch situation.

3.6.2 Determination of the theoretically desired connections

With regard to the determination of the search circles, a problem occurred with the centres that comprised more than one villages. In those cases an approximate georgraphic midpoint was selected as the centre although in some cases this resulted in the midpoint of the search circle being an unhabitated/ sparsely populated area of the municipality.

Theoretically desired connections that are influenced by a (natural) barrier (in the Netherlands these are rivers) are marked. These connections might not exist in reality because of the barrier and should be treated separately when checking for missing connections in the next step.

The resulting theoretical network appeared realistic, although some connections are missing due to the limitations of the classification of centres (municipality level and classification on the basis of inhabitants only). Since for example the port of Rotterdam was not defined as a centre, connections too and from the port were not taken into account. Moreover, connections between villages that are part of one municipality are not included in the analysis since municipalities were treated as one centre.

3.6.3 Identification and matching of actual connections

The road network in the Netherlands, especially in the case study area, is very dense. Therefore, we did not check for missing connections and did not take into account a detour factor. Between most cities, several routes can be chosen from. One of these routes has to be selected as the actual connection and a decision had to be taken as to how to select this route. In the pilot, navigation software was used to select a route as the actual connection between two centres. Thereby, the fastest route was selected and the CBDs of the cities were chosen as start and end point of the route. The fastest route seems to be an appropriate choice, since in general it appears to be via the higher order roads.

The data describing the actual road layout of the entire existing rural road network was not readily available for the Pilot area of South Holland. Conducting road inventory studies for this purpose was too costly and time consuming and certainly not feasible for a one off evaluation such as this. However, should these evaluations become a structural and compulsory part of future SPIs or other similar evaluations, inventories will need to be carried out and recorded by the relevant road authorities. On the short term one must rely on available data sources and liaise closely with the local road authorities to verify these with their local knowledge. This can also be time consuming.

Since the road network evaluation is focussed on the rural road network, clearer guidelines need to be developed in order to clearly define rural and urban roads. Land use charts would be a logical option although this would entail an extra step in the evaluation process.

3.6.4 Calculation of the SPI

By comparing the actual road categories to the theoretically desired ones it was possible to evaluate each connection. Since one connection can consist of several actual road categories, some connections partly passed and partly failed. In these cases, the length of the part that failed and the length of the part that passed were calculated. By combining the results of the individual connections, the score for each road category was calculated.

With regard to the score of the individual connections it has to be mentioned that in some cases relatively short sections of the connections, connecting freeways to urban areas- failed. The question arises whether also these sections should apply to the SafetyNet requirements or if one should allow a certain percentage of the route to be of a lower category and only base the assessment on the primary part of the connection.

Overall, some 82% of the road network in South Holland meets or exceeds the SafetyNet classification requirements. To an extent this score is influenced by the presence of higher order roads fulfilling dual roles, as high order connection but also as lower order connection. If one looks at individual classes, BB roads score worst. 22% of the roads that should be BB are of a lower category. This is caused by the extensive use of single carriageway rural roads in the Netherlands which, according to SafetyNet, should be double carriageway. Considering the area already occupied by roads and the fact that land is at a premium, it is hardly likely that the majority of these roads could be rebuilt to comply with these requirements. Besides that, many of these roads have overtaking bans and other traffic management measures which conform to many of the Sustainable Safety requirements and which are currently not considered by the SafetyNet approach. This begs the question whether the SafetyNet functional classification is not too stringent. Based on the results of the pilot in South Holland consideration should be given to reviewing the functional requirements for the various road types and/or the road categories that are desired for different types of connections.

4 Greek pilot

GEORGE YANNIS [B], ELEONORA PAPADIMITRIOU [B], ANTONIS CHAZIRIS [B]

[B]NTUA

4.1 Introduction

The region of Peloponnese, situated in the south of Greece (including the NUTS3 codes: GR232-233 and GR251-255) was selected for the calculation of Road Network SPI in Greece. This case study area covers a large geographical area and includes numerous cities and towns of various sizes and populations. It shows a relatively "closed" road network and has a mountainous mainland. It is interesting to investigate whether the road network SPI can deal with this mountainous mainland.

4.2 Definition and classification of urban centres

As a result of the large size of the study area, the number of urban centres to be examined is a few hundreds; therefore the number of theoretical connections would be too large. 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.

Nevertheless, the list of remaining urban centres (of lower than 2,000 inhabitants) was thoroughly examined, in order to identify additional centres which have an important administrative or economic role, and thus attract a significant amount of interurban traffic, but have a low permanent population. Within this framework, 13 additional urban centres were selected:

- 3 of them correspond 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)
- 5 of then correspond 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.
- 5 of them 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 (more analytical data e.g. on unemployment and land use are available but not in an electronic form, therefore the process of coding and processing this data would be beyond the scope of this study). In particular, the study area does not include any type 1 centre and the only type 2 centre in the region of Peloponnese is Patra, located to the northwest (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 number of inhabitants. For example, Kalavryta (one of the major winter resorts in Greece), Killini (main harbour to the Ionian Sea), Epidavros (important centre with major archeological sites and many cultural events around the year) and Porto Heli (popular summer resort) were upgraded into type 4 centres.

The resulting classification is shown in *Table 4.1*.

	1	2	Centre type 3	4	5
Urban areas	-	Patra	Korinthos	Loutrakion	Arhea Korinthos
			Kalamata	Nafplion	Eksamilia
				Argos	Agioi Theodoroi
				Tripoli	Assos-Leheon
				Sparti	Velon
				Pirgos	Zevgolateion
				Amaliadha	Vraxation
				Eghio	Isthmia
				Palea Epidavros	Nemea
				Porto Heli	Xylokastron
				Killini	Athikia
				Kalavrita	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

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

Table 4.1 Centres in the region of Peloponnese.

4.3 Determination of theoretically desired connections

As already mentioned, the study area does not include any type 1 centre. In fact, only two type 1 centres exist in Greece (Athens and Thessaloniki) therefore a pilot study including such centre types would require a very large area to be examined. The most populated city in the region of Peloponnese is Patra, located to the northwest (type 2 centre - 168.000 inhabitants). Moreover Patra is the only type 2 centre in Peloponnese, therefore 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).

For the establishment of the theoretical road connections, the common methodology was implemented. 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. Exeptionally, 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, 105 theoretical connections were determined as shown in *Figure 4.1*

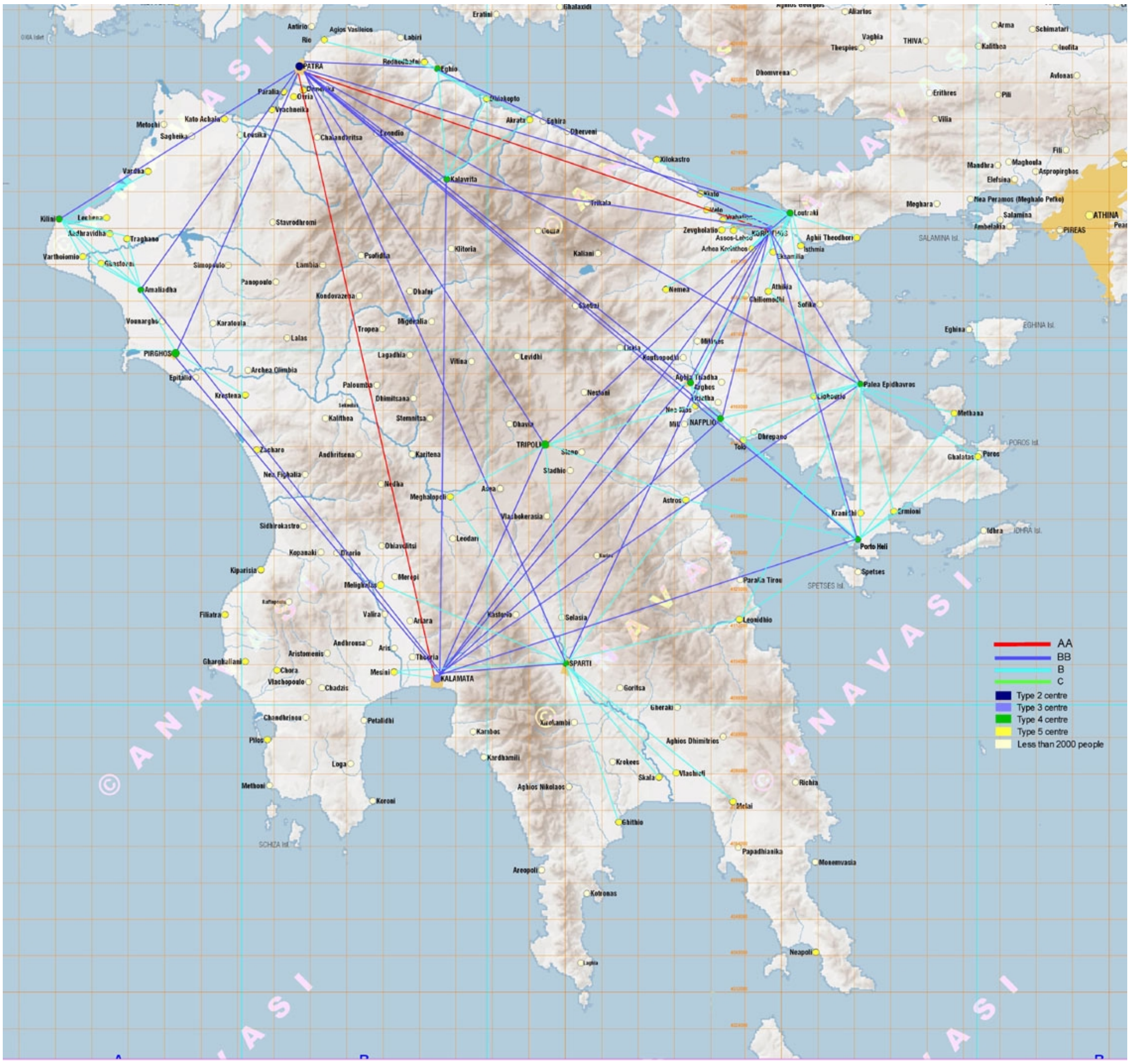


Figure 4.1 Summary of theoretical connections.

4.4 Identification and matching of actual connections

No official national digital map and related GIS tools were available for this study, therefore a route planner (TopoNavigator v3.4) was used instead for the determination of the actual connections. 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. On the other hand, it was obligatory to use the road classification of the route planner and translate this into the SafetyNet road classification, as shown in *Table 4.2*.

SafetyNet category	TopoNavigator 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 4.2 Translating the local road categories into SafetyNet road categories.

The main limitation of the road classification of the route planner was the lack of information on road separation. On the basis of the author's knowledge of the road network in the study area, as well as of previous surveys carried out in the study area, a couple of adjustments were made in order to include road sections with separation (e.g. small section of 16 km with median in the Patra-Korinthos national road).

As a general remark, it can be said that the SafetyNet road categorization might be too strict for the particular setting. In particular, 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 seldom or not at all 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 (see *Appendix 4A*). The following remarks can be made:

- If a maximum detour factor equal to 1.6 was to be considered, as suggested in the Manual, 34% 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% and 1% respectively).

Considering a maximum detour factor higher then 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.

The actual connections matched to a theoretical connection are presented in *Figure 4.2*, where the road category of each segment of the connection is also highlighted.

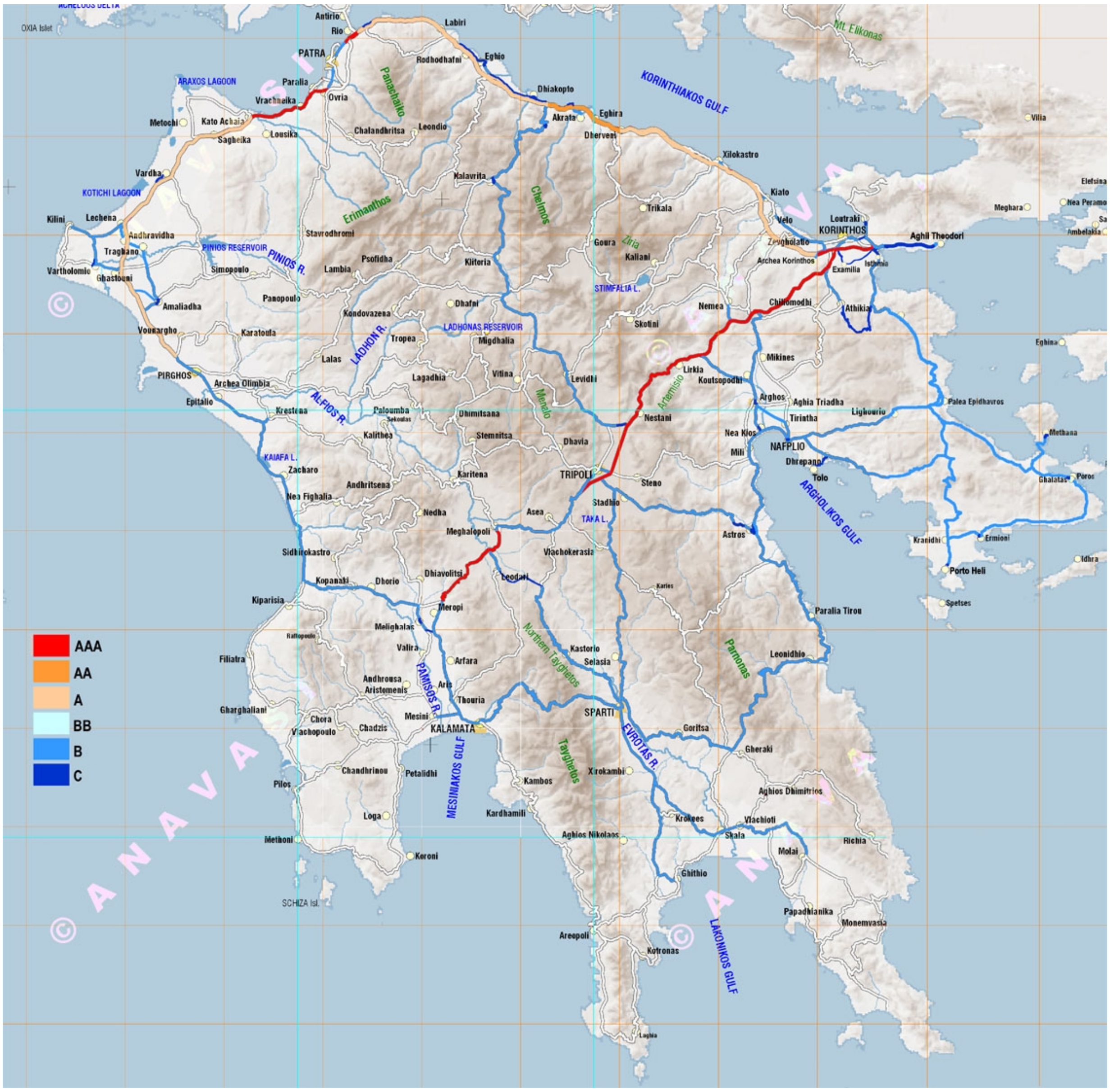


Figure 4.2 Summary of actual connections.

4.5 Calculation of the SPI

Following the above, the road network SPI for the study area was calculated as shown in *Table 4.3* and *Figure 4.3.* In total, 6,979 kilometres of road were examined, out of which 4,344 were of appropriate or higher actual road category than the theoretical one, resulting in a total road SPI equal to 66.5% 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 4.3*, theoretical connections of type AA are met only by 10% of the total length of the actual connections.

Respectively, around 52% 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 93% for type B connections. It is also interesting to note that about 10% of the total length of these connections corresponds to AAA and A roads, confirming the fact that a limited number of roads is used for many connections.

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	5.6%	4.8%	48.9%	0.0%	40.3%	0.4%
A	0,0%	0.0%	0.0%	0.0%	0.0%	0.0%
BB	20.2%	3.9%	27.5%	0.0%	46.7%	1.8%
B	8.7%	0.0%	4.1%	0.0%	80.7%	6.6%
C	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 4.3 SPI scores per road category (table).

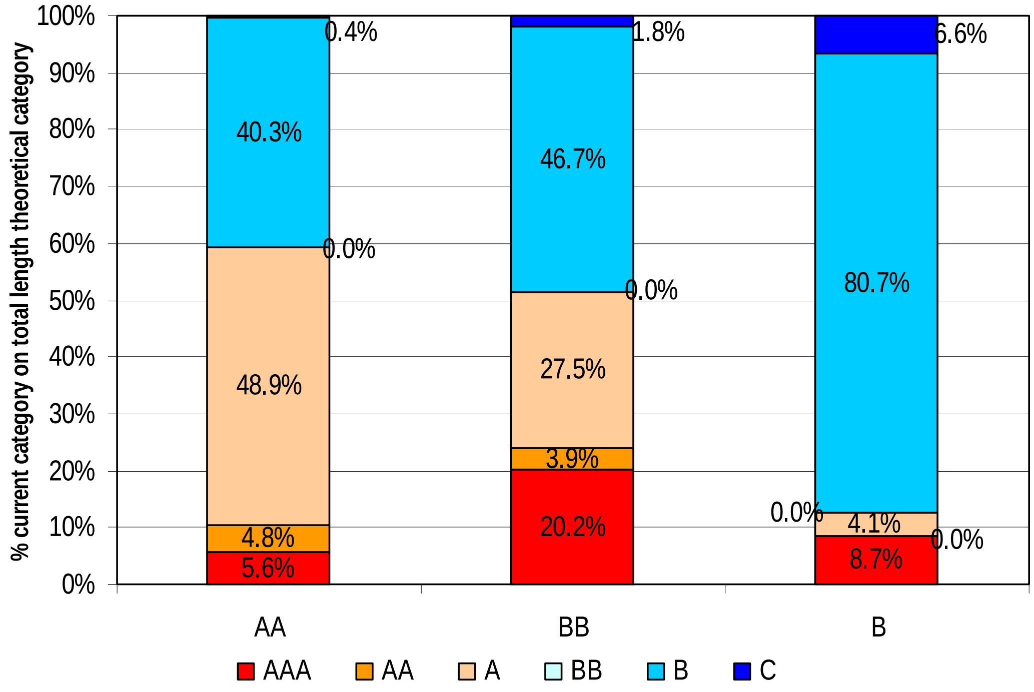


Figure 4.3 SPI scores per road category

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.

4.6 Conclusions and discussion

The Greek pilot study revealed a number of issues that could further improve the methodology and its efficiency on future pilots. More specifically, according to the real conditions and the particularities of each study area, the methodology should be adapted by implementing small changes.

Regarding the definition and classification of the centres, it was anticipated that population as a unique measure is not an optimal indicator. For the Greek pilot, 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 resulting list of urban centres was concluded to be a good representation of reality.

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 very large, the radius of the respective circular search area would be very high resulting in connections that normally do not have sense. 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 Greek pilot, 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 had no meaning. It was initially decided to drop this circular area. Later, 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. The main limitation was however the lack of information on road separation. Moreover, the SafetyNet road categorization might be too strict for Greece, since there is seldom a dual carriageway for lower-level roads. This results in a quite low SPI score, especially for the AA (10% of the roads that should be AA are in fact AA or higher) and BB (52% of the roads that should be BB are in fact BB or higher) road categories.

A detour factor of 1,6 was concluded not to be realistic for the Greek pilot 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.

Appendix 4A Testing different detour factors

	Connection		Length	Celestial latitude	Factor = 1,6 Assigned?	Factor = 2 Assigned?	Factor = 3 Assigned?
1	Amaliadha	Andravidha	18.12	14.2	Yes	Yes	Yes
2	Amaliadha	Gastouni	12.3	10.5	Yes	Yes	Yes
3	Amaliadha	Pirghos	20.06	16	Yes	Yes	Yes
4	Amaliadha	Traghano	12.44	11.6	Yes	Yes	Yes
5	Amaliadha	Vartholomio	17.15	14.6	Yes	Yes	Yes
6	Arghos	Nafplio	11.72	9.9	Yes	Yes	Yes
7	Arghos	NeaKios	5.92	5.3	Yes	Yes	Yes
8	Eghio	Rio/AgiosVassilios	31.67	25	Yes	Yes	Yes
9	Eghio	Akrata	32.09	23.2	Yes	Yes	Yes
10	Eghio	Diakofto	15.47	12.6	Yes	Yes	Yes
11	Eghio	Kalavrita	49.86	24.4	No	No	Yes
12	Eghio	Rododafni	3.62	3.1	Yes	Yes	Yes
13	Kalamata	Kalavrita	178.33	110	No	Yes	Yes
14	Kalamata	PaleaEpidavros	189.61	113.5	No	Yes	Yes
15	Kalamata	PortoHeli	231.66	97.3	No	No	Yes
16	Kalamata	Amaliadha	132.38	107.4	Yes	Yes	Yes
17	Kalamata	Korinthos	166.16	123.6	Yes	Yes	Yes
18	Kalamata	Mesini	10.74	9	Yes	Yes	Yes
19	Kalamata	Nafplio	151.45	84.5	No	Yes	Yes
20	Kalamata	Pirghos	111.73	92.1	Yes	Yes	Yes
21	Kalamata	Sparti	57.35	28.5	No	No	Yes
22	Kalamata	Tripoli	88.59	56.9	Yes	Yes	Yes
23	Kalavrita	Akrata	45.87	22.5	No	No	Yes
24	Kalavrita	Diakofto	37.16	19.8	No	Yes	Yes
25	Kalavrita	Eghio	49.79	24.3	No	No	Yes
26	Kilini	Amaliada	28.22	23.8	Yes	Yes	Yes
27	Kilini	Andravida	15.86	11.5	Yes	Yes	Yes
28	Kilini	Gastouni	17.17	13.3	Yes	Yes	Yes
29	Kilini	Lehena	12.38	10.4	Yes	Yes	Yes
30	Kilini	Tragano	20.29	15.5	Yes	Yes	Yes
31	Kilini	Vardha	26.93	22	Yes	Yes	Yes
32	Kilini	Vartholomio	12.17	9.7	Yes	Yes	Yes
33	Korinthos	Kalavrita	109.92	72.1	Yes	Yes	Yes
34	Korinthos	PaleaEpidavros	54.51	39.5	Yes	Yes	Yes
35	Korinthos	PortoHeli	107.31	74.7	Yes	Yes	Yes
36	Korinthos	ArcheaKorinthos	8.55	5.7	Yes	Yes	Yes
37	Korinthos	Eghio	95.34	81.6	Yes	Yes	Yes
38	Korinthos	Examilia	6.27	4.7	Yes	Yes	Yes
39	Korinthos	Kalamata	166.5	123.6	Yes	Yes	Yes
40	Korinthos	Lourtaki	7.47	5.9	Yes	Yes	Yes
41	Korinthos	Nafplio	61.14	43.3	Yes	Yes	Yes
42	Korinthos	Sparti	138.99	105.6	Yes	Yes	Yes
43	Loutraki	AghiiTheodhori	20.13	15	Yes	Yes	Yes
44	Loutraki	ArcheaKorinthos	18.75	11.5	No	Yes	Yes
45	Loutraki	Arghos	59.05	43.6	Yes	Yes	Yes
46	Loutraki	Asos	25.09	13	No	Yes	Yes
47	Loutraki	Athikia	29.87	17.9	No	Yes	Yes
48	Loutraki	Examilia	15.15	9.6	Yes	Yes	Yes
49	Loutraki	Isthmia	8.51	6.8	Yes	Yes	Yes
50	Loutraki	Kiato	38.15	20.4	No	Yes	Yes
51	Loutraki	Lighourio	62.24	40.6	Yes	Yes	Yes
52	Loutraki	Nemea	48.07	32.5	Yes	Yes	Yes
53	Loutraki	Velo	30.91	18.6	No	Yes	Yes
54	Loutraki	Vrachati	27.01	14.6	No	Yes	Yes
55	Loutraki	Xilokastro	51.8	32	No	Yes	Yes
56	Loutraki	Zevgholatio	26.41	15.8	No	Yes	Yes
57	Nafplio	Arghos	11.72	9.9	Yes	Yes	Yes
58	Nafplio	Nea Kios	7.59	6	Yes	Yes	Yes

					Factor = 1,6	Factor = 2	Factor = 3
	Connection		Length	Celestial latitude	Assigned?	Assigned?	Assigned?
59	Palea Epidavros	Athikia	46.89	28.8	No	Yes	Yes
60	Palea Epidavros	Ermioni	54.3	28.9	No	Yes	Yes
61	Palea Epidavros	Galatas	38.58	30.3	Yes	Yes	Yes
62	Palea Epidavros	Kranidi	46.76	28.4	No	Yes	Yes
63	Palea Epidavros	Ligourio	15.07	10.5	Yes	Yes	Yes
64	Palea Epidavros	Methana	40.56	21.6	No	Yes	Yes
65	Palea Epidavros	Tolo	42.67	29.2	Yes	Yes	Yes
66	Palea Epidavros	Nafplio	38.8	32	Yes	Yes	Yes
67	Patra	Kalavrita	86.8	41	No	No	Yes
68	Patra	Killini	74.12	62.8	Yes	Yes	Yes
69	Patra	PaleaEpidavros	181.6	142.4	Yes	Yes	Yes
70	Patra	PortoHeli	234.4	164.2	Yes	Yes	Yes
71	Patra	Amaliadha	82.1	60.4	Yes	Yes	Yes
72	Patra	Arghos	172.24	110.9	Yes	Yes	Yes
73	Patra	Eghio	38.08	30.3	Yes	Yes	Yes
74	Patra	Kalamata	208.83	138.7	Yes	Yes	Yes
75	Patra	Korinthos	132.6	110	Yes	Yes	Yes
76	Patra	Loutraki	142.7	113.3	Yes	Yes	Yes
77	Patra	Nafplio	182.94	121	Yes	Yes	Yes
78	Patra	Pirghos	97.65	69.2	Yes	Yes	Yes
79	Patra	Sparti	259.18	144	No	Yes	Yes
80	Patra	Tripoli	203.79	99.4	No	No	Yes
81	Pirghos	Amaliadha	21.2	16	Yes	Yes	Yes
82	Pirghos	Krestena	20.66	18.2	Yes	Yes	Yes
83	Porto Heli	Astros	113.2	40.9	No	No	Yes
84	Porto Heli	Ermioni	17.67	12.2	Yes	Yes	Yes
85	Porto Heli	Galatas	56.51	33.2	No	Yes	Yes
86	Porto Heli	Kranidi	6.82	6.7	Yes	Yes	Yes
87	Porto Heli	Leonidio	159.78	30.4	No	No	No
88	Porto Heli	Ligourio	58.8	33.2	No	Yes	Yes
89	Porto Heli	Methana	78.5	36	No	No	Yes
90	Porto Heli	Nafplio	80.59	40.1	No	No	Yes
91	Porto Heli	Tolo	74.95	33.3	No	No	Yes
92	Sparti	Meligalas	84.8	44.2	No	Yes	Yes
93	Sparti	Astros	86.57	44.5	No	Yes	Yes
94	Sparti	Ghithio	43.32	37	Yes	Yes	Yes
95	Sparti	Leonidhio	81.14	39.7	No	No	Yes
96	Sparti	Meghalopoli	63.84	44.7	Yes	Yes	Yes
97	Sparti	Messini	68.12	37.9	No	Yes	Yes
98	Sparti	Molai	64.77	47.9	Yes	Yes	Yes
99	Sparti	Skala	37.6	32.3	Yes	Yes	Yes
100	Sparti	Tripoli	57.77	48.4	Yes	Yes	Yes
101	Sparti	Vlachiotis	41.66	34.2	Yes	Yes	Yes
102	Tripoli	Arghos	54.64	35	Yes	Yes	Yes
103	Tripoli	Astros	40.17	33.6	Yes	Yes	Yes
104	Tripoli	Meghalopoli	34.17	23.5	Yes	Yes	Yes
105	Tripoli	NeaKios	60.5	34.2	No	Yes	Yes

5 Israeli pilot

VICTORIA GITELMAN[C]

[C]Technion

5.1 Introduction

For Israel, the whole country served as a pilot area and the road network SPI was calculated for a sample of the road network.

The country has a territory of 22,073 square kilometres, of which 21,643 kilometres is land area. The country is not equally populated: the majority of population is concentrated in Tel-Aviv, Central, Haifa and Jerusalem districts (13.8% of the total land area); the Northern district is less densely populated (20.7% of the total land area), where the Southern district is the largest (65.5% of the total) and is scarcely-populated one. A significant part of the Southern district is covered by deserts.

In 2006, the average population of the country was 7,054 ,000 inhabitants. The total road network is 17,686 kilometres, of which 7,854 kilometres are rural roads (CBS, 2007a). The rural network includes: 167 kilometres of motorways (with 100-110 km/h speed limits), 963 kilometres of dual-carriageway roads (with 90 km/h speed limits), whereas the remaining 6,724 kilometres are undivided roads (with typically 80 km/h speed limits), including 1,594 kilometres of access roads.

The list of urban areas considered was the whole list of administrative units (municipalities/ towns/ villages/ communities) of the country, which is maintained by the Central Bureau of Statistics (CBS, 2007b). Urban centres for the pilot were sampled based on this list.

5.2 Definition and classification of centres

To calculate the Road Network SPI for the pilot the steps outlined in the manual were followed. The classification of the urban areas according to their sizes was performed using five types as defined in *Table 2.2*.

The data is provided by the Central Bureau of Statistics (CBS, 2007b) and availably on a administrative units level (municipalities/ towns/ villages/ communities). Each administrative unit (local authority) has defined boundaries and the number of inhabitants (the data applied were of year 2006). The data on industrial areas, shopping areas, etc, are not available on a systematic basis and therefore, were not taken into consideration. The definitions of administrative units were not changed for the pilot.

In total, for year 2006, in the country there were: 5 units of type 1, 9 units of type 2, 36 units of type 3, 64 units of type 4 and about 1,100 units of type 5 (1,057 units with known number of inhabitants and 54 with an unknown number). *Table 5.1* shows the list of centres for Israel.

Centre type				
1	2	3	4	5
JERUSALEM	BE'ER SHEVA	HERZLIYYA	ABU SINAN	ABBIRIM
TEL AVIV - YAFO	PETAH TIQWA	KEFAR SAVA	ARAD	ABU GHOSH
HAIFA	NETANYA	HADERA	AR'ARA	ADAMIT
RISHON LEZIYYON	HOLON	RA'ANNANA	AR'ARA-BANEGEV	ADANIM
ASHDOD	BENE BERAQ	BET SHEMESH	ARI'EL	ADDERET
	RAMAT GAN	LOD	ARRABE	ADDIRIM
	BAT YAM	NAZARETH	AZOR	ADI
	ASHQELON	RAMLA	BEIT JANN	ADORA
	REHOVOT	MODI'IN-MAKKABBIM-RE'U	BET SHE'AN	AFEQ
		NAHARIYYA	BETAR ILLIT	AFIQ
		QIRYAT ATTA	BINYAMINA-GIV'AT ADA	AFIQIM
		GIV'ATAYIM	EIN MAHEL	AGUR
		QIRYAT GAT	EL'AD	AHAWA
		ELAT	FUREIDIS	AHI'EZER
		AKKO	GAN YAVNE	AHIHUD
		HOD HASHARON	GANNE TIQWA	AHISAMAKH
		KARMI'EL	GEDERA	AHITUV
		NAZERAT ILLIT	GIV'AT SHEMU'EL	AHUZZAM
		UMM AL-FAHM	GIV'AT ZE'EV	AHUZZAT BARAQ
		RAHAT	I'BILLIN	AL-ARYAN
		TIBERIAS	IKSAL	AL-AZY
		QIRYAT MOTZKIN	IR KARMEL	ALE ZAHAV
		AFULA	JISR AZ-ZARQA	ALFE MENASHE
		ROSH HAAYIN	JUDEIDE-MAKER	ALLON HAGALIL
		QIRYAT YAM	KAFAR KANNA	ALLON SHEVUT
		RAMAT HASHARON	KAFAR MANDA	ALLONE ABBA
		QIRYAT BIALIK	KAFAR QARA	ALLONE HABASHAN
		MODI'IN ILLIT	KAFAR QASEM	ALLONE YIZHAQ
		TAYIBE	KEFAR YONA	ALLONIM
		SHEFAR'AM	KOKHAV YA'IR	ALMA
		DIMONA	KUSEIFE	ALMAGOR
		YAVNE	MA'ALE IRON	ALMOG
		MA'ALE ADUMMIM	MA'ALOT-TARSHIHA	ALMON
		BAQA -JATT	MEVASSERET ZIYYON	ALUMIM
		OR YEHUDA	MIGDAL HAEMEQ	ALUMMA
		NES ZIYYONA	MUGHAR	ALUMMOT
			NAHEF	AMAZYA
			NESHER	AMIR
			NETIVOT	AMIRIM
			OFAQIM	AMMI'AD
			OR AQIVA	AMMINADAV
			PARDES HANNA-KARKUR	AMMI'OZ
			QALANSAWE	AMMIQAM
			QIRYAT MAL'AKHI	AMNUN
			QIRYAT ONO	AMQA
			QIRYAT SHEMONA	AMUQQA
			QIRYAT TIV'ON	ANI'AM
			REINE	ARAMSHA
			SAKHNIN	ARBEL
			SEDEROT	ARGAMAN
			SHAGHOR	ARSUF
			SHOHAM	ARUGOT
			TAMRA	ASERET
			TEL SHEVA	ASFAR
			TIRAT KARMEL	ASHALIM
			TIRE	ASHDOT YA'AQOV(IHUD
			TUR'AN	ASHDOT YA'AQOV(ME'U
			YAFI	ASHERAT
			YEHUD	ATERET
			YIRKA	ATLIT
			YOQNE'AM ILLIT	AVDON

Table 5.1 Lists of centres of Israel. For type 5, only the beginning of the list is presented.

The selection of urban areas for the pilot was random, from each group of certain type. To define the number of units required for each type, the following rules were applied:

- to provide a representative coverage, it is generally recommended to select 3 units or at least 5%, per each type (Hakkert and Gitelman, 2007);
- on the other hand, the total amount of units of each type should be accounted for.

Therefore, for the pilot, 8 urban centres (i.e. initial points for making circular areas for the analysis) were selected, including: one type 1 centre, one type 2 centre, three type 3 centres and three type 4 centres.

5.3 Determination of theoretically desired connections

Once the urban centres are defined, the theoretically desired connections between the centres can be determined. The basis for defining the theoretically desired connections relies on search circles around each one of the urban centres selected for the study. The radius of each circle is defined by the shortest distance between two centres of the same type, starting from the urban centre selected (and drawn with each town as the midpoint). The area within each circle is considered as the area of influence of that specific town. Connections to other towns (of smaller size) are analyzed within the circle area defined.

Using the guidelines provided for the pilot and a map, the following process was applied:

1. Select type 1 centre as the starting centre.
2. Locate this centre on the map and search for the nearest centre of the same type.
3. Measure the distance between the centres. This becomes the radius for the search area defined by a circle around the starting centre.
4. Within the search area note all the type 2 and 3 centres.

In a similar manner the search area around type 2 centre was defined and all the type 3 and type 4 centres within the search area were identified. The process was repeated for all type 3 and 4 centres, and all smaller centres within each search area were identified in this way.

According to the guidelines, in the above procedure, an exception was made for selecting type 5 centers within the type 3 search area: not all the type 5 centres were considered but only those which fell into the distance between the basic type 3 and the nearest type 4 centres. In the case when a type 4 centre was not available (within the type 3 circular search area), at least 10 type 5 centres were considered.

Applying the above procedure to each centre resulted in a list with all connections that need to be assessed.

5.4 Identification and matching of actual connections

The actual road connections between the urban centres were found using a geographic information system. For each pair of units a *basic connection* was defined which is typically the shortest route, going through the highest road classes. Each connection (route) is a composition of segments, where each segment is defined by a road number and length.

To characterize the actual road connections, a "translation" of Israeli rural road categories into the SafetyNet road categories was required. The correspondence applied in the pilot is presented in *Table 5.2*.

SafetyNet class	Israeli rural road type
AAA	Motorway or dual-carriageway road with grade-separated junctions
AA	Main dual carriageway road, typically 2 digit number, heavily-traveled
A	Main single carriageway road, typically 2 digit number, heavily-traveled
BB	Regional dual carriageway road, typically 3 digit number
B	Regional single carriageway road, typically 3 digit number
C	Local road, typically 4 digit number

Table 5.2 Suggested correspondence between the Israeli road types and SafetyNet road classes.

Using the definition of road categories in *Table 5.2*, a connection between two centres can be characterized in terms of composition of road categories: the proportion of length (or percentage) of the connection corresponding to each road category.

We need to note here that at the beginning of the pilot, for each pair of urban centres also additional actual connections (routes) were defined, using a spectrum of up to 45 degrees around the geographic direction of the basic connection and a possible length of up to 1.6 times the basic connection. This way, between major centres, 3-4 routes were found, and 1-2 routes between minor units. In total, over 200 routes were defined for the connections between the urban centres selected for the pilot. When several routes are available per a connection, the different route compositions should be weighted to provide a summary figure; the weights were assigned according to actual preferences in using different routes connecting two towns (expert judgment). Such calculations were performed for all the connections defined for the pilot (the results are available). However, comparisons revealed that weighting of several routes for the same connection always results in a worse characteristic of the connection than it could be using the *basic connection* only. Thus, as we are not interested in a systematic lowering of the evaluation results, on the one hand, and, conversely, accounting for the conditions of pilots carried out in other countries (the use of automatic route planners, with typically shortest and best routes' selection), we decided to perform the evaluations in the Israeli pilot using the basic (i.e. the best available) connections only.

5.5 Results for each circular search area

As mentioned before, 8 urban centres were selected for the Israeli pilot. Each centre dictates a circular search area with all urban centres for which connections with the original centre should be found and evaluated. The evaluation implies a comparison of the theoretical and actual road connections to establish a degree of compliance. The results for each case (circular search area) are presented below.

5.5.1 Type 1 centre

The type 1 urban centre selected was Tel Aviv. As can be seen from the map (*Figure 5.1*), according to the rules, the nearest type 1 centre, to define the circular search area, might be Rishon LeZiyyon. However, in this case, the two type 1 centres are separated by another urban area only and therefore it is reasonable to expect that a significant proportion of traffic between the two centres goes through urban connections. To solve this problem, an additional rule was suggested stating that another centre of the same type should be separated from the original centre by a rural area. Thus, the nearest type 1 centre in this case should be Ashdod, which dictated the radius of the search area. Type 2 and 3 centres belonging to the area selected are indicated in *Figure 5.1*, in blue and yellow colours, accordingly.

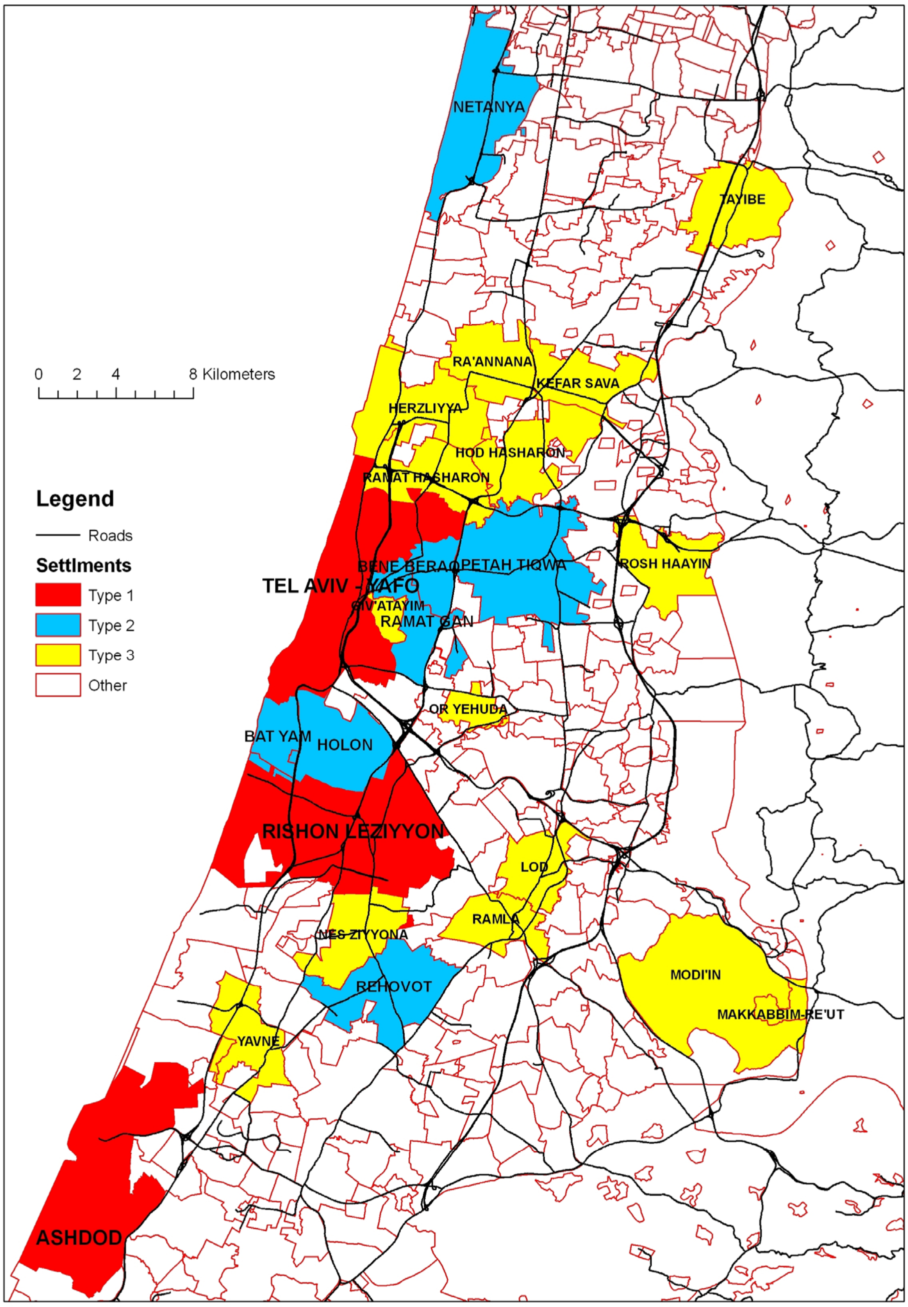


Figure 5.1 Urban centres in the search area of type 1 centre (Tel Aviv).

Another question raised in this context was whether all the centres of "lower" type should be considered for the evaluation of road connections available between the urban centres? The connections are estimated in terms of rural road types, and, therefore, the consideration becomes irrelevant when the majority of traffic between the two centres may go through the urban streets. Thus, it was suggested that other urban centres selected for the evaluation of road connections should not have a common border with the original urban centre (one that dictated the search circle).

The urban centres, which were finally involved in the evaluation of Tel Aviv circle area, are listed in *Table 5.3*. For type 1 and 2 centres the required (theoretical) connection should be of AAA type (a motorway or dual-carriageway road with grade-separated junctions), for type 3 centres – of AA type (main dual-carriageway road).

Table 5.3 provides the results of assessing the actual connections. It can be seen that many actual connections comprise several road types. Comparing the existing roads with the theoretical requirements, it can be seen that:

– for type 1 and 2 centres, the connections meet the requirements in three out of four cases;

– for type 3 centres, the connections satisfy the demand ("meets" or "exceeds") in four out of twelve cases; one case (Tel Aviv – Taibe) fails clearly (as part of the connection goes through a single-carriageway road), where in seven cases (marked as "fails*") the fact of failure can be considered as *conditional*. This is due to the fact that BB road type found for these connections also indicates a dual-carriageway road, like AA type (required). The major difference between the BB and AA road type is in their classification as "regional" versus "main" road. Differences between the two road types can be seen in the design speed, lane width, shoulder width, etc. However, both types are equipped with safety barriers on medians, barriers or obstacle-free zones on roadsides, characterized by high traffic volumes (especially, in the centre of the country) and have similar traffic control devices at intersections.

		Connection type							Length of current connection	
Starting centre:	TEL AVIV - YAFO	**Current**						Theoretical	km	**Current vs theoretical**
Nearest centre:		**AAA**	**AA**	**A**	**BB**	**B**	**C**			
Type 1 Within search area	ASHDOD	**100,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**		AAA	34,7	Meets
Type 2	NETANYA	**100,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**		AAA	16,3	Meets
	PETAH TIQWA	**100,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**		AAA	10,2	Meets
	REHOVOT	**36,6%**	**0,0%**	**0,0%**	**63,4%**	**0,0%**		AAA	19,4	Fails
Type 3	OR YEHUDA	**65,67%**	**0,00%**	**0,0%**	**34,3%**	**0,0%**		AA	9,8	Fails*
	HOD HASHARON	**72,05%**	**0,00%**	**0,0%**	**27,9%**	**0,0%**		AA	12,8	Fails*
	HERZLIYYA	**100,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**		AA	2,4	Exceeds
	TAYIBE	**34,7%**	**0,0%**	**0,0%**	**38,5%**	**26,9%**		AA	26,5	Fails
	YAVNE	**100,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**		AA	20,7	Exceeds
	KEFAR SAVA	**85,8%**	**0,0%**	**0,0%**	**14,2%**	**0,0%**		AA	10,7	Fails*
	LOD	**94,8%**	**5,2%**	**0,0%**	**0,0%**	**0,0%**		AA	15,4	Meets
	MODI'IN-MAKKABBIM	**62,7%**	**0,0%**	**0,0%**	**37,3%**	**0,0%**		AA	27,8	Fails*
	NES ZIYYONA	**64,9%**	**30,5%**	**0,0%**	**4,6%**	**0,0%**		AA	17,2	Fails*
	ROSH HAAYIN	**68,9%**	**0,0%**	**0,0%**	**31,1%**	**0,0%**		AA	15,2	Fails*
	RAMLA	**9,0%**	**91,0%**	**0,0%**	**0,0%**	**0,0%**		AA	15,5	Meets
	RA'ANNANA	**89,8%**	**0,0%**	**0,0%**	**10,2%**	**0,0%**		AA	10,9	Fails*

Table 5.3 Evaluation of connections in type 1 centre search area (Tel Aviv as starting centre). Fails means a connection fails conditional (see text for a further explanation).*

5.5.2 Type 2 centre

The type 2 urban centre selected was Bat Yam. The nearest type 2 centre, to define the circular search area, was Rehovot. The urban centres, involved in the evaluation in this case, are listed in *Table 5.4*: in total, five type 3 and five type 4 centres. For type 2 and 3 centres the theoretical connection should be of AA type (main dual-carriageway roads), for type 4 centres – of BB type (regional dual-carriageway roads).

Table 5.4 provides the results of assessing the actual connections. As previously, many actual connections comprise several road types. Comparing the existing roads with the theoretical requirements, it can be seen that in the majority of cases the existing connections meet or exceed the requirements for road categories. This result includes three cases of "conditional" failure (marked as "fail*") which can be accepted due to the similarity between the BB and AA road types (see above an explanation for the type 1 centre).

One connection (Bat Yam-Ganne Tiqwa) should be judged as not satisfactory as part of it goes through a local (type C) road.

		Connection type							Length of current connection	
Starting centre:	BAT YAM	**Current**						Theoretical	km	**Current vs theoretical**
Nearest centre:		**AAA**	**AA**	**A**	**BB**	**B**	**C**			
Type 2	REHOVOT	**20.8%**	**0.0%**	**0.0%**	**79.2%**	**0.0%**	**0.0%**	AA	14.9	Fails*
Within search area										
Type 3	OR YEHUDA	**42.1%**	**0.0%**	**0.0%**	**57.9%**	**0.0%**	**0.0%**	AA	12.6	Fails*
	YAVNE	**100.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	AA	14.7	Exceeds
	NES ZIYYONA	**26.9%**	**0.0%**	**0.0%**	**73.1%**	**0.0%**	**0.0%**	AA	11.5	Fails*
	RAMLA	**23.0%**	**77.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	AA	18.2	Meets
	RAMAT HASHARON	**100.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	AA	18.4	Exceeds
Type 4	AZOR	**100.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	BB	6.7	Exceeds
	GIV'AT SHEMU'EL	**100.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	BB	16.9	Exceeds
	GANNE TIQWA	**68.7%**	**0.0%**	**0.0%**	**20.7%**	**0.0%**	**10.6%**	BB	18.0	Fails
	YEHUD	**69.1%**	**0.0%**	**0.0%**	**30.9%**	**0.0%**	**0.0%**	BB	16.9	Meets
	QIRYAT ONO	**62.0%**	**0.0%**	**0.0%**	**38.0%**	**0.0%**	**0.0%**	BB	13.7	Meets

Table 5.4 Evaluation of connections in type 2 centre search area (Bat Yam as starting centre).

5.5.3 Type 3 centres

Three type 3 urban centres were selected for building search areas. They are: Qiryat Yam (in the north of the country), Qiryat Gat (in the south) and Ra'annana (in the centre of the country).

For Qiryat Yam, the nearest type 3 centre was Qiryat Atta, which defined the circular search area. This area did not include any type 4 centre; all type 5 centres were considered. In total, the area included three urban centres, as presented in Table 5.5.

For Qiryat Gat, the nearest type 3 centre was Bet Shemesh, which defined the circular search area. This area included four type 4 centres, where the nearest type 4 centre was Qiryat Malakhi. The distance between the type 3 and the nearest type 4 centre defined the circular search area for type 5 centres, where 37 type 5 centres were identified. All the urban centres included in this case are presented in Table 5.6.

For Ra'annana, the nearest type 3 centre was Hod Hasharon, which defined the circular search area. This area did not include any type 4 centre; therefore, all type 5 centres were identified (10 in total). The urban areas of this case are presented in Table 5.7.

In all these cases, for type 3 and 4 centres the theoretical connection should be of BB type (regional dual-carriageway roads), for type 5 centres – of B type (regional single-carriageway road).

Table 5.5 to Table 5.7 provide the results of assessing the actual connections. As in the previous cases, many actual connections consist of several road types. Comparing the existing roads with the theoretical requirements, it can be seen that:

- for connections between type 3 and type 3 or type 4 urban centres, the required road type (dual-carriageway road) is usually available;
- as to type 3-type 5 connections, the situation changes depending on the country region. In the north and center of the country (densely populated areas), the existing connections typically meet or exceed the requirements for road categories, whereas in the south of the country, in the majority of cases (two thirds) the existing connection fails to satisfy the requirement. This is due to fact that most of the small centres/ villages are not situated along the main roads (of types AA or BB, i.e. dual-carriageway roads) but on an access road (of C type). In some cases (marked as "fails*" in Table 9), the share of type C is small, less than 10% of the total length of connection and the result can, therefore, be judged as acceptable.

Table 3c - Type 3 centres

		Connection type							Length of current connection	
Starting centre:	QIRYAT YAM	**Current**						Theoretical	km	**Current vs theoretical**
Nearest centre:		**AAA**	**AA**	**A**	**BB**	**B**	**C**			
Type 3	QIRYAT ATTA	**0,0%**	**46,2%**	**0,0%**	**0,0%**	**53,8%**	**0,0%**	BB	5,0	Fails
Within search area	n/a							BB		
Type 4	[centre type 4] n/a									
Nearest centre:	KEFAR BIALIK	**0,0%**	**68,4%**	**0,0%**	**0,0%**	**31,6%**	**0,0%**	B	3,4	Meets

Table 5.5 Evaluation of connections in type 3 centre search area (Qiryat Yam as starting centre).

Table 3c - Type 3 centres

		Connection type							Length of current connection	
Starting centre:	QIRYAT GAT	**Current**						Theoretical	km	**Current vs theoretical**
Nearest centre:		**AAA**	**AA**	**A**	**BB**	**B**	**C**			
Type 3	BET SHEMESH	**0,0%**	**3,1%**	**96,9%**	**0,0%**	**0,0%**	**0,0%**	BB	31,9	Exceeds
Type 4	GEDERA	**0,0%**	**100,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**	BB	28,8	Exceeds
	GAN YAVNE	**0,0%**	**100,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**	BB	33,9	Exceeds
	QIRYAT MAL'AKHI	**0,0%**	**100,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**	BB	14,4	Exceeds
	SEDEROT	**0,0%**	**29,2%**	**0,0%**	**0,0%**	**70,8%**	**0,0%**	BB	26,8	Fails
Nearest centre:	QIRYAT MAL'AKHI									
Within search area	Qedma	0%	91%	0%	0%	0%	9%	B	11,6	Fails*
Type 5	Negba	0%	83%	0%	0%	0%	17%	B	11,3	Fails
	Temurim	0%	100%	0%	0%	0%	0%	B	12,6	Exceeds
	Avigdor	0%	97%	0%	0%	0%	3%	B	17,2	Fails*
	Sapir	0%	58%	0%	0%	0%	42%	B	12,0	Fails
	Ein Zurim	0%	54%	4%	0%	0%	42%	B	13,0	Fails
	Masoot Itzhak	0%	48%	17%	0%	0%	34%	B	14,5	Fails
	Zrihia	0%	78%	0%	0%	0%	22%	B	9,0	Fails
	Nir Banim	0%	88%	0%	0%	0%	13%	B	8,0	Fails
	Sgula	0%	90%	0%	0%	0%	10%	B	6,7	Fails*
	Vardon	0%	90%	0%	0%	0%	10%	B	6,7	Fails*
	Nahala	0%	75%	0%	0%	0%	25%	B	8,0	Fails
	Gat	0%	50%	0%	0%	50%	0%	B	8,0	Meets
	Zbadiel	0%	100%	0%	0%	0%	0%	B	4,0	Exceeds
	Komamiot	0%	53%	0%	0%	0%	47%	B	7,5	Fails
	Aluma	0%	67%	0%	0%	0%	33%	B	6,0	Fails
	Uza	0%	100%	0%	0%	0%	0%	B	0,7	Exceeds
	Noam	0%	50%	0%	0%	0%	50%	B	6,0	Fails
	Shalva	0%	71%	0%	0%	0%	29%	B	4,2	Fails
	Eitan	0%	86%	0%	0%	0%	14%	B	3,5	Fails
	Even Shmuel	0%	86%	0%	0%	0%	14%	B	3,5	Fails
	Ahuzam	0%	93%	0%	0%	0%	7%	B	5,4	Fails*
	Yad Natan	0%	100%	0%	0%	0%	0%	B	7,5	Exceeds
	Noga	0%	78%	0%	0%	22%	0%	B	10,2	Meets
	Shahar	0%	60%	0%	0%	26%	14%	B	13,3	Fails
	Nir Hen	0%	63%	0%	0%	28%	9%	B	12,7	Fails*
	Nehura	0%	70%	0%	0%	30%	0%	B	11,4	Meets
	Sde Yoav	0%	100%	0%	0%	0%	0%	B	9,6	Exceeds
	Cohav Mihael	0%	85%	0%	0%	15%	0%	B	13,0	Meets
	Zohar	0%	58%	0%	0%	39%	4%	B	13,9	Fails*
	Sde David	0%	49%	0%	0%	51%	0%	B	16,3	Meets
	Tlamim	0%	46%	0%	0%	52%	2%	B	17,3	Fails*
	Heletz	0%	41%	0%	0%	57%	2%	B	19,3	Fails*
	Beit Nir	0%	24%	0%	0%	76%	0%	B	17,0	Meets
	Glaon	0%	31%	0%	0%	69%	0%	B	13,0	Meets
	Sde Moshe	0%	28%	56%	0%	0%	17%	B	3,6	Fails
	Lachish	0%	10%	63%	0%	0%	27%	B	9,6	Fails

Table 5.6 Evaluation of connections in type 3 centre search area (Qiryat Gat as starting centre).

		Connection type							Length of current connection	
Starting centre:	RA'ANNANA	Current						Theoretical	km	Current vs theoretical
Nearest centre:		**AAA**	**AA**	**A**	**BB**	**B**	**C**			
Type 3	HOD HASHARON	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**0.0%**	**0.0%**	BB	1.7	Meets
Within search area										
Type 4	n/a									
Nearest centre:	[centre type 4]							BB		
	n/a									
Type 5 (all)	ARSUF	**50.3%**	**0.0%**	**0.0%**	**49.7%**	**0.0%**	**0.0%**	B	13.1	Exceeds
	BET BERL	**0.0%**	**0.0%**	**0.0%**	**79.9%**	**0.0%**	**20.1%**	B	4.9	Fails
	BENE ZIYYON	**0.0%**	**70.8%**	**0.0%**	**0.0%**	**0.0%**	**29.2%**	B	4.5	Fails
	BAZRA	**0.0%**	**100.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	B	2.3	Exceeds
	GELIL YAM	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**0.0%**	**0.0%**	B	4.1	Exceeds
	GAN HAYYIM	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**0.0%**	**0.0%**	B	3.1	Exceeds
	GANNE AM	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**0.0%**	**0.0%**	B	3.6	Exceeds
	GA'ASH	**56.4%**	**0.0%**	**0.0%**	**43.6%**	**0.0%**	**0.0%**	B	14.7	Exceeds
	KEFAR MALAL	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**0.0%**	**0.0%**	B	0.9	Exceeds
	SHEFAYIM	**50.3%**	**0.0%**	**0.0%**	**49.7%**	**0.0%**	**0.0%**	B	13.1	Exceeds

Table 5.7 Evaluation of connections in type 3 centre search area (Ra'annana as starting centre).

5.5.4 Type 4 centres

Three type 4 urban centres were selected for building search areas. They are: Kafar Qara (in the north of the country), Beit Jann (in the north) and Kefar Yona (in the centre of the country).

For Kafar Qara, the nearest type 4 centre was Ar'ara, which defined the circular search area. This area included 12 type 5 urban centres, as presented in Table 5.8.

For Beit Jann, the nearest type 4 centre was Nahef, which defined the circular search area. This area included 16 type 5 urban centres, as presented in Table 5.9.

For Kefar Yona, the nearest type 4 centre was Zoran-Qadima, which defined the circular search area. This area included 11 type 5 urban centres, as presented in Table 5.10.

In these cases, for both type 4 and 5 centres the theoretical connection should be of B type (regional single-carriageway roads).

Table 5.8 to Table 5.10 provide the results of assessing the actual connections. As in previous cases, many actual connections consist of several road types. Comparing the existing roads with the theoretical requirements, it can be seen that the majority of existing connections (both type 4-type 4 and type 4-type 5) failed to satisfy the requirement for road type. The main reason for this is that most of the small centres/ villages are not situated along the main road (of types AA, BB, A or B) but on an access road (type C). In several cases in the centre of the country (marked as "fails*" in Table 5.10), the share of type C is small, less than 10% of the total length of connection, which enables to judge the results as satisfactory.

		Connection type							Length of current connection	
Starting centre:	KAFAR QARA	Current						Theoretical	km	Current vs theoretical
Nearest centre:		AAA	AA	A	BB	B	C			
Type 4	AR'ARA	0.0%	84.7%	0.0%	0.0%	0.0%	15.3%	B	2.6	Fails
Within search area										
Type 5	KEFAR GLIKSON	0.0%	0.0%	0.0%	0.0%	40.9%	59.1%	B	8.6	Fails
	MA'ANIT	0.0%	55.5%	0.0%	0.0%	44.5%	0.0%	B	7.6	Meets
	KEFAR PINES	0.0%	83.1%	0.0%	0.0%	0.0%	16.9%	B	9.4	Fails
	EN IRON	0.0%	83.1%	0.0%	0.0%	0.0%	16.9%	B	9.4	Fails
	QAZIR-HARISH	0.0%	48.5%	0.0%	0.0%	13.7%	37.7%	B	8.7	Fails
	GIV'AT NILI	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	B	6.5	Fails
	REGAVIM	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	B	3.5	Fails
	ALLONE YIZHAQ	0.0%	0.0%	0.0%	0.0%	44.5%	55.5%	B	7.9	Fails
	AVI'EL	0.0%	0.0%	0.0%	0.0%	57.9%	42.1%	B	10.4	Fails
	BARQAY	0.0%	75.4%	0.0%	0.0%	24.6%	0.0%	B	5.6	Meets
	EN SHEMER	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	B	8.2	Exceeds
	UMM AL-QUTUF	0.0%	48.5%	0.0%	0.0%	13.7%	37.7%	B	8.7	Fails

Table 5.8 Evaluation of connections in type 4 centre search area (Kafar Qara as starting centre).

		Connection type							Length of current connection	
Starting centre:	BEIT JANN	Current						Theoretical	km	Current vs theoretical
Nearest centre:		AAA	AA	A	BB	B	C			
Type 4	NAHEF	0.0%	0.0%	36.1%	0.0%	40.9%	23.0%	B	13.1	Fails
Within search area										
Type 5	AMIRIM	0.0%	0.0%	22.0%	32.0%	29.5%	16.5%	B	18.2	Fails
	HURFEISH	0.0%	0.0%	36.1%	0.0%	47.6%	16.4%	B	18.3	Fails
	MORAN	0.0%	0.0%	17.8%	0.0%	47.0%	35.2%	B	11.4	Fails
	PEQI'IN (BUQEI'A)	0.0%	0.0%	0.0%	0.0%	54.8%	45.2%	B	6.6	Fails
	RAME	0.0%	0.0%	0.0%	0.0%	56.5%	43.5%	B	6.9	Fails
	SAJUR	0.0%	0.0%	13.5%	0.0%	49.5%	37.0%	B	10.8	Fails
	SHEZOR	0.0%	0.0%	18.2%	0.0%	52.4%	29.4%	B	10.2	Fails
	SHEFER	0.0%	0.0%	22.0%	32.0%	29.5%	16.5%	B	18.2	Fails
	PAROD	0.0%	0.0%	24.8%	23.6%	33.1%	18.6%	B	16.2	Fails
	MERON	0.0%	0.0%	16.9%	24.5%	45.9%	12.7%	B	23.7	Fails
	KAMMON	0.0%	0.0%	22.4%	0.0%	30.0%	47.6%	B	17.8	Fails
	EIN AL-ASAD	0.0%	0.0%	24.0%	16.8%	32.1%	27.0%	B	16.7	Fails
	HARASHIM	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	B	5.0	Fails
	HALUZ	0.0%	8.2%	16.3%	0.0%	44.9%	30.6%	B	24.5	Fails
	HAZON	0.0%	0.0%	28.8%	0.0%	45.2%	25.9%	B	17.3	Fails
	KEFAR HANANYA	0.0%	0.0%	34.8%	0.0%	40.8%	24.4%	B	14.3	Fails

Table 5.9 Evaluation of connections in type 4 centre search area (Beit Jann as starting centre).

		Connection type							Length of current connection	
Starting centre:	KEFAR YONA	Current						Theoretical	km	Current vs theoretical
Nearest centre:		AAA	AA	A	BB	B	C			
Type 4	ZORAN-QADIMA	0.0%	92.7%	0.0%	0.0%	0.0%	7.3%	B	6.8	Fails*
Within search area										
Type 5	BURGETA	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	B	2.8	Exceeds
	BET HALEWI	0.0%	73.5%	0.0%	0.0%	0.0%	26.5%	B	6.2	Fails
	BET YIZHAQ-SH. HEFER	0.0%	82.2%	0.0%	0.0%	0.0%	17.8%	B	4.4	Fails
	KEFAR MONASH	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	B	4.5	Exceeds
	NORDIYYA	0.0%	79.6%	0.0%	0.0%	0.0%	20.4%	B	3.3	Fails
	TENUVOT	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	B	2.8	Exceeds
	YANUV	0.0%	81.7%	0.0%	0.0%	0.0%	18.3%	B	2.7	Fails
	GE'ULIM	0.0%	59.7%	0.0%	0.0%	0.0%	40.3%	B	3.7	Fails
	PARDESIYYA	0.0%	90.9%	0.0%	0.0%	0.0%	9.1%	B	4.4	Fails*
	ZUR MOSHE	0.0%	90.9%	0.0%	0.0%	0.0%	9.1%	B	4.4	Fails*
	HANNI'EL	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	B	1.5	Fails

Table 5.10 Evaluation of connections in type 4 centre search area (Kefar Yona as starting centre).

5.6 Calculation of the SPI scores

According to the SPI Manual (Hakkert & Gitelman, 2007), to calculate the road network SPI, the current and theoretical networks are compared to each other, where the road network SPI is the percentage of appropriate current road category length per theoretical road category length. "Appropriate" in this case means that the current road category is equal to or higher than the theoretical road category (where AAA is the highest and C is the lowest category).

Looking at the pilot structure and results in detail, one can note that we actually estimate 11 cases of requirements for a certain road category (for a connection between the two defined types of urban areas), where each case is presented by different number of real connections considered. Such a description of the pilot results is summarized in *Table 5.11*. It can be seen that the number of real connections considered per a case changes from 1 to 49.

When the number of real connections per case is more than one, there is a need for a combination (weighting) of separate results to attain a final estimate. A simple statistical technique for estimating the sample mean and variance in this case, is given in *Appendix 5A.*

Urban centre	Type 1	Type 2	Type 3	Type 4	Type 5
Type 1	Case 1: AAA required, 1 connection considered	Case 2: AAA required, 3 connections considered	Case 3: AA required, 12 connections considered	Indirectly*	Indirectly*
Type 2		Case 4: AA required, 1 connection considered	Case 5: AA required, 5 connections considered	Case 6: BB required, 5 connections considered	Indirectly*
Type 3			Case 7: BB required, 3 connections considered	Case 8: BB required, 4 connections considered	Case 9: B required, 49 connections considered
Type 4				Case 10: B required, 3 connections considered	Case 11: B required, 39 connections considered
Type 5					C*

*Table 5.11 Structure of the pilot results: number of real connections considered per each theoretical road link which is required between the defined urban centres *not considered*

In the Israeli pilot, we applied unequal weights of connections which were according to their actual lengths. Calculating the variance, an unbiased estimator was used (see *Appendix 5A*). The final estimates - weighted means and standard deviations – of the proportions of connections which correspond to the appropriate (of higher) road categories, for each case considered, are presented in *Table 5.12*.

Case (types of centres connected)	Desired road category	Actual road category: weighted results (wm ± sd)*						Satisfies the requirement
		AAA	AA	A	BB	B	C	
Case 1 (1-1)**	AAA	100.0%	0%	0%	0%	0%	0%	100%
Case 2 (1-2)	AAA	73.3% ± 38.9%	0%	0%	26.7%	0%	0%	73%
Case 3 (1-3)	AA	66.0% ± 27.6%	10.9% ± 27.1%	0%	19.3%	3.9%	0%	77%
Case 4 (2-2)**	AA	20.8%	0%	0%	79.2%	0%	0%	21%
Case 5 (2-3)	AA	60.6% ± 39.8%	18.6% ± 37.0%	0%	20.8%	0%	0%	79%
Case 6 (2-4)	BB	77.7% ± 17.7%	0%	0%	19.6% ± 16.8%	0.0%	2.6%	97%
Case 7 (3-3)	BB	0%	8.5% ± 26.5%	80.0% ± 67.1%	4.5% ± 38.0%	6.9%	0%	93%
Case 8 (3-4)	BB	0%	81.7% ± 36.2%	0%	0%	18.3%	0%	82%
Case 9 (3-5)	B	4.9% ± 15.5%	57.1% ± 31.9%	2.5% ± 10.8%	7.9% ± 22.3%	17.1% ± 24.9%	10.5%	90%
Case 10 (4-4)	B	0%	38.0% ± 59.9%	20.9% ± 23.8%	0%	23.7% ± 27.1%	17.3%	83%
Case 11 (4-5)	B	0%	20.5% ± 35.2%	13.5% ± 12.6%	6.5% ± 11.8%	30.9% ± 19.5%	28.7%	71%

*Table 5.12 Estimates of the proportions of connections corresponding to the required (or higher) road categories, in 11 cases considered. *wm – weighted mean, sd – standard deviation. **only one actual connection available; no weighting applied.*

It can be seen from *Table 5.12* that in many cases where weighted estimates were calculated, the standard deviation is high or relatively high in comparison with the mean value. Such results indicate that the final estimates are surrounded by a high level of uncertainty, which could stem, on the one hand, from relatively low numbers of the actual connections considered (per a case) and, conversely, from high variability of shares of the road types which form these connections.

Summing up the results based on the mean values only, the shares of road lengths which satisfy (or exceed) the requirements will be as presented in the last column in *Table 5.12*. In addition, *Figure 5.2* shows, for each theoretical road category, a summary distribution of the current road categories, as those were observed in the connections included in the Israeli pilot. One can see that:

– the only connection which fully satisfies the theoretical demand is between the two biggest cities (type1-type 1 urban areas), which are connected by a motorway;

– another connection where a motorway/ grade-separated road is expected (type1-type2 urban areas) includes more than a quarter of dual-carriageway roads with at-grade junctions and therefore, fails to satisfy the requirement;

– for the connections where main dual-carriageway roads are required (AA-type) the level of compliance varies widely (20%-80%) but can be greatly improved (up to 100%) if we accept that BB-type roads can serve as a substitute for the AA-type;

– for the connections where regional dual-carriageway roads are required (BB-type) the level of compliance is relatively high (82%-97%). However, it can be questioned at least in one case (type3-type 3 areas' connection), because a significant share of the connection goes through an A-type road, which is a single-carriageway road and therefore not necessarily a better safety class than the BB-type road;

– for the connections where at least regional single-carriageway roads are expected (B-type) the level of compliance is relatively high (70%-90%) but not full because certain shares of these connections go through local (C-type) roads.

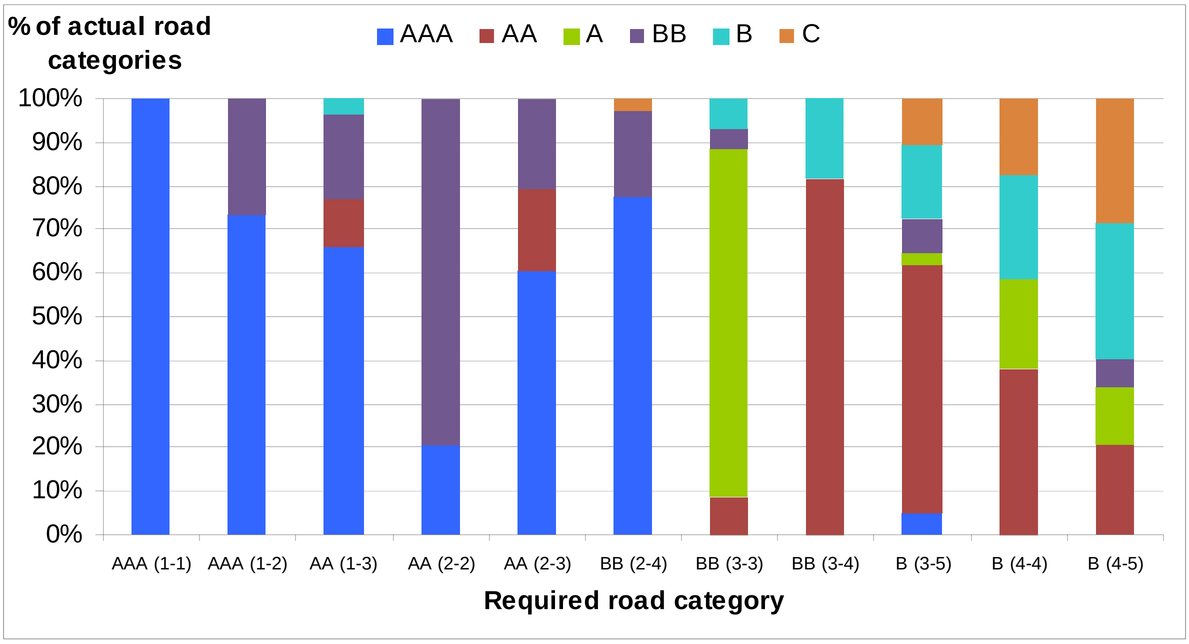


Figure 5.2 A summary correspondence between the required and actual road categories in the connections included in the Israeli pilot.

To calculate the final SPIs and obtain the values comparable with other pilots, for each theoretically required road category, the percentage of appropriate current road categories is estimated. The final scores are shown in *Table 5.13* and *Figure 3.7*.

Theoretically desired road category	Current road category					
	AAA	AA	A	BB	B	*C*
AAA	84.8%	0.0%	0.0%	15.2%	0.0%	*0.0%*
AA	62.1%	12.4%	0.0%	22.9%	2.6%	*0.0%*
A	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BB	26.1%	41.1%	14.4%	7.4%	10.1%	*0.9%*
B	2.6%	40.3%	7.9%	7.1%	23.4%	*18.7%*
C	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5.13 Final SPI scores per road category.

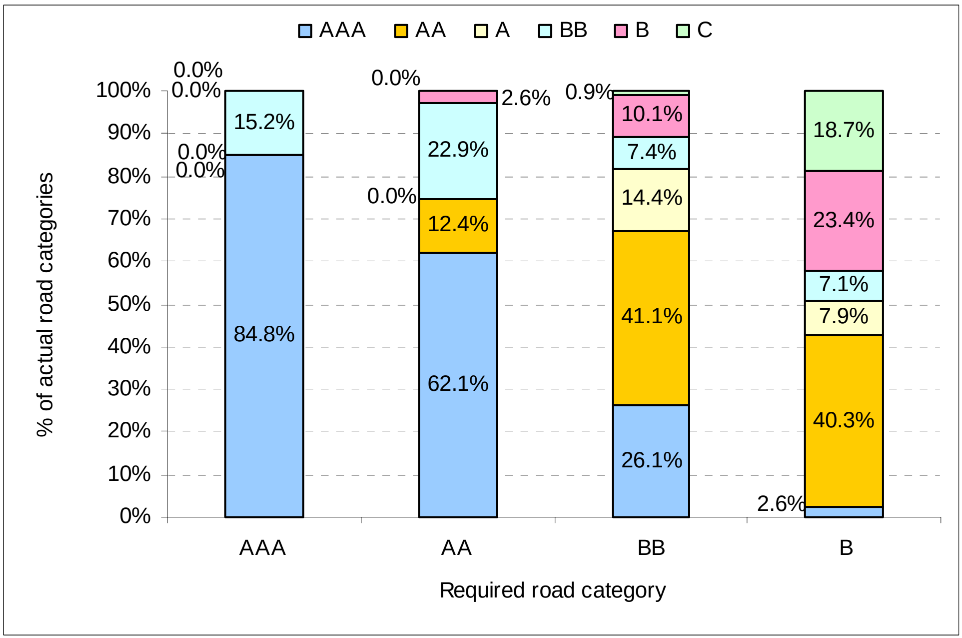


Figure 5.3 Final SPI scores per road category.

It can be seen that for most road categories, the actual road categories comply fairly well with the theoretically desired road category: 85% of the required AAA roads are in fact AAA roads, 89% of the required BB roads are in fact BB or higher road categories, and 81% of the required B category roads are B or higher level roads.

The requirements for AA roads are less often met: only 74.5% of the roads that need to be AA are in reality AA or AAA roads, implying that 25.5% of the connections belong to lower road categories. (However, as mentioned previously, the differences between the AA and BB road categories are not strict in Israeli conditions, meaning that actual BB-type connections sometimes have road design characteristics similar to the AA-type roads).

Overall, some 81% of the connections considered for the Israeli road network meet or exceed the SafetyNet classification requirements.

5.7 Conclusions and discussion

In general, the method suggested for the pilot's performance seems clear and realizable. Carrying out the Israeli pilot, some adaptations of the method were made, in accordance with the country's conditions and data availability.

The urban centres considered were from the official list of administrative units of the country, where the definition of urban centres was based on the number of inhabitants. Other information on the land use, which could influence the actual trips' generation, was not accounted for as it is not available on a systematic basis for the majority of urban centres.

Within the pilot, the connections between the urban centres are estimated in terms of rural road types, and, therefore, the consideration becomes irrelevant when the majority of traffic between the two centres may go through the urban streets. Hence, two supplementary rules were introduced for selecting the centres: first, another centre of the same type should be separated from the original centre by a rural area; second, other urban centres (of lower type) should not have a common border with the original urban centre, which dictated the search circle.

The Israeli pilot did not use a predefined area. Instead, the urban centres which determined the circular search areas (in order to characterize the available road connections) were selected using a random sampling from the whole list of urban centres of the country. This approach enabled to select and consider the road connections from different regions of the country, which, as expected, were not identical. If a certain area of the country was selected for the pilot, the evaluation results would probably be different. Hence, the way of selection of urban centers should be similar if one plans to compare the results from different countries.

The actual road connections between the urban centres were found using a geographic information system. The search was not fully automatic but did apply expert knowledge on the network structure and use. For each pair of centres the best available connection was defined, which is typically the shortest route, going through the highest road classes. At this step, for each pair of urban centres also additional actual connections (routes) were identified. However, the calculations demonstrated that weighting of several routes for the same connection typically results in a worse characteristic of the connection than it could be using the best available connection only. Thus, the consideration of several routes for the same connections was excluded from the pilot's results.

In general, one should remember that the definition of existing connections did not consider the information on actual use of roads, i.e. on traffic volumes, origin-destination patterns, etc. This means that the evaluation concerned mostly the *possibility* of use of the existing road network and not the actual network's performance in serving the traffic.

To characterize the actual road connections on a common basis, Israeli rural road categories were "translated" into the SafetyNet road classes. The correspondence suggested seems reasonable, in general, but raises reservations when specific evaluation results are considered. For example, a reservation arose in the case when a requirement for the AA-road type was stated and the BB-road type was observed (and the case was consequently judged as "failing" to satisfy the requirement), because both types represent dual-carriageway roads with rather similar road design characteristics and equipment.

Another reservation concerns the stated priority of A-road type over the BB-road type (the main single-carriageway road and regional dual-carriageway road, accordingly), because the safety benefits of the A-type road over the BB-type are not obvious under Israeli conditions. In general, the SafetyNet road classification seems too complicated and not fully applicable for a specific country.

The majority of actual connections analyzed comprise several road types. In many cases, existing connections, especially those connecting bigger urban centres, meet or exceed the requirements for road categories. However, the findings are not uniform and vary widely, depending on the geographic region, centre type, etc. As a result, the final (weighted) estimates per a connection type have high or relatively high standard deviations, indicating a high level of uncertainty of the results.

The road network SPIs were estimated based on the mean values of shares of road lengths which satisfy (or exceed) the requirements, for each connection type. The level of compliance for various connection types was of 70%-90%, with 100% compliance for the biggest centres' connection. When the SPI scores were estimated for the aggregated road categories, the level of compliance between the actual and the theoretically desired categories was relatively high, of 81%-89%, in the cases of the required AAA-, BB- and B-road categories, where as for the AA-required category, the level of compliance was lower, of 75%. Overall, some 81% of the connections considered for the Israeli road network meet or exceed the SafetyNet classification requirements.

In general, the pilot's results seem reasonable and representative for the Israeli road network. The lower levels of correspondence which were observed for some connection types can be partially related to the interpretation of the SafetyNet road classes for Israeli road network (e.g. the case of BB-road type available when the AA-type is required). Besides, in the case of connection with very small (type 5) centres, the presence of a short share of the type C road should probably not be treated as a "failure". This is because such a result frequently reflects the situation where the village is situated on an access road and not on a higher trafficked main or regional road, which can be judged as an even preferable location due to safety reasons.

Appendix 5A Statistical technique for estimating weighted mean and weighted sample variance

Weighted mean

The weighted mean, or weighted average, of a non-empty set of data

$$[x_1, x_2, \dots, x_n],$$

with weights

$$[w_1, w_2, \dots, w_n],$$

is the quantity calculated by

$$\bar{x} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i},$$

which means:

$$\bar{x} = \frac{w_1 x_1 + w_2 x_2 + \cdots + w_n x_n}{w_1 + w_2 + \cdots + w_n}.$$

So data elements with a high weight contribute more to the weighted mean than do elements with a low weight. The weights must not be negative. They may be zero, but not all of them (because division by zero is not allowed).

Weighted sample variance

Typically when you calculate a mean it is important to know the variance and standard deviation of that mean. When a weighted mean μ^* is used, the variance of the weighted sample is different from the variance of the unweighted sample.

The *biased* weighted sample variance is defined similarly to the normal *biased* sample variance:

$$\sigma^2_{\mathrm{normal}} = \frac{\sum_{i=1}^{N} (x_i - \mu)^2}{N} \qquad \sigma^2_{\mathrm{weighted}} = \frac{\sum_{i=1}^{N} w_i (x_i - \mu^*)^2}{\sum_{i=1}^{N} w_i}$$

For small sample of populations, it is customary to use **an unbiased estimator** for the population variance. In normal unweighted samples, the *N* in the denominator (corresponding to the sample size) is changed to $N - 1$. Thus, the unbiased estimator of weighted population variance is given by:

$$s^2 = \frac{\sum_{i=1}^{N} w_i}{\left(\sum_{i=1}^{N} w_i\right)^2 - \sum_{i=1}^{N} {w_i}^2} \sum_{i=1}^{N} w_i \left(x_i - \mu^*\right)^2$$

Which can also be written in terms of running sums for programming as:

$$s^2 = \frac{\sum_{i=1}^{N} w_i {x_i}^2 \sum_{i=1}^{N} w_i - \left(\sum_{i=1}^{N} w_i x_i\right)^2}{\left(\sum_{i=1}^{N} w_i\right)^2 - \sum_{i=1}^{N} {w_i}^2}$$

The standard deviation is simply the square root of the variance above.

6 Portuguese pilot

CARLOS LIMA AZEVEDO[D], ELISABETE ARSÉNIO[D], JOÃO CARDOSO[D]

[D]LNEC

6.1 Introduction

The national continental territory bellow Tagus River was chosen as the Portuguese pilot study for the calculation of Road Network SPI. This area is around 34,000 km^2 and has a total of 1,700,000 habitants (2006 estimation) and 1,050,000 habitations (2006). The region is divided into five NUTS 3 regions[2]: Península de Setúbal, Alentejo Litoral, Alto Alentejo, Alentejo Central; Baixo Alentejo and Algarve. This area has several types and sizes of urban areas, various road types and also good conditions for urban areas identification, and thus satisfies the criteria for the implementation of a pilot study. However it is not representative of all major roads at the country level.

The pilot area is characterised by a very disperse human occupation except in the Setúbal Península and the South coast of the Algarve. Both these regions are also characterised by intense industrial, commercial or touristic activities.

The entire pilot modelling, the classification of urban centres, the identification of links to be assessed, the development of a routing model and the calculation of road network SPI were performed in ArcGis (ESRI, 2005).

Data related to territory occupation (geometry, population and number of houses) was collected at the Portuguese smallest administrative unit level called Freguesia (Civil Parish). The pilot area comprises a total number of 438 Freguesias (see *Figure 6.1*). These data were collected at the INE (Instituto Nacional de Estatística) for the population and housing information, and at the IGEO (Instituto Geográfico Português), for the GIS geometry.

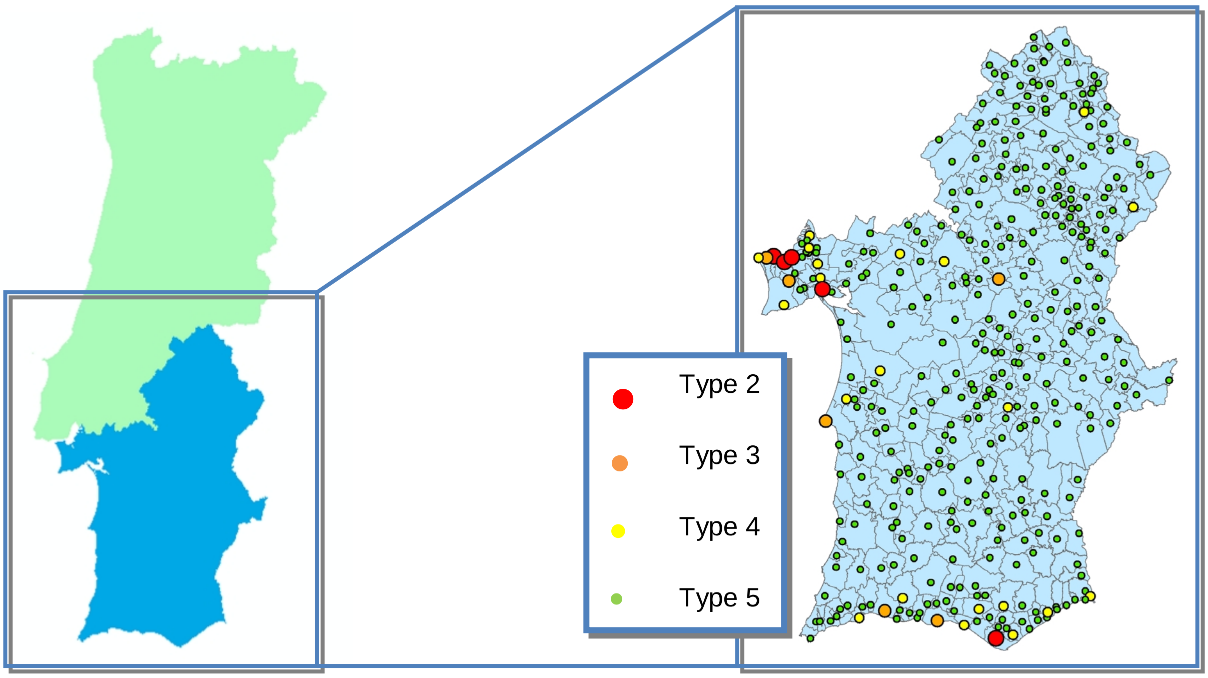


Figure 6.1 Portuguese Pilot Area and Urban Centres by Class.

[2] Nomenclature of Territorial Units for Statistics - a standard for referencing the divisions of countries for statistical purposes, developed by the EU

The road network comprises a total of 160,516 links which corresponds to 28,000 km of road. The GIS network information was provided by InfoPortugal S.A. (http://www.infoportugal.pt/), a Portuguese company focused on geographic data information and navigation systems.

6.2 Identification and Classification of urban centres

In the pilot area, the topology of the human occupation and the local administrative historic evolution stands out a generic and direct relationship between each Freguesia and single urban centres. Therefore, each urban center was associated with the respective Freguesia and its coordinates were related to the coordinates of the correspondent administrative headquarters.

However, some groups of Freguesias represent the same urban area, forcing a meticulous analysis of the territory for particular cases, which implied the merging of Freguesias (see *Figure 6.2*). The housing density, the road connectivity and satellite images were the main factors used as merging criteria. This analysis resulted in a final number of 372 urban centres.

The estimation of the population for each urban center was based on the 2001 national census and on the growth of the population of the corresponding Municipality between 2001 and 2006 (See Equation 1 and 2).

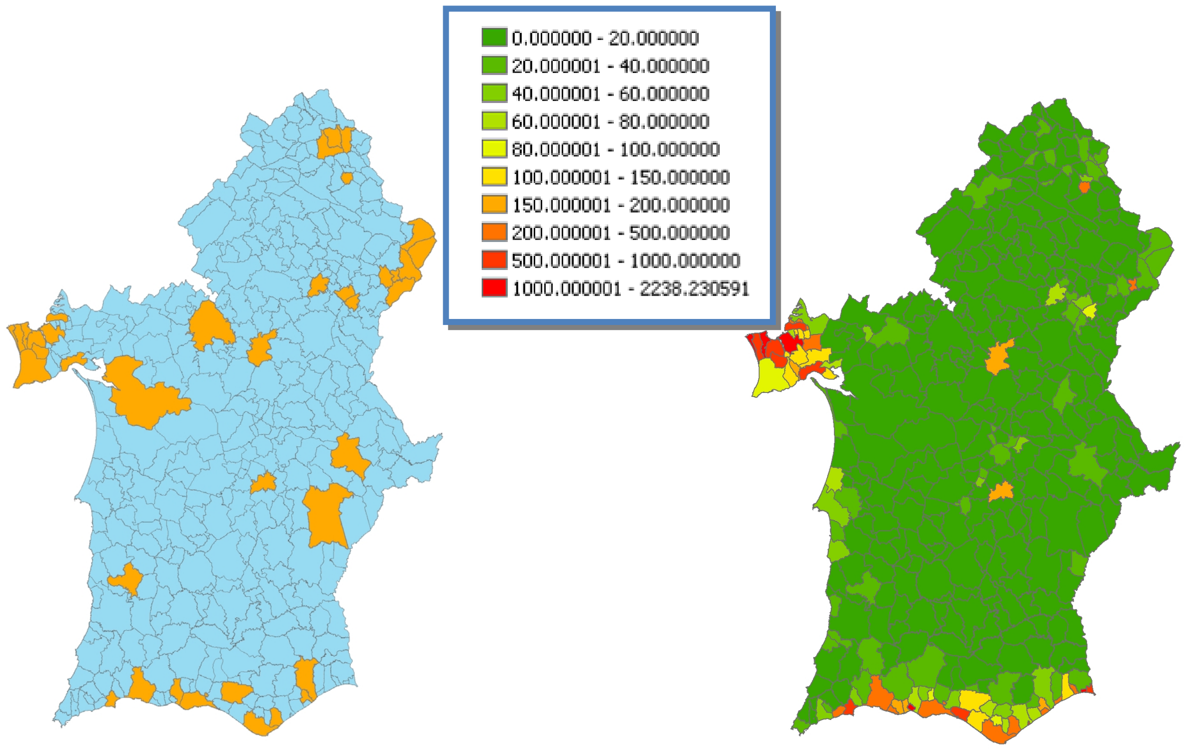


Figure 6.2 *Freguesias merged and housing density by Freguesia (number of homes/km²).*

$$Pop_{\text{Freguesia Merged}} = Pop_{\text{Fre 1}} + Pop_{\text{Freg 2}} \qquad \text{(Eq.1)}$$

$$Pop^{2006}_{Fre} = Pop^{2001}_{Fre} \cdot \left(1 + \frac{Pop^{2006}_{Mun} - Pop^{2001}_{Mun}}{Pop^{2001}_{Mun}} \right) \qquad \text{(Eq.2)}$$

Following the guidelines provided by the SafetyNet Manual, the population was used as a classification criterion according to *Table 2.2*. Using this classification, the pilot area does not include any Type 1 centre, as the most populated urban center is Almada with 148,361 inhabitants. Another remark is that there are many urban centres (170) with less than 1,000 inhabitants, suggesting the importance of Type 5 centres.

As mentioned in *Section 2.b*) of *Appendix A*, the classification method can be improved by considering additional indicators besides the number of inhabitants. The added data should have influence in the amount of traffic between the urban centres in the pilot area. In this particular case, infrastructures that have an important contribution to the attraction of road traffic were considered. Important port and airport facilities were considered as criteria in upgrading urban centre categories. Therefore, the SafetyNet classification of three urban centres was changed considering this attraction factor:

– Faro, in the Algarve, changed from Type 3 to Type 2 (Airport facility)

– Setúbal, in the Península de Setúbal, changed from Type 3 to Type 2 (Port facility)

– Sines, in the Alentejo Litoral, changed from Type 4 to Type 3 (Port facility)

The south coast of the Algarve is a major touristic region at the national level. Housing densities are substantially greater for the Freguesias in this region than in the rest of the pilot area (see *Figure 6.2*). These urban centres generate an important amount of traffic during the touristic summer season (May to September). The impact of this traffic on the network was not taken into account. However, it should be mentioned at once that it represents an important factor that has to be considered in deeper analysis of this region. Nevertheless, the introduction of tourist and recreation attraction factors and the definition of the thresholds for accounting their effects should be carefully analyzed, as it depends on multiple variables besides the traffic volume and the periods of traffic.

The resulting classification is shown in *Table 6.1* (see also *Figure 6.1*).

Centre type				
1	2	3	4	5
	Almada	Sines	Alcochete	*340 URBAN CENTRES*
	Seixal	Charneca	Vendas Novas	
	Barreiro	Fernão Ferro	Pinhal Novo	
	Setúbal	Évora	Palmela	
	Faro	Portimão	Grândola	
		Albufeira	Santo Andre	
			Silves	
			S. Brás de Alportel	
			V.R.S. António	
			Quarteira	
			Costa da Caparica	
			Montijo	
			Sesimbra	
			Montemor-o-Novo	
			Elvas	
			Beja	
			Lagos	
			Loulé	
			Olhão	
			Portalegre	
			Tavira	

Table 6.1 Urban Centres in the Portuguese Pilot Study – Final classification.

6.3 Determination of theoretically desired connections

After the identification and classification of the pilot area urban centres, the next step was the determination of the theoretical connections. Following the method presented in *Chapter 2*, circular search areas were used for each of the urban centres (Type 2, 3 and 4). For this purpose, the radius of each search area was obtained from the closest urban centre of the same type, except for the connections between Type 3 and Type 5, where the radius of the search area was obtained from the distance to the closest Type 4 centre. The search areas of all urban centres in the pilot area are represented in the *Figure 6.3*. In this picture we can also see the Type 3 urban centre Albufeira (marked with a red arrow on the close-up) with two different search areas: a smaller for the identification of links with Type 5 centres and the largest for the connections with Type 4 centres.

For Type 5 centres, the connection with the closest urban centre of the same type was assessed.

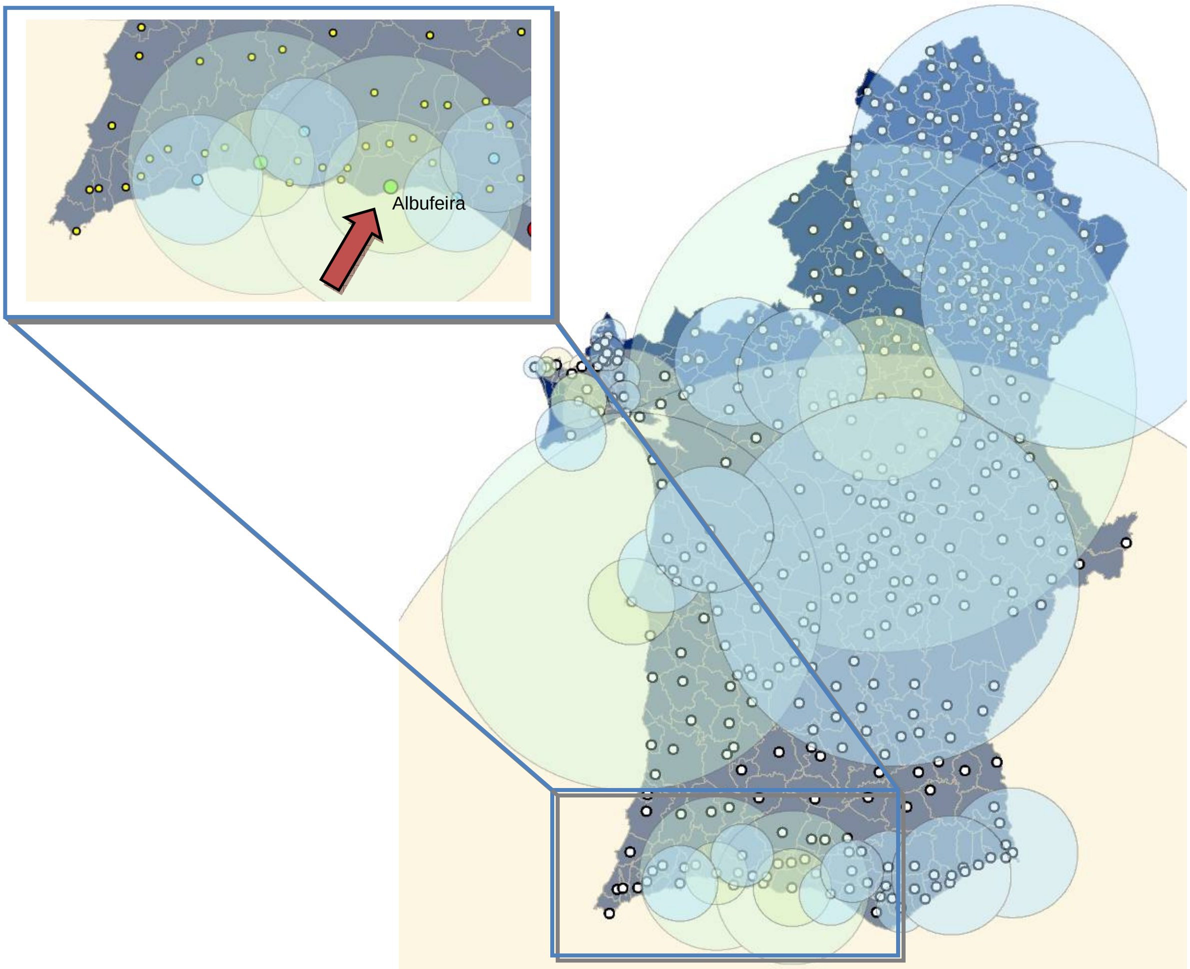


Figure 6.3 Search areas (Buffers).

With this method a total of 647 connections were identified. Each connection was then classified using *Table 2.2*. For the Type 3 urban centre Albufeira, from the above picture, for example, a total of 11 connections were identified: 4 Type BB connections and 6 Type B connections (see *Table 6.2*).

Starting centre:	**Albufeira**	Theoretically desired road category
Nearest centre:	**Portimão** (25,8 km)	BB
Within search area, Type 4	Quarteira	BB
	Silves	BB
	Loulé	BB
Nearest centre of type 4:	**Quarteira** (13,0 km)	
Within search area, Type 5	Paderne	B
	Algoz	B
	Tunes	B
	Boliqueime	B
	Armação de Pera	B
	Alcantarilha	B

Table 6.2 Table of required connections of Albufeira (Type 3 centre).

Additionally some links were added manually. The fact that there are three Type 2 centres very close to each other, at the Península de Setúbal (Almada, Seixal and Barreiro), reduces substantially the radius of the correspondent search area. The connections between some relatively close Type 4 centres and at least one of those Type 2 centres were not identified by the SafetyNet method. Therefore, three more BB and B links were considered. From this issue one could also suggest the possibility of merging very close urban centres to one new urban centre, for the determination of search areas, even if they are separated by a small portion of rural area. In those cases, however, attention should be paid to the connections between the urban centres that are merged as well.

Another issue is that some important centres are very close but outside an adequate sized search area from another centre. Not considering the connection between them would exclude natural and important links of the network. Therefore, two BB and eight B links were added manually.

Table 2.2 assumes an indirect connection between Type 2 and Type 5 centres. If these urban centres are very close to each other, the SafetyNet model doesn't consider any connection between them even if in reality it exists. Hence, four B connections were added manually.

Finally, some of Type 5 urban centres didn't fit in any search area, remaining unconnected to the rest of the network. Therefore, five Type C connections were added manually.

All these links were added to the network, resulting in the total number of 693 connections with the following classification (see *Figure 6.4*):

- 13 Type AA connections
- 39 Type BB connections (5 added manually)
- 381 Type B connections (15 added manually)
- 260 Type C connections (25 added manually)

Additionally to the connections due to the tourist traffic attraction (see *Section 0*), the consideration of other connections with urban areas outside the pilot study would definitely improve the model. Lisbon, which is very close to the Península de Setúbal, and Spain, that is located at the West border of the pilot area, represent important urban centres that would substantially modify the structure of the considered theoretical network.

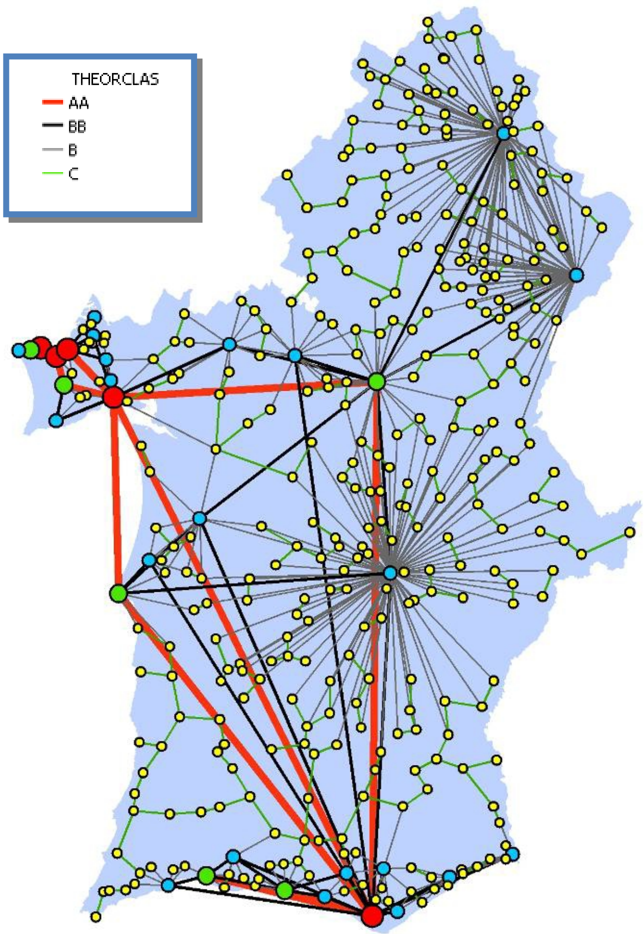


Figure 6.4 Theoretical connections in the Portuguese pilot study.

6.4 Identification and matching of actual connections

The next step in the SPI calculation is the determination and evaluation of actual connections between urban centres.

In Portugal, there is, at the present time, no official digital database of the national network. In addition, the local rural road network has never been surveyed and there is no official geometric data about those roads.

In this study, we resorted to a Portuguese private company called InfoPortugal S.A. (http://www.infoportugal.pt). This company is specialized in the production and survey of geographic contents and digital maps. The InfoPortugal S.A. database contains georreferenced information of all road sections (national and local network) and some other variables used in their own route planner, such as road configuration, road name or even an estimation of the average travel speed.

InfoPortugal S.A provided a georeferenced database (GIS shapefile) of the pilot area with the following information (GIS attributes) for each road section of the network:

- Name of road
- Length of section
- Number of lanes
- One-way sections
- Average speed estimation

These variables cover only part of the needed data for the SafetyNet functional road classification, presented in the *Table 2.1* of Chapter 2. In fact, there isn't any information about obstacle free zone for the current Portuguese network. The classification of the pilot network into SafetyNet road categories must be carried out without this variable.

Concerning the type of intersections there is no available direct information about national and local intersections. However, there is a national standard ("Norma de Intersecções"- JAE, 1993) that defines each type of intersections according to the type of the correspondent roads. One could then improve the method by relating these two variables, but just for the national network.

In Portugal, the road network is divided in national and local network. The former comprises the 'Fundamental Network' and the 'Complementary Network'. Motorways (AE) and other main national roads (IP) form the 'Fundamental Network'. The 'Complementary Network' is composed by main regional roads (IC) and other national roads (EN). The local network comprises all the other roads (paved and unpaved) under municipal or other local authorities' administration. All these road categories were derived from the name of each road section provided by InfoPortugal S.A.:

- Motorway (AE – example: "*A22*")
- Main national road (IP – example: "*IP2*")
- Main regional road (IC – example: "*IC30*")
- Other national road (EN – example: "*EN125*")
- Other regional road (ER – example: "ER338")
- Municipal road (EM – example "EM507")
- Municipal track (CM – example: "CM1096")
- Rural track (CR – example: "Caminho Rural da Zimbreira")
- Agricultural track (CA – example: "Caminho Agrícola Hortas de Tabual")
- Interchange section (Acesso – example: "A22 Acesso")
- Urban local roads (Local)

Streets, avenues, squares, alleys and other urban roads were all classified as "Local". Roads from the national network on urban areas were considered also as "Local", as the SafetyNet SPI calculation just considers rural roads.

Additionally to the category of the road, the number of lanes and one-way sections from the InfoPortugal S.A. database were also used for the classification according to the SafetyNet categories (*Table 2.1*). The separation of opposite traffic directions was introduced as a new attribute in the GIS model, and filled manually.

Table 6.3 shows the translation of the Portuguese road classification into SafetyNet functional road classification used in the pilot study.

It is important to stress that the SafetyNet road classification might not fit entirely with the type of roads existing in this particular case. For instance, there is less than 1.5% AA and BB roads in the national road network, showing that, in the South of Portugal dual-carriageway roads are not used for lower-level roads, but almost just for motorways. In fact a large number of Type BB sections were found in intersection segments of Type B roads. Interchange sections of grade separated intersections of Type AAA and AA roads were considered as Type A roads, but marked with "Accss" label for its differentiation.

SafetyNet road classes	AAA	AA	A	BB	B	C
Road category	AE	IP, IC	IP, IC, Acess	EN	EN	ER, EM, EF, CM, CR, CA
Carriageway	Dual	Dual	Single	Dual	Single	Single
Lane configuration	2x2 or more	2x1, 2x2, (2x3)	1x2, 1x3	2x1, 2x2	1x2, 1x3, (1x4), (1x1)	1x2, 1x1

Table 6.3 Classification of the Portuguese pilot roads into SafetyNet road categories.

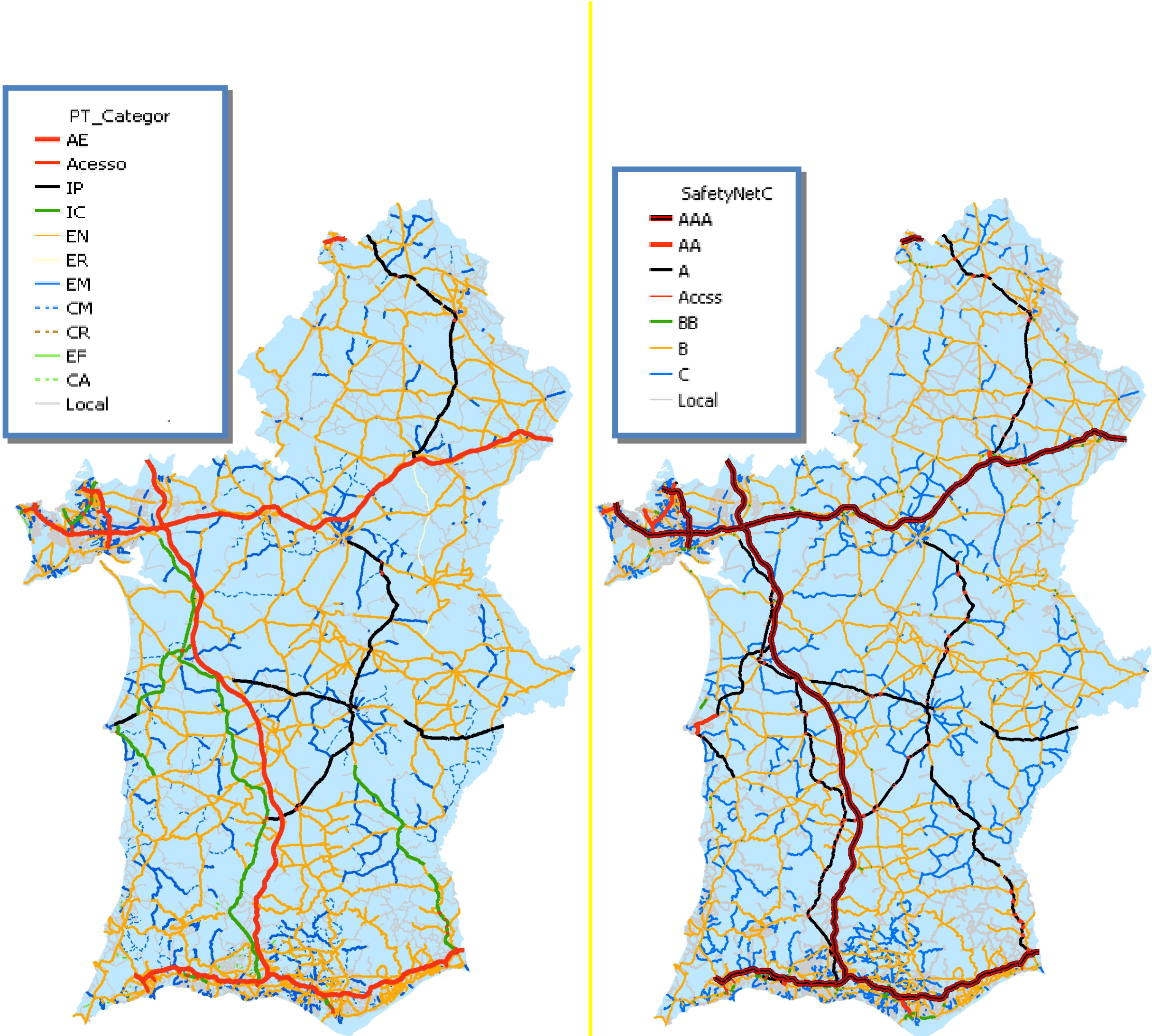


Figure 6.5 Pilot real network by road category – National Categories and SafetyNet categories.

For the matching of the theoretical connections with the actual ones, a routing model was developed in ArcGis, using the "Network Analyst" tool. This model (see *Figure 6.6*) is based on the fastest route criterion, without hierarchy preference and taking into account one-way sections.

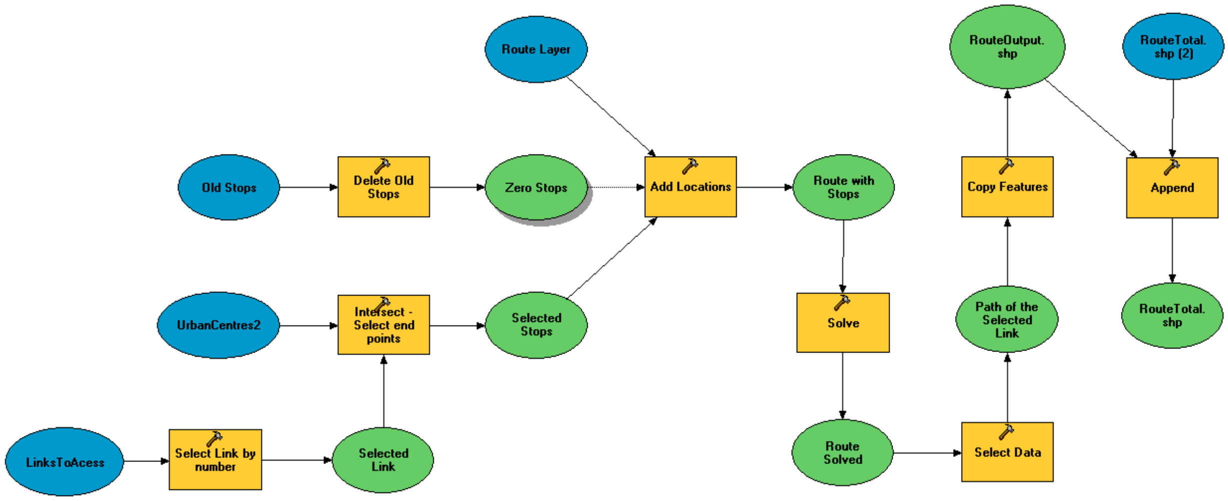


Figure 6.6 Route model on ArcGis NetworkAnalyst.

The model comprises the following steps: selection of the connection to be assessed; selection of the two (from – to) urban centres of the connection; creation of the route layer and route analysis criteria; determination of the route and the type of roads by SafetyNet categories. Moreover, the model was iterated 693 times, one for each of the theoretical connections identified. *Figure 6.7* illustrates one of the iterations of the model. In this example, where the total route length is 245 km, 93.8% of Type AAA, 3.0% of AA, 0.4% of A (all "Accss"), 0.9% of BB, 0.1% of B, 0.2% of C and 1.7% of Local roads were identified. Different routes for each of the directions of the assessed link were not considered.

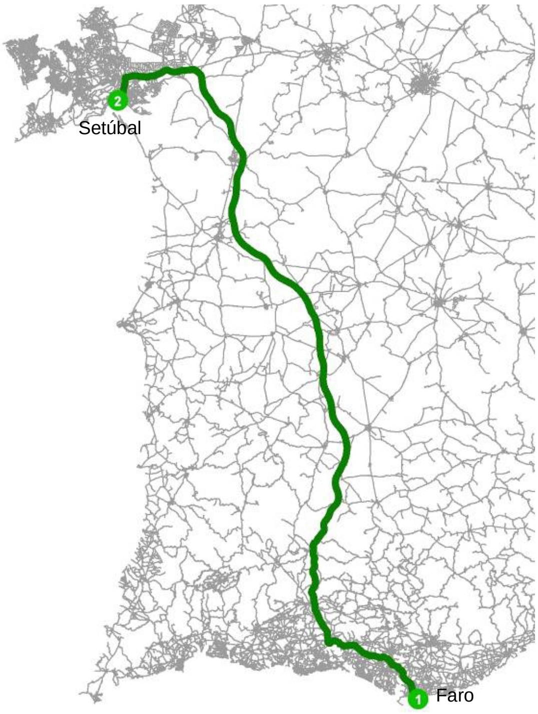


Figure 6.7 *Example of output from the route model: Faro – Setúbal connection (theoretical – AA).*

It is important to point out that the shortest route criterion would probably result in different results from the method previously used (fastest road criterion). The magnitude of this difference should be analysed in further applications of the SafetyNet method, as the calculated SPIs can result in different values.

The detour factor suggested in the SafetyNet Manual was firstly used for the determination of excluded connections. However, the indicated value of 1.6 seemed too severe especially in areas where natural barriers gain influence. This is the case of the *Península the Setúbal* and the *Algarve* regions where the Tagus River estuary and a ridge of mountains, respectively influence network design. Additionally, SafetyNet calculations consider just rural roads, disregarding urban roads. The method used for the Portuguese Pilot study uses urban centres coordinates inside urban areas (not at its border) and real connection with urban road sections. The detour factor was then increased to 1.8 and connections influenced by natural barriers analysed individually. For this reason, 34 out of 68 connections with a detour factor above 1.8 were kept in the model, resulting in a final number of 669 connections to be assessed.

Finally, in the case study presented in the Manual it is suggested that the categories of roads that are used by more than one connection, should be upgraded to a higher category. This is done, in the Manual case study, by comparing the total traffic of the connections and the corresponded road capacity. In the Portuguese pilot, there are some road sections allocating more than one connection. The section of the motorway near *Faro* (*A22*) has a total of 13 connections allocated. Unfortunately, there is no actual database with traffic of all road section of the pilots' area network. Therefore, no constrains were imposed for roads with multiple connections.

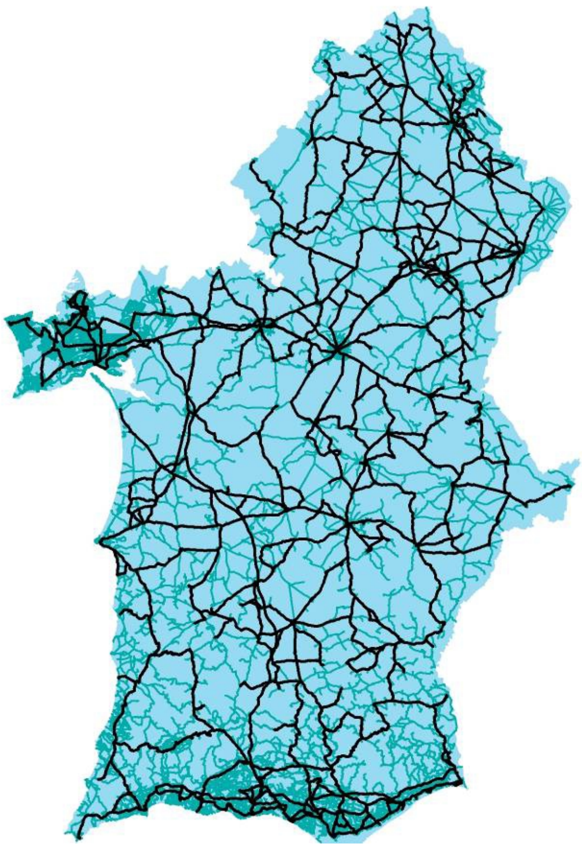


Figure 6.8 *Roads used by all the 669 connections of the Portuguese pilot study.*

6.5 Calculation of the SPI

The next and final step of the method is the comparison between the categories of the actual connections and the theoretically desired ones. It is important to mention that the SPI factor is calculated by connection and not by existing road section. In fact, some road sections were evaluated more than one time, since they allocate more than one connection. For all 669 connections, a total of 16,000 km were analysed (see *Table 6.4*). The "Local" sections were not considered and "Accss" (interchange sections) were included in the Type A category.

		Current classification						
	(km)	**AAA**	**AA**	**A**	**BB**	**B**	**C**	**Total**
Theoretical classification	**AA**	731.315	85.887	203.936	18.839	37.718	4.332	1082.027
	BB	1211.028	166.669	311.551	66.587	248.872	24.821	2029.527
	B	778.371	297.672	3915.825	178.336	5532.954	472.813	11175.971
	C	0.000	14.748	135.468	12.035	1281.592	255.348	1699.191
								15986.716

Table 6.4 Distribution of current road classes by theoretical classification.

For each urban centre, the selected connections were assessed and the theoretical classification was compared to the ones of the road sections identified by the route model. *Table 6.5* illustrates the calculation for the connections identified by the search area represented in the *Figure 6.3* and *Table 6.2* for the case of Albufeira. For this urban centre, two different search areas were used, as Albufeira is a Type 3 urban centre, and connections of Type BB and B were assessed. Although Local sections were identified by the routing model, they were not included in the SPI calculation as they constitute the urban sections part of the connection.

		Length	**Theo.**	**Current Category**						
Starting centre:	**Albufeira**	**[km]**		**AAA**	**AA**	**A**	**BB**	**B**	**C**	**Local**
Nearest centre:	**Portimão**	40.105	**BB**	65.1%	2.2%	3.1%	11.9%	8.5%	1.0%	8.2%
Search area	25,8 km									
Type 4	Quarteira	19.420	**BB**	0.0%	0.0%	0.0%	2.1%	33.0%	29.1%	35.8%
	Silves	30.115	**BB**	60.4%	2.9%	2.6%	14.6%	14.9%	0.0%	4.7%
	Loulé	31.984	**BB**	67.0%	1.6%	2.8%	10.6%	8.8%	0.0%	9.2%
Nearest centre:	**Quarteira**									
Search area	13,0 km									
Type 5	Paderne	12.930	**B**	0.0%	0.0%	0.0%	7.5%	77.3%	0.0%	15.2%
	Algoz	12.614	**B**	0.0%	0.0%	0.0%	7.7%	74.9%	0.0%	17.4%
	Tunes	12.163	**B**	0.0%	10.4%	30.4%	15.9%	23.3%	0.0%	20.1%
	Boliqueime	13.129	**B**	0.0%	0.0%	0.0%	12.1%	78.2%	0.0%	9.7%
	Armação de Pera	13.338	**B**	0.0%	0.0%	0.0%	0.0%	45.7%	14.2%	40.2%
	Alcantarilha	10.888	**B**	0.0%	0.0%	0.0%	0.0%	45.3%	0.3%	54.5%

Table 6.5 Connections assessment – Partial calculation of SPI for Albufeira connections.

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	67.6%	7,9%	18.9%	1.7%	3.5%	0.4%
A	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BB	59.7%	8.2%	15.4%	3.3%	12.3%	1.2%
B	7.0%	2.7%	35.0%	1.6%	49.5%	4.2%
C	0.0%	0.0%	8.0%	0.7%	75.4%	15.0%

Table 6.6 SPI scores per road category for the Portugese pilot (table).

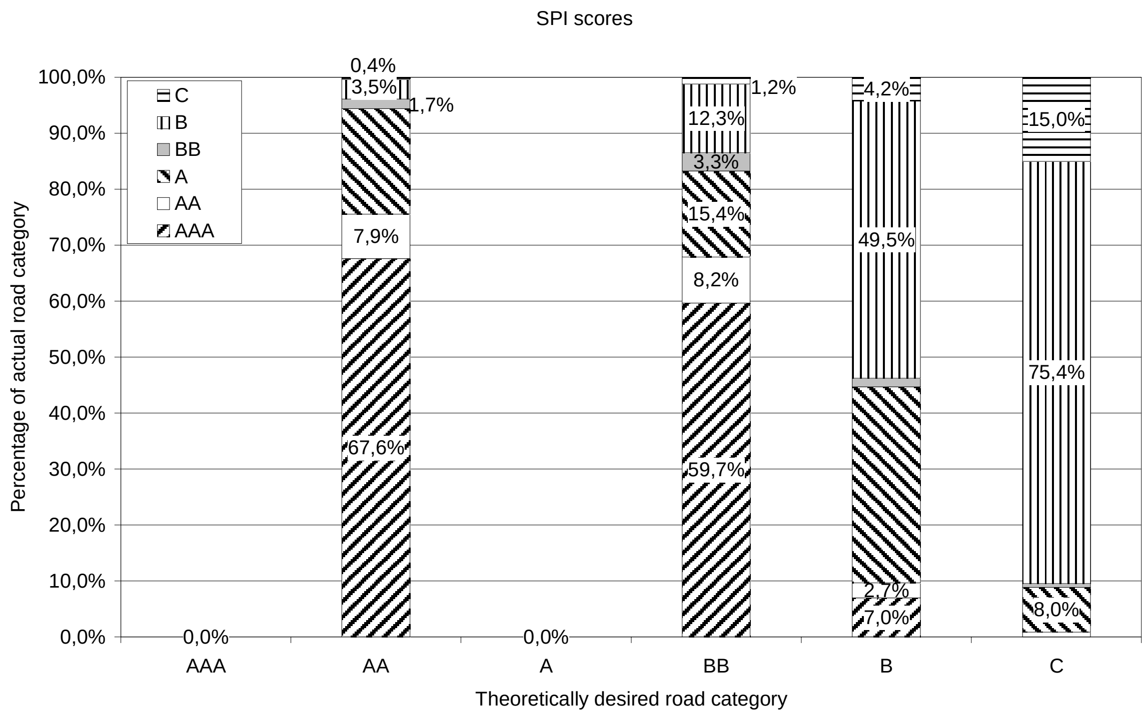


Figure 6.9 *SPI scores per road category for the Portuguese pilot.*

From Table 6.6 and *Figure 6.9* it may be concluded that 75.5% of all roads that should be AA are in reality AA or higher, 86.5% of all roads that should be BB are in reality BB or higher, 95,8% of all roads that should be B are in reality B or higher and 100% of the roads that should be C are in reality C or higher. In total, 14,975 km had a current road category appropriate or higher than the theoretical category needed, resulting in a total road network SPI of 93.7%**.** As mentioned in *Section 6.3*, Type B connections are the most frequent (381 out of 693 connections). These connections have a high SPI score, justifying the high total network SPI. Type C theoretical connections are always associated with appropriate or higher classes of roads, as this category is the minimum road standard indicated by the SafetyNet classification. When Type C connections are not considered for the calculation, the total road network SPI doesn't change much (92.9**%**), suggesting that their contribution to the needed network is small (total Type C connection length is relatively small).

The calculated results reveal a satisfactory network configuration considering the variables used for the road classification. The consideration of the obstacle-free zone and intersections configuration would probably change (reduce) the SPI value, especially for the actual roads classified in the study as Type BB and B connections. In fact, in this pilot area, both categories are not often associated with roundabouts and with an acceptable obstacle-free zone, as defined in the SafetyNet Functional road classification.

6.6 Conclusions and discussion

The SPI calculation method proposed by the SafetyNet Manual is intelligible and doesn't require exhaustive calculations when the needed information is available. The use of a GIS application and the development of automatic computation processes allow a regular and flexible calculation of road network SPI. The calculated results revealed a satisfactory network configuration for the Portuguese pilot area, taking into account the considerations of the used method. However, some adaptations were necessary and some issues of its application were raised:

- The identification of urban centres can be improved as current boundaries aren't actually available for the Portuguese case. The smallest Portuguese administration units, called Freguesias, were used. Local roads and, thus, the urban centre boundaries, were identified using the individual road names provided by InfoPortugal S.A.. Some Freguesias were individually analysed and merged considering the absence of rural area between them, housing density and their road connectivity. This process can be complex and time-consuming when large areas are being analyzed and the territorial occupation is dense. The availability of national data on urban centres borders is therefore essential for the efficiency of the SPI calculation process. Additionally, territory occupation and population data must be up to date as the network is constantly changing and its indicators need to be recalculated.
- Besides the population criterion, important transport infrastructures were used for the classification of urban centres. Main ports and airports were considered in this case study and it was shown that the consideration of other attraction factors can improve the estimation of effective SPI. Other attraction factors such as industries, large commercial and leisure facilities, touristic areas and international borders are essential for the modelling of real networks. The consideration of these factors must, however, be based on strict and harmonized rules so that the results of SPI calculations can be compared between countries.
- The use of circular search areas based on the nearest urban centre of the same class seems an intelligible and efficient method for the selection of the connections to be assessed. Nevertheless, three issues were raised when applying it to the Portuguese pilot study:
  a) The position of the search circles, centred at the coordinates of the headquarters of the Freguesias administration, will ignore other possible connections when applied to large urban areas.
  b) Connections that should be analysed between the assessed urban and other important urban centres close to the search area boundaries will be ignored. This forces an individual detection of those cases or the use of more flexible search areas.
  c) For the pilot study small urban centres that were not connected to any higher class centre due to its location outside search areas were identified. In reality they are connected to the actual network, and their connections need to be assessed.
- One of the major issues in the SPI calculation for the Portuguese pilot network was the SafetyNet Functional road classification. The absence of an official georreferenced database forced the use of InfoPortugal S.A, a private company

specialized in the production and survey of geographic contents and digital maps. The attributes of the provided network allowed the classification of all road sections into the SafetyNet Functional categories. However, some assumptions were made during the process, as obstacle-free zone and intersections type were not available. For the collection of both variables an extensive field work at national level is thus required. Additionally the categories proposed by the SafetyNet Manual are strict and are not entirely compatible with the Portuguese reality. For instance, distributor roads with dual carriageway (Type BB) are usually used in urban areas, not in rural areas, representing less than 2% of the actual connections assessed. Another issue about road classification is the use of Type A category on Table 2.1 which doesn't appear on the needed connections between urban areas (Table 2.2). Finally, the obstacle-free zone variable should be quantified (in meters) in the SafetyNet Manual for improved road classification.

- The use of GIS modelling in this pilot study allowed an extremely flexible calculation method of SPI. In fact, the choice of the shortest or the fastest route as criterion, the use of road hierarchy or other cost variable is easily added to the model. In case the calculation process should be adjusted, for example in order to harmonize the method between different countries, a GIS tool has the advantage that it is flexible and the new scores can easily be calculated.
- The use of a detour factor in the identification of the needed connections is a critical issue, and it requires further research. The suggested value of 1.6 times the direct distance is not adequate in many situations. In fact, natural barriers and human occupation of the territory can force some connections to be longer than the accepted value calculated with the detour factor. That was the case for the Península the Setúbal and the Algarve in the Portuguese pilot study. Also, for wide areas of study, the use of a unique detour factor is not adequate as the topology of the territory can vary significantly.
- The road network SPI is calculated for each connection; however, sometimes, multiple connections use the same road section. This complicates the process of having an indicator computed for each road section. Additionally, the use of traffic volume for the consideration of multiple connections in the road classification, as suggested in the SafetyNet Manual, must follow a well defined criterion.

This chapter presented the first application of the road network SPI, as proposed by the SafetyNet Manual, to part of the Portuguese road network. The territory bellow Tagus River was chosen as pilot area. The proposed method proved an intelligible process, comparable between countries, to evaluate the road network configuration. However, the Portuguese pilot study revealed a few issues that should be further developed for an effective application to Portuguese reality, such as the road and urban centres classification, the connection identification and the route model. The use of GIS applications improved the flexibility of the method and allowed the development of automatic computation processes of calculation.

7 Conclusions and recommendations

On the basis of the experiences with the method and guidelines and the resulting SPI scores in the pilot countries, conclusions are drawn on the limitations and applicability of the road network SPI and the guidelines that were provided for calculating the SPI. Section 7.2 subsequently provides recommendations for improving the guidelines and the method in the short and the long term.

7.1 Conclusions

From the different pilot projects, conclusions were drawn with regard to the applicability of the method and the issues that need attention when calculating the road network SPI. In this Section for each step of the method, the main issues are discussed.

7.1.1 Definition and classification of urban centres

According to the guidelines that were provided, cities should be defined by the boundaries of the city areas and classified into five classes on the basis of the number of inhabitants. In general, the data that were needed for this classification were available and it was possible to make a list of urban areas for the pilot countries. However, there are some issues that need further discussion.

First of all, the available data is determinative for the definition of a centre, i.e. the definition of a centre depends on the level at which data is available. Therefore, it is not always possible to define centres by the boundaries of the city area as was proposed by the guidelines. In the Netherlands for example, data was available for municipalities instead of villages (one municipality may consist of several villages that are separated by rural area). Therefore in the Dutch case study, a centre was defined as a municipality instead of a village or city. Another issue that plays a role with regard to the definition of a centre is the clustering of cities. In Israel and the Netherlands, some cities are so close to each other that there is no rural area in between them. The same happened in Portugal, where some groups of Freguesias represented the same urban area. In those cases, the cities or groups of Freguesias could be seen as one urban centre.

The most logical would be to define each centre (village, city) that is surrounded by rural area as one centre. However, one is dependent on the available data. Therefore, we recommend to analyse the data on the level at which data is available[3] and to evaluate the results carefully. In case one centre clearly consists of various subcentres that are by themselves large enough to act as individual centres, they should be treated as individual centres. On the other hand, if two or more cities are not separated by rural area, they should be treated as one centre. All changes that are made to the results of the basic method should be noted and explained so that the process can be tracked.

Besides the definition of a centre, the classification of the centres also needs some discussion. In all pilot projects the centres were grouped into five classes on the basis of the number of inhabitants. The class of a centre represents the importance of that centre or the amount of traffic that is generated (or attracted) by the centre. Of course, the importance of or the amount of traffic generated by a centre also depends on other factors like the amount of industry, retail/commercial activity, governmental agencies and recreational/tourist facilities. From the pilot projects it was concluded that some important existing centres (like ports or recreational areas) may be excluded or classified to a lower category than they should be in case only the number of inhabitants is taken into account.

[3] In case data is available at different spatial aggregation levels, we recommend to choose the level that is closest to a centre being a build up area that is surrounded by rural area.

In order to obtain a realistic theoretically desired network, centres like ports and tourist attractions should be taken into account. In case one would want to define centres on the basis of other characteristics like industry and recreational areas as well, indicators would be needed for these factors, e.g. the surface of industrial area, the number of employees, or the number of beds in tourist areas. Data on these indicators were not available (or at least not easy to obtain) in the pilot countries. Therefore, we recommend to classify centres on the basis of the number of inhabitants and to evaluate the resulting list of centres. Missing centres can be added and centres can be upgraded in case there are facilities that attract a lot of traffic. This evaluation should be done by somebody with knowledge of the local situation and all changes should be reported and explained.

Another issue with regard to the classification of the centres is that the limits of the classes are chosen quite arbitrarily, there is no theoretical base for these exact limits and by changing the limits, one changes the distribution of centres across types and the theoretically desired network. Further research is necessary in order to obtain a theoretically sound classification system. The current classification system is evaluated indirectly by evaluating the theoretically desired network that results from the second step. In general, the theoretically required network seemed reasonable from traffic safety point of view. The current classification system thus provides a good first estimation in order to determine a theoretically desired road network.

7.1.2 Determination of the theoretically desired connections

The theoretically desired connections were determined using the search circles. Some pilot countries automated the process (Portugal, Israel), other countries (Greece, The Netherlands) determined the theoretically desired connections manually.

The list of connections that were determined for the pilot countries appeared to be realistic for most countries. In case connections were found to be missing, this was mainly due to missing centres (e.g. ports). In Portugal, not all relevant connections were identified by the search areas, due to relatively small search areas (caused by short distances between two centres of the same type). Moreover, some small urban centres (type 5 centres) were not connected to any higher class centre since it was not in any search area.

In some cases, theoretically desired connections were determined that are not found in practice. This is sometimes caused by a (natural) barrier. The search circles do not take natural barriers into account. In case of a barrier (like a mountain, a river or a lake), cities that are geographically close may lack a connection between them. Therefore, researchers that apply the method are advised to mark connections with a barrier. These connections need extra attention when identifying and matching the actual connections (see next section).

7.1.3 Identification and matching of actual connections

The provided guidelines were very brief with regard to this step. In most countries, there are different routes possible between two centres. One of the routes has to be selected as actual connection[4]. The pilot countries each executed this step in their own way. Greece and the Netherlands used a route planner to select an actual connection and searched for the fastest route. Portugal built a routing model in a GIS tool. Israel used a geographic information system and searched for the basic connection[5].

This step should be dealt with in a pragmatic way, using the tools that are available. With regard to the selection of the most appropriate route; the fastest route seemed to work in the Netherlands, Greece and Portugal, the basic connection seemed to work in Israel. When

[4] In theory one could also take into account several routes and the distribution of the traffic over these routes, however, this would complicate the method and result in an evaluation of both the road network and route choice.

[5] The basic connection is typically the shortest road going through the highest road categories.

selecting the route, it is important that a safe route (using high road categories) is selected. In the Manual (Hakkert & Gitelman, 2007), both the fastest and safest route (the route via the highest road categories) were determined and the safest route was selected instead of the fastest route in case this was less than 5% slower than the fastest route (in case the fastest route is also the safest route one does not have to choose). This complicates the method and from the pilot projects it is concluded that the fastest route in general also uses the higher road categories. Therefore, we do not expect this complicating criterion to improve the results. We recommend to select the fastest route when identifying actual connections. However, the actual connections should be evaluated by someone with knowledge of the local situation and in case there is a safer route that is just somewhat longer it should be selected instead of the fastest route.

Another suggestion from the Manual was to apply a detour factor of 1.6. This detour factor seems not appropriate for all pilot areas. In Greece, natural barriers cause detour factors to be higher than 1,6. We propose to deal with the detour factor in a pragmatic way. In principle, the detour factor should be 1,6 and connections exceeding this detour factor should be examined on a case-specific basis. In case there is a (natural) barrier (e.g. mountain, river) causing a detour factor to be higher, a detour factor of 2 can be accepted. Another possibility in dealing with natural barriers is to remove a theoretically desired connection. This can be done in case the barrier makes traffic between these cities unlikely. Of course the removal of a theoretically desired connection should be noted and well explained.

A third suggestion from the Manual was to define a maximum capacity per road category. In case that more than one connection uses the same road, a theoretically desired road category could be upgraded when the estimated daily traffic volume (that follows from the combination of connections) exceeds the maximum capacity of a road category. This also complicates the method. For each road section one should determine by which connections it is used. Upgrading the theoretically desired categories of certain roads will have an impact on the SPI scores. In the pilots, this factor was not taken into account. This issue should be further analysed when improving the method.

In case a route is selected as the actual connection, the roads that are part of the actual connection (a route may consist of various roads of different categories) must be classified on the basis of the SafetyNet road categorization. This appeared to be possible in all pilot countries, although the data sources and information used differed per country. For some pilots, knowledge of the local situation was necessary to be able to determine the road categories. For each connection the actual road categories as well as the length of the road sections of the different road categories should be noted.

There was some confusion about whether the urban parts of a route should be taken into account and about how the urban part of the route should be determined. We suggest to leave the urban part of a route out of the evaluation, since the method is meant for evaluating the rural part of the network. The most appropriate definition of the rural part of the route depends on the data that is available. Land use charts would be a logical option.

7.1.4 Calculation of the SPI

The calculation of the SPI is quite straightforward if the preceding steps of the method are applied. The actual road category/categories is/are compared to the theoretically desired one. For each connection, it can be determined what length (expressed in km) of the connection meets the requirement and what length does not. By summing up the results for each (theoretically desired) road category, the proportion of appropriate road category can be calculated for each road category.

In general, the resulting scores seem quite realistic, although the scores of Greece seem low compared to the other pilot areas. The scores provide an idea of the level of safety of the road network in a country. It should be noted, that the theoretically desired road network differs greatly between the case study areas. In the case study area of Greece for example, the largest centre was of type 2 (and there was only one) and there were many type 5 centres. In the pilot area in the Netherlands, there were two type 1 centres and the area is densely populated. This puts different requirements on the road network and makes it difficult to compare the scores for different countries. From the results it can also be seen that it is not a good idea to combine the results into one overall score. The score was highest for Portugal, due to a high weight of lower level roads in the total SPI score, which have a high score comparing to higher road categories. One overall score may give a biased view. Another possibility is to analyse the score for each connection type (type 1 centre – type 1 centre; type1 centre - type2 centre; etc) as was done in the Israeli pilot. This complicates the calculation and the interpretation of the results, but provides more insight into the exact problems.

When the results are analysed in more detail, there appear to be some road categories that have lower scores. In general, AA roads and BB roads are not applied extensively whereas the SafetyNet procedure requires this category resulting in poor scores for AA roads in Greece, Israel and Portugal and poor scores for BB roads in Greece and The Netherlands. The SN requirements for the different road categories possibly should be interpreted less strictly and the theoretically desired road cateogies between different types of centres possibly need revision. More research is needed concerning this issue.

With regard to the score of the individual connections it has to be mentioned that in some cases relatively short sections of the connections (connecting freeways to urban areas) failed. The question arises whether these sections should comply with the SafetyNet requirements or if one should allow a certain percentage of the route to be of a lower category and only base the assessment on the primary part of the connection.

7.2 Recommendations

First of all, the experiences of the pilot countries were used to update the guidelines. The updated guidelines are shown in Appendix B. Countries are invited to apply these guidelines for calculating the road network SPI in order to assess the safety level of the road network in their country. In our opinion, the current method provides insight into the strengths and weaknesses in a road network.

However, there are still some issues that need further research in the future in order to improve the method for calculating the road network SPI. These issues are:

– A theoretically sound classification of urban centres. Production and attraction may provide more appropriate classification variables than the number of inhabitants. Moreover, more research is needed regarding a theoretical basis for the limits of the classes

– The SafetyNet road categorization. Possibly the theoretically desired road categories between some combinations of centres are too strict in the current method. There is no scientific basis yet for the theoretically desired road categories between different types of centres. More insight should be obtained into the consequences for traffic safety of applying different road categories between certain types of urban centres.

In general, the relation between the SPI scores and traffic safety should be analyzed in order to obtain more insight into the validity of the road network SPI.

8 Literature

CBS (2007a). Statistical abstract of Israel 2007. Central Bureau of Statistics, Jerusalem.

CBS (2007b). Internet site: cbs.gov.il/ishuvim. Accessed 07.01.08.

Dijkstra, A. (2003a). Kwaliteitsaspecten van duurzaam-veilige weginfrastructuur. R-2003-10. Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV, Leidschendam. [in Dutch]

ESRI (2005). ArcGIS Network Analyst. ESRI Portugal-Sistemas de Informação Geográfica, S.A.

FGSV (1988). Richtlinien für die Anlage von Straßen RAS. Teil: Leitfaden für die funktionelle Gliederung des Straßennetzes RAS-N. Forschungsgesellschaft für Straßen- und Verkehrswesen FGSV, Köln. [in German]

Hakkert, A.S, Gitelman, V. and Vis, M.A. (Eds.) (2007) Road Safety Performance Indicators: Theory. Deliverable D3.6 of the EU FP6 project SafetyNet.

Hakkert, A.S. and Gitelman, V. (Eds.) (2007) Road Safety Performance Indicators: Manual. Deliverable D3.8 of the EU FP6 project SafetyNet.

Appendix A Guidelines that were used for the pilots

For the pilot projects guidelines were developed. These guidelines were filled out by each participating country during the execution of the pilot projects. Following the guidelines which are shown below, each participant was guided through the steps needed for the calculation of the SPI. Together with the guidelines, an Excel sheet was given to each participant which had to be filled out in order to calculate the SPI. The Excel sheet contained a format of the tables. These tables are displayed right after the guidelines.

First, determine the pilot area which can be a region or a chosen sample size. The first step is the definition and classification of the centres. The second step is the identification and matching of actual connections. And the third step is the calculation of the SPI.

Definition and classification of centres (step 1)

1. Determination of the urban areas in the pilot area.
    a. An urban area is defined by the boundaries of the city area.
    b. Determine for each urban area the number of inhabitants. In the pilot project, only the number of inhabitants will be used for classifying the urban areas. However, more data will give more information about the relations between the urban areas which can be useful later on. Imagine that if a relative small urban area has a lot industrial areas, there will be a lot of traffic from the neighbour urban area to these industrial areas. This will have consequences for the theoretical connection needed between these Right now, this is too complex to handle. Later on, we can improve the method by adding new information types besides the number of inhabitants. If it is possible, please collect also the following information for each urban area:
        i. Employment
        ii. Surface of industrial areas
        iii. Production/attraction
        iv. Surface of shopping areas

        These aspects will give us more information about the amount of traffic between the urban areas in the pilot area. If you have more suggestions, please let us know! With your help we can improve the pilot project.
    c. Classify the urban areas into the 5 types, which are:
        i. Type 1 centre = > 200,000 inhabitants
        ii. Type 2 centre = 100,000 to 200,000 inhabitants
        iii. Type 3 centre = 30,000 to 100,000 inhabitants
        iv. Type 4 centre = 10,000 to 30,000 inhabitants
        v. Type 5 centre = < 10,000 inhabitants
        vi. Put all urban areas in Table 1 and Table 2 in the Excel file.
2. After determination of the urban areas, the next step is to search for the needed connections between these areas in the pilot area. For this step, you will need the Table 3a-3d.
    a. Start with type 1 centres:
        i. Choose one type 1 centre as starting position
        ii. Search for the nearest type 1 centre and note them both in Table 3a.
        iii. Note the distance between these two type 1 centres. This distance is the radius of the circular search area.
        iv. Note all type 2 centres within this search area and list them in Table 3a.

  v. Note also all type 3 centres within this search area and list them in Table 3a.
  vi. Repeat the steps i-v for all type 1 centres, also in Table 3a.
- b. Type 2 centres:
  i. Choose one type 2 centre as starting position
  ii. Search for the nearest type 2 centre and note them both in Table 3b.
  iii. Note the distance between these two type 2 centres. This distance is the radius of the circular search area.
  iv. Note all type 3 centres within this search area and list them in Table 3b.
  v. Note also all type 4 centres within this search area and list them in Table 3b.
  vi. Repeat the steps i-v for all type 2 centres, also in Table 3b.
- c. Type 3 centres:
  i. Choose one type 3 centre as starting position
  ii. Search for the nearest type 3 centre and note them both in Table 3c.
  iii. Note the distance between these two type 3 centres. This distance is the radius of the circular search area.
  iv. Note all type 4 centres within this search area and list them in Table 3c.
  v. Repeat the step i-v for all type 3 centres.
  vi. Search for the nearest type 4 centre and note them both in Table 3c.
  vii. Note the distance between these two centres. This distance is the radius of the circular search area.
  viii. Note all type 5 centres within this search area and list them in Table 3c.
  ix. Repeat the steps i-v for all type 3 centres, also in Table 3c.
- d. Type 4 centres:
  i. Choose one type 4 centre as starting position
  ii. Search for the nearest type 4 centre and note them both in Table 3d.
  iii. Note the distance between these two type 4 centres. This distance is the radius of the circular search area.
  iv. Note all type 5 centres within this search area and list them in Table 3d.
  v. Repeat the steps i-iv for all type 4 centres, also in Table 3d.

Identification and matching of actual connections (step 2)

1. Road categories
   a. Translate road categories of your country into the SafetyNet categories.
2. Connections:
   b. Fill out Table 3 with the current connections between all the listed urban areas.
   c. Determine the theoretical needed connections between all the listed urban areas. For the theoretical needed connections see Table 2.1 of this report.

Calculation of the SPI (step 3)

1. Calculation of the SPI
   a. Calculate for each road category (AAA, AA, BB, B, C) the percentage of appropriate current road category length, and fill out Table 4.
   b. And make a graph of the SPI, like figure 8.5 of the Manual (page 104).

Tables from the Excel file which are mentioned in the guidelines

Urban area	Centre type	Number of inhabitants	Employment	Surface of industrial area	Production/ attraction	Surface of shopping area
[name] Etcetera	[1,2,3,4,5] Etcetera	[number]	[number]	[number]	[number]	[number]

Table 1

	Centre type				
	1	2	3	4	5
Urban areas	[name] [name]	[name] [name]	[name] [name]	[name] [name]	[name] [name]

Table 2

		Connection type		Length of current connection
Starting centre:	[centre type 1]	Current	Theoretical	
Nearest centre:	[centre type 1]			[km]
Within search area				
Type 2	[centre]			[km]
	[centre]			[km]
Type 3	[centre]			[km]
	[centre]			[km]

Table 3a

		Connection type		Length of current connection
Starting centre:	[centre type 2]	Current	Theoretical	
Nearest centre:	[centre type 2]			[km]
Within search area				
Type 3	[centre]			[km]
	[centre]			[km]
Type 4	[centre]			[km]
	[centre]			[km]

Table 3b

		Connection type		Length of current connection
Starting centre:	[centre type 3]	Current	Theoretical	
Nearest centre:	[centre type 3]			[km]
Within search area				
Type 4	[centre]			[km]
	[centre]			[km]
Nearest centre:	[centre type 4]			[km]
Within search area				
Type 5	[centre]			[km]
	[centre]			[km]

Table 3c

		Connection type		Length of current connection
Starting centre:	[centre type 4]	Current	Theoretical	
Nearest centre: Within search area	[centre type 4]			[km]
Type 5	[centre]			[km]
	[centre]			[km]

Table 3d

	Percentage of current category on total length of theoretical category				
Theoretical category	AAA	AA	BB	B	C
AAA					
AA					
BB					
B					
C					

Table 4

Appendix B Updated Guidelines

After completing the pilot projects it was possible to update the guidelines. This appendix presents the updated guidelines. For the Tables, see Appendix A.

First, determine the pilot area which can be a region or a chosen sample size. The first step is the definition and classification of the centres. The second step is the identification and matching of actual connections. And the third step is the calculation of the SPI.

Definition and classification of centres (step 1)

1. First, determine the pilot area which can be a region or a chosen sample size.
2. Determination of the urban centres in the pilot area.
    a. An urban centre is defined by the boundaries of the city area. Ideally each individual city or village that is surrounded by rural area is treated as an individual urban centre. In case the data is not available on the desired level, analyse the data on the level closest to the desired level and (1) combine urban centres that are not separated by an urban area and (2) split up urban centres that clearly consist of various sub centres. It should be clearly noted which centres are combined or split up.
    b. Determine for each urban centre the number of inhabitants and classify the urban centres into the 5 types, which are:
        i. Type 1 centre = > 200,000 inhabitants
        ii. Type 2 centre = 100,000 to 200,000 inhabitants
        iii. Type 3 centre = 30,000 to 100,000 inhabitants
        iv. Type 4 centre = 10,000 to 30,000 inhabitants
        v. Type 5 centre = < 10,000 inhabitants
        vi. Put all centres in Table 1 and Table 2.
    c. Evaluate the resulting list of urban centres. In case (agricultural, industrial, recreational or other) centres are missing or classified in the wrong class, add or upgrade the centre and motivate why the centre is added or upgraded.
3. After determination of the urban centres, the next step is to search for the needed connections between these centres. For this step, you will need Table 3a-3d. Please mark connections that might be influenced by a (natural) barrier like a mountain or river.
    a. Start with type 1 centres:
        i. Choose one type 1 centre as starting position
        ii. Search for the nearest type 1 centre and note them both in Table 3a.
        iii. Note the distance between these two type 1 centres. This distance is the radius of the circular search area.
        iv. Note all type 2 centres within this search area and list them in Table 3a.
        v. Note also all type 3 centres within this search area and list them in Table 3a.
        vi. Repeat the steps i-v for all type 1 centres, also in Table 3a.
    b. Type 2 centres:
        i. Choose one type 2 centre as starting position
        ii. Search for the nearest type 2 centre and note them both in Table 3b.
        iii. Note the distance between these two type 2 centres. This distance is the radius of the circular search area.
        iv. Note all type 3 centres within this search area and list them in Table 3b.
        v. Note also all type 4 centres within this search area and list them in Table 3b.

        vi. Repeat the steps i-v for all type 2 centres, also in Table 3b.
    c. Type 3 centres:
        i. Choose one type 3 centre as starting position
        ii. Search for the nearest type 3 centre and note them both in Table 3c.
        iii. Note the distance between these two type 3 centres. This distance is the radius of the circular search area.
        iv. Note all type 4 centres within this search area and list them in Table 3c.
        v. Repeat the step i-v for all type 3 centres.
        vi. Search for the nearest type 4 centre and note them both in Table 3c.
        vii. Note the distance between these two centres. This distance is the radius of the circular search area.
        viii. Note all type 5 centres within this search area and list them in Table 3c.
        ix. Repeat the steps i-v for all type 3 centres, also in Table 3c.
    d. Type 4 centres:
        i. Choose one type 4 centre as starting position
        ii. Search for the nearest type 4 centre and note them both in Table 3d.
        iii. Note the distance between these two type 4 centres. This distance is the radius of the circular search area.
        iv. Note all type 5 centres within this search area and list them in Table 3d.
        v. Repeat the steps i-iv for all type 4 centres, also in Table 3d.

Determine the theoretical needed connections between all the listed urban areas. For the theoretical needed connections see Table 2.1 of this report. Evaluate the resulting theoretically desired connections. In case any connections are missing, these can be added . However, this should be noted and motivated.

Identification and matching of actual connections (step 2)

1. Translate road categories of your country into the SafetyNet categories.
2. Fill out Table 3a-3d with the current connections between all the listed urban areas.
    a. This step should be dealt with in a pragmatic way, use the tools available (e.g. a route planner, a GIS tool).
    b. When selecting a route, it is important that a safe road is selected. In most pilot countries, the fastest route seemed to be appropriate. The selected routes should be evaluated and in case there is a safer route within 1,6 times the distance of the celestial length, it should be selected.
    c. In case the length of the actual connection exceeds the threshold of 1,6 times the celestial length, it should be evaluated. In case there is no barrier, the actual connection is too long and should be noted as missing. In case there is a natural barrier, first it should be evaluated whether there should be a connection. In case there should be a connection, the detour factor should be calculated and evaluated (a detour factor of two or in some cases even three is allowed in case of natural barriers).
    d. A current connection can consist of several roads. Write down all roads with their road category including the length of each road category. Only the rural parts of the roads have to be taken into account.

Calculation of the SPI (step 3)

1. Determine for each connection which length is of an appropriate category and which part is not. 10% of each connection (the rural part of the connection) is allowed to be of a lower category than the theoretically desired one. These 10% should be subtracted from the length that does not meet the theoretically desired category.

2. Aggregate the scores for each (theoretically desired) road category (AAA, AA, BB, B, C) and fill out Table 4.
3. And make a graph of the SPI, like figure 8.5 of the Manual (page 104).