Baseline

Baseline report on the KPI Infrastructure

January 2023

Baseline

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Any comments or feedback regarding this report should be sent to baseline@vias.be.

Version history

Version	Date	Changes
0.0	April 30, 2022	First pre-draft of the report to define the content
1.0	September 13, 2022	First draft, missing data from Portugal and Malta
2.0	October 1, 2022	Second draft, including data from Malta and feedback from reviewers
2.1	November 25, 2022	Correction of Swedish data, adding Portuguese data and reformulation of some paragraphs
Final	January 31, 2023	Minor text adjustments

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Executive summary

This document includes information on the results of the data collection and analysis for the ***KPI Infrastructure***. Several versions of this KPI were eligible:

- KPI(1): Percentage of the distance driven over roads with a safety rating above an agreed threshold
- KPI(2): Percentage of the road network length of roads with a safety rating above an agreed threshold
- KPI(3): Percentage of the distance driven over roads either with opposite traffic separation (by barrier or area) or with a speed limit equal to or lower than xx km/h in relation to total distance travelled [on all roads]
- KPI(4): Percentage of the road network length of roads either with opposite traffic separation (by barrier or area) or with a speed limit equal to or lower than xx km/h in relation to the total road network length.

The first two definitions of the KPI on Infrastructure safety require the choice of a safety rating and the definition of a safety threshold. These could be chosen by the EU Member States themselves.

Six EU Member States provided data for the KPI on infrastructure safety: Finland, Latvia, Lithuania, Malta, Portugal and Sweden. Finland provided data for four definitions of the indicator; the other countries only for one: Sweden used indicator KPI(3) and Latvia, Lithuania, Portugal and Malta used indicator KPI(4). All countries provided data on rural roads; Sweden, Finland, Portugal and Lithuania also provided data for motorways (there are no motorways in Latvia and Malta). Finland was the only country to provide data on urban areas. In Finland, the values for the KPIs refer to public roads only. In addition, Finland, Portugal and Malta provided a regional distribution of the values.

For rural roads, the speed limit threshold used for KPIs (3) and KPI (4) was 70 km/h. The results for rural roads for the six countries are shown in the table below:

Table 1. Results for rural roads

	Finland	Latvia	Lithuania	Malta	Portugal	Sweden
KPI(1)	70.4%					
KPI(2)	48.7%					
KPI(3)	31.3%					64,3%
KPI(4)	19.0%	4.4%	53.77%	39,2%	27,8%	

The strong differences in the values for KPI(4) are linked to differences in the road network characteristics and speed limits. So it is hardly possible to make sensible comparisons. It should be noted that, in general, KPI's that are based on distance travelled have higher values than those based on the length of the road network.

All KPIs in relation to motorways had a value of 100%. It is proposed to develop a KPI that is specifically tailored to motorways. It is also proposed to develop an alternative road infrastructure KPI for urban roads.

Other recommendations include the convergence of road classification systems in the EU, considering infrastructure KPIs that are based on self-reported data, and use the results of road safety audits as a basis for constructing road infrastructure KPIs.

The annex to the report includes methodological guidelines for data collection and calculation of the four KPIs.

1. Introduction

1.1 Context

The Communication of the European Commission "Europe on the Move – Sustainable Mobility for Europe: safe, connected and clean" of 13 May 2018 confirmed the EU's long-term goal of moving towards zero fatalities in road transport by 2050 and added that the same should be strived for as far as serious injuries are concerned. It also proposed new interim targets of reducing the number of road deaths and serious injuries by 50% between 2020 and 2030. To measure progress, the most basic – and important – indicators are of course the final outcome indicators, namely traffic related deaths and serious injuries.

In order to gain a better understanding of the different issues that influence overall safety performance, the Commission has elaborated, in cooperation with Member State experts, a first set of key performance indicators (KPIs). The list of the KPIs is given in *Table* . The minimum requirements for these KPIs are described in the *Commission Staff Working Document SWD (2019) 283* (European Commission, 2019), further referred to as 'SWD'.

Table 2. List of European KPIs for road safety

KPI area	KPI definition
Speed	Percentage of vehicles travelling within the speed limit
Safety belt	Percentage of vehicle occupants using the safety belt or child restraint system correctly
Protective equipment	Percentage of riders of PTWs and bicycles wearing a protective helmet
Alcohol	Percentage of drivers driving within the legal limit for blood alcohol content (BAC)
Distraction	Percentage of drivers not using a handheld mobile device
Vehicle Safety	Percentage of passenger cars with a Euro NCAP safety rating equal or above a threshold
Infrastructure	Percentage of distance driven over roads with a rating above an agreed threshold
Post-crash care	Time elapsed between the emergency call following a collision resulting in personal injury and the arrival at the scene of the collision of the emergency services

Funding has been made available by the European Commission to support Member States in the data collection and analysis for these KPIs. Eighteen Member States participate in a common project, called "Baseline". The aim of the BASELINE project, funded partially by the European Commission, is to assist participating Member States' authorities in the collection and harmonized reporting of these KPIs and to contribute to building the capacity of Member States which have not yet collected and calculated the relevant data for the KPIs. The outcomes of this project will be used to set future European targets and goals based on the KPIs.

1.2 Participation in Baseline

The following EU Member States participated in the Baseline project: Austria; Belgium; Bulgaria; Cyprus; Czech Republic; Finland; Germany; Greece; Ireland; Latvia; Lithuania; Luxembourg; Malta; The Netherlands; Poland; Portugal; Spain; and Sweden. Some data regarding KPIs of EU Member States that did not participate in Baseline have also been included in some of the deliverables.

1.3 Final deliverables of the Baseline project

The final public outcomes and deliverables of the Baseline project are:

- Eight specific reports, each one dealing with a different KPI
- A dashboard with the KPIs
- A website on which all public information is accessible
- A final report including the key results of the project and recommendations for next steps.

1.4 The KPI on infrastructure safety and its alternative formulations

This document is the report providing information on the ***KPI Infrastructure***. This KPI has been initially defined by the Commission as:

> ***(1) Percentage of the distance driven over roads with a safety rating above an agreed threshold***

No methodology had been prescribed by the Commission nor had any threshold been defined. The European Commission only specified that the indicator should be based on a network rating or assessment methodology and take into account distance driven or another proxy for exposure. Moreover, the Commission stated that in the first phase, ***urban areas could be excluded*** by Member States to reduce the overall complexity of this KPI.

The Commission also recognized that "*Since many Member States do not yet have the data available for distance travelled, so as a first (and necessary) step it is proposed to gather data for the % **of network length** that is above the agreed safety rating threshold.*" (European Commission, 2019). This alternative KPI is easier to calculate than the previous one. So this provides an alternative formulation of the KPI:

> ***(2) Percentage of the road network length of roads with a safety rating above an agreed threshold***

In the SWD document the Commission also stated that temporarily, a simplified version of the KPI may be used where no safety rating methodology is available:

> ***(3) Percentage of the distance driven over roads either with opposite traffic separation (by barrier or area) or with a speed limit equal to or lower than xx km/h in relation to total distance travelled [on all roads]***

The speed limit to be used was left to the discretion of the Member States.

If we combine this with the possibility to replace "distance driven" with "network length", another and even more simplified version of the KPI can be considered:

> ***(4) Percentage of the road network length of roads either with opposite traffic separation (by barrier or area) or with a speed limit equal to or lower than xx km/h in relation to the total road network length.***

The speed limit to be used was left to the discretion of the Member States.

The first two versions of the KPI on Infrastructure safety requires a choice of a safety rating and a definition of a safety threshold. In Section A2 of the Annex, the concept of safety ratings is explained, as well as how these can be used to calculate the KPI values for a whole network. This annex is taken from the texts in the Methodological Guidelines for the KPI Infrastructure (Van den Berghe et al., 2021).

It should be noted that Article 5 of the EU Directive on Road Infrastructure Safety Management (as revised by DIR 2019/1936) indicates that "*The Commission shall provide guidance on the methodology for carrying out systematic network-wide road safety assessments and safety ratings*". The Commission, with the assistance of the Expert Group on Road Infrastructure Safety (EGRIS) is currently developing a methodology for network-wide road safety assessment based on the combined rating of the "in-built" safety of roads and historic crash data. However, the assessment methodology, resulting safety classes and thresholds have not yet been finalized and published, and could therefore not yet been taking into consideration.

2. Methodology

2.1 Overall process

For each KPI, a "KPI Expert Group" (KEG) was established, which was responsible for the design of the methodological guidelines and for the review of a draft version of this report. The KEG for the infrastructure indicator consisted of the following persons:

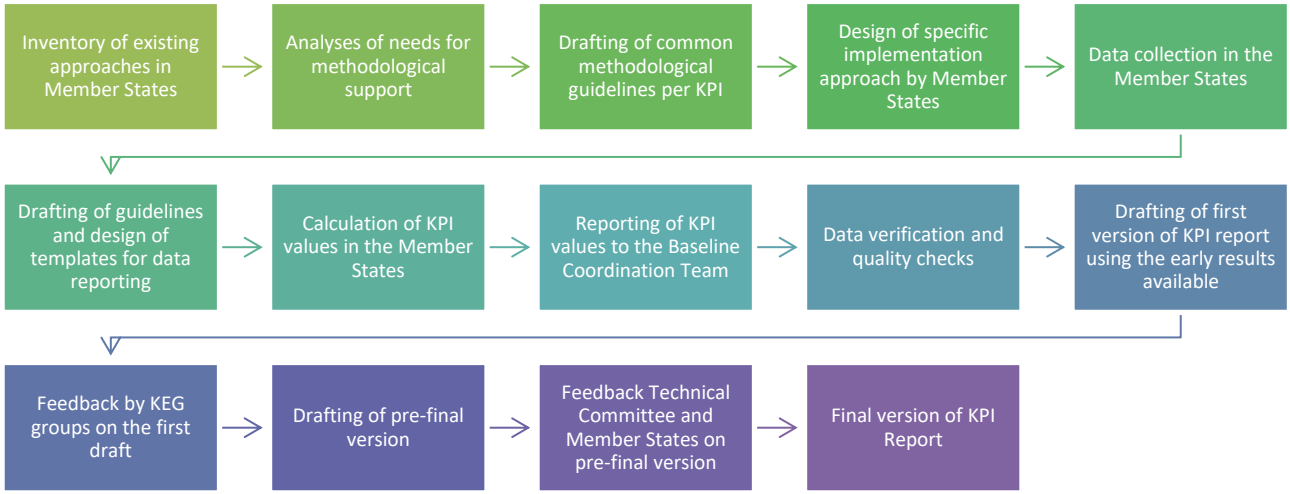
- Wouter Van den Berghe, Vias institute (Belgium)
- Stijn Daniels, Vias institute (Belgium)
- Anastasios Dragomanovits, NTUA (Greece)
- Govert Schermers, SWOV (Netherlands)
- Marco Irzik, BASt (Germany).

The overall process developing the methodological guidelines was overseen by the Baseline Technical Committee, which focused in particular on issues that were important for several KPIs (e.g., structure and content of the guidelines, minimum sampling size, number of observations and locations, weighting of data, data reporting, etc.). The Technical Committee consisted of:

- Peter Silverans, Vias institute (Belgium) - Coordinator
- Wouter Van den Berghe, Vias institute (Belgium)
- Frits Bijleveld, SWOV (Netherlands)
- Sheila Ferrer López, DGT (Spain)
- Peter Larsson, Trafikverket (Sweden)
- Markus Schumacher, BASt (Germany)
- Veronika Valentova, CDV (Czech Republic)
- George Yannis, NTUA (Greece)

The process followed for arriving at this report is summarized in *Figure 1*.

Figure 1. Process leading to this report



2.2 Support tools developed

For every KPI, methodological guidelines were developed, covering topics such as:

- definition of the KPI concerned, and possibly complementary or alternative KPIs
- methods to be used for data collection
- breakdowns requested of the KPI values (road category, vehicle type, day of week, …)
- minimum sample of observations/cases and observation locations
- methods for weighting and analysing the data
- nature and format of data to be reported

The methodological guidelines of the KPI Infrastructure (Van den Berghe et al., 2021) can be accessed from the Baseline website via this link. Most elements of these Methodological Guidelines have been integrated in this report, either within the main body of the text, or as part of the Annex.

In order to streamline and harmonize the data flow, data reporting guidelines and data reporting templates were developed. The data reporting templates (in Excel) were used by the Member States for reporting their KPI values to the Baseline Coordination Team. An extract of such a data file is shown in the figure below.

Figure 2. Data reporting templates

	A	B	C	D	E	F	G	H	I	J	K
1		**BASELINE - Infrastructure**									
2		**Minimum Level (required)**		KPI 1: Safety rating: "Accident costs below median calculated by the road length in each road class" - indicator calculated by distance driven							
3						**Million vehicle km/year**					
4		**Region**	**Type of road***	**Road segments**	**Total number of road segments (N)**	**Exposure per road segment**	**DSi**	**Exposure on roads with safety rating above the threshold**	**Ei**	**Si**	**KPI (1)**	**CI (95%) -**
5		*(all regions)*	**motorways-Total**	(all road segments)	174	42.718	1.000	7433	7433	1.000	100.0	
6		*(all regions)*	**rural roads-Total**	(all road segments)	12580	2.171	0.704	19221	27315	0.704	70.4	
7		*(all regions)*	**urban roads-Total**	(all road segments)	1001	1.989	0.793	1579	1991	0.793	79.3	
8												

2.3 Minimum and optional requirements for the KPI Infrastructure within Baseline

The minimum requirements for the KPI Infrastructure were to calculate, for a given year, a KPI value for at least 'rural roads' and 'motorways'. A KPI value for roads in urban areas was optional. In Section A3.2 of the Annex, more information is given about the road typology and categorisation.

The choice of the safety rating method (KPIs (1) and (2)) and the speed limit threshold (KPIs (3) and (4)) were left to the discretion of the participating Member States. Project partners were suggested to provide three threshold values (low, average, high) if they used KPI (1) and KPI (2).

In the methodological guidelines the following speed limits were suggested for use in KPIs (3) and KPIs (4):

- 30 km/h for roads with the possibility of a collision between a vulnerable road user and a motorised vehicle (this includes all roads in built-up areas, except for roads where vulnerable road users are separated from motorized vehicles).
- 50 km/h for roads in built-up areas with facilities to separate vulnerable road users from motorized traffic.
- 50 km/h for roads with the possibility of a right angle collision between motorized vehicles (typically for interurban roads with a high density of intersections and/or where the density of accesses to private properties is high).
- 70 km/h for roads with the possibility of a head on collision between passenger vehicles (typically for interurban or rural roads with long road segments without intersections).

Participating Member States could provide values for any of the four versions of the KPI; it was optional to do it for more than one. Of the six countries that provided an infrastructure safety KPI, only Finland provided values for more than one KPI definition; moreover, Finland also provided data for urban areas.

It was also optional to provide KPI values at regional level, since in many countries, responsibility for road design and road safety (for some or all road types) is at the regional level; moreover, the safety situation could differ between regions. Finland, Malta and Portugal also provided data at regional level.

3. Results

3.1 Metadata

Six EU Member States provided data for the KPI on infrastructure safety: **Finland, Latvia, Lithuania, Malta, Portugal and Sweden**. Finland provided data for all four definitions of the infrastructure KPI; the other countries used only one of the four versions: Sweden used indicator KPI (3) and Latvia, Lithuania and Portugal used indicator KPI (4). Four countries provided data for both rural roads and motorways (Finland, Lithuania, Portugal and Sweden). Finland and Malta provided data on urban roads. In Finland, the values for the KPIs refer to public roads but exclude most city streets.

The reference year to which the data apply are

- Finland: 2016-2020
- Latvia: 2021
- Lithuania: 2021
- Malta: 2020
- Portugal: 2013-2020
- Sweden: 2020

Finland was the only country that provided values for KPIs (1) and (2). This requires the use of **a safety assessment rating system** and the definition of a safety threshold to distinguish "safe" from "unsafe" (or less safe) road sections. The rating system used was the average crash cost per vehicle km. More details can be found in Peltola et al. (2013). To be considered a safe road, accident costs per kilometre driven must be below the median calculated by road length in each road class. In practice this means, that accident costs on 50 % of the road length is higher that the threshold in each road class. These thresholds are lower for main roads than for regional roads and connecting roads. Please note that in Finland, "Motorways" are not considered as a separate road type for this purpose, but are part of a broader category called "Class I roads", with a distinct safety threshold.

The **speed limit thresholds** used for KPIs (3) and KPI (4) were:

- for KPI (3) in Sweden: 70 km/h.
- for KPIs (3) and (4) In Finland: 40 km/h on urban public roads and 70 km/h on other public roads
- for KPI (4) in Latvia, Lithuania and Portugal: 70 km/h on rural roads
- for KPI (4) in Malta:
    - 30 km/h for roads with the possibility of a collision between a vulnerable road user and a motorized vehicle (this includes all roads in built-up areas, except for roads where vulnerable road users are separated from motorized vehicles).
    - 50 km/h for roads in built-up areas with facilities to separate vulnerable road users from motorized traffic.
    - 70 km/h for roads with the possibility of a head on collision between passenger vehicles (typically for interurban or rural roads with long road segments without intersections).

It should be noted that the speed limits used in Malta are design speeds that may not reflect actual speed limits.

3.2 KPI values for motorways

Table shows the values of the KPIs for motorways (there are no motorways in Latvia and Malta). As can be seen, in all cases these are 100%. These results can be explained as follows:

- According to the definition, for KPIs (3) and (4) it suffices for a road to have median separation in order to be considered as safe. Since all motorways have median separations, they are all considered be safe according to the requirements for KPIs (3) and KPIs (4).
- The Finnish values for KPIs (1) and (2) can be explained by the rating system and thresholds that were applied, based on average crash cost per vehicle km. This threshold has been set for Class 1 roads in Finland, which includes both motorways and other primary roads, and all motorways exhibit average crash costs below the defined threshold.

Table 3. Infrastructure KPIs for motorways

	Finland	Lithuania	Portugal	Sweden
KPI (1)	100.0%			
KPI (2)	100.0%			
KPI (3)	100.0%			100.0%
KPI (4)	100.0%	100.0%	100.0%	

It is well known that motorways are, on average, much safer than rural roads (see e.g. https://toolkit.irap.org/road-types/motorways/). The safety is higher because there are no/limited opportunities for head-on or crossing crashes and design is of highest standard. But having KPI values equal to 100% may give the wrong impression that no road crashes will occur, which is overly optimistic. It can be concluded that the current definitions of KPIs are more relevant for rural roads than for motorways, in particular KPI (3) and KPI (4). The 100% rate for KPI(1) and KPI(2) is a consequence of the decision of Finland to group motorways together with lower class roads and define a common threshold. It is then reasonable that all motorways, being safer than lower class roads, will stand as 100% safe. Given the volume of traffic on motorways in most countries, it seems appropriate to have specific assessment ratings and/or specific safety thresholds for motorways, that are different from those used for rural roads.

3.3 KPI values for rural roads

Table shows the KPI values for rural roads. Rural roads are all roads that are not motorways and not urban roads. However, each country has its own classification system. Thoroughfares in cities or busy roads passing through villages may be classified as rural roads in one country but as urban roads in another country. An additional complication for international comparisons is that each country has several types of rural roads, with different speed limits and safety characteristics; some of the rural roads may be gravel roads. The distribution of these types of roads and the relative volume of traffic, varies considerably across countries, making comparisons of the KPI values currently almost meaningless.

Table 4. Infrastructure KPIs for rural roads

	Finland	Latvia	Lithuania	Malta	Portugal	Sweden
KPI (1)	70.4%					
KPI (2)	48.7%					
KPI (3)	31.3%					64,3%
KPI (4)	19.0%	4.4%	53.77%	39,2%	27,8%	

The values for Finland show that KPI (2) has a lower value than KPI (1) and KPI (4) a lower value than KPI (3). Although the values are only available for Finland, this finding can probably be generalised to other European countries (if a similar safety rating method would be applied). The reason is that roads with high traffic volume have often a lower crash risk per kilometre and/or have better safety characteristics than rural roads with low traffic volume. This affects the difference between KPI(1) and KPI(2), and between KPI(3) and KPI (4).

One can see that for KPI (3), Finland and Sweden have quite different values. It should be noted that Sweden uses the following definition for its KPI for infrastructure: "Share of traffic volume with median barriers on national roads with speed limits above 80 km/h". In 2020 the value of this KPI was 85% (including motorways). Although only 6% of the roads in Sweden have median barriers, they account for 42% of the traffic volume. Please note that the value in *Table* refers to rural roads only and is calculated with a speed limit threshold of 70 km/h.

The very low value of KPI(4) for Latvia can be explained by the fact that the speed limit on rural roads in Latvia is 90 km/h and very few roads have median separation banners. The value of KPI (4) for Lithuania only applies to national (state) roads. The relatively high value for Lithuania can be explained to some extent by two factors: (a) state roads

in villages have a speed limit of 70 km/h or lower; and (b) 28% of the national (state) road network consists of gravel roads, for which the speed limit is 70 km/h. It is recalled that the value for Malta is based on design speeds.

3.4 KPI values for urban roads

Malta's value for KPI (4) for urban roads is 76,0 %, which is much higher than the value for rural roads. Finland provided KPI values for urban roads, for each of the four definitions. The values are:

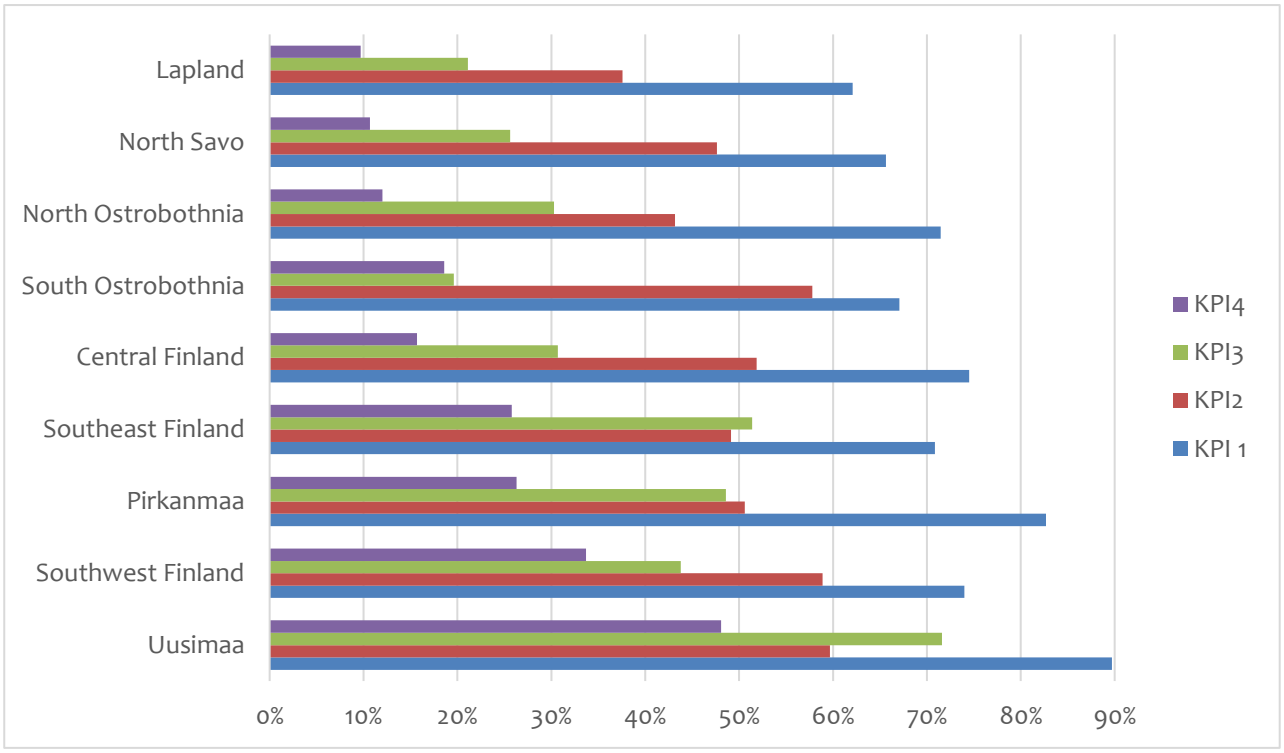
- KPI (1): 78.6%
- KPI (2): 72.9%
- KPI (3): 27.8%
- KPI (4): 41.1%

When comparing these values with the rural road data in Finland (*Table*), one can see that the values of KPI(1) and KPI(2) are higher for urban roads than for rural roads. However, these values cannot be compared directly because different safety thresholds have been used. It may also come as a surprise that KPI(4) has a higher value than KPI(3), unlike what has been found for rural roads. This can be explained by the fact that the Finnish figures for urban roads only include certain public roads inside urban areas; most city streets are not included. In Finland the urban roads with the highest speed limits (60 km/h) are often those carrying high traffic volumes; they are often well separated from housing as well as from pedestrians and bicyclists. However, for KPI3 and KPI4 they are still considered as non-safe because of a relatively high speed limit. Urban road with a speed limit of 40 km/h or less have a lower average daily traffic (average 1 650 vehicles/day) than those with higher speed limits (average 2 980 vehicles/day). In other words: speeds limits of 40 km/h or less are more often used on urban roads with low average daily traffic. This causes the KPI4 being higher than KPI3 on urban roads.

3.5 Breakdowns by region

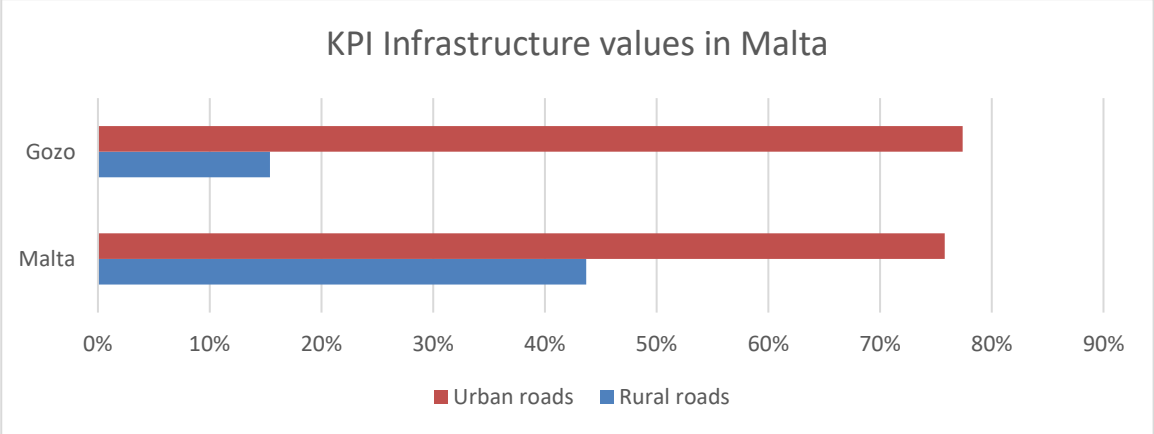
Finland, Malta and Portugal provided also a regional breakdown of the KPI values. The values for Finland are shown in *Figure* . As can be seen, in all Finnish regions KPI(1) has the highest value and KPI(4) the lowest. The region with the highest KPI values is Uusimaa (the region around the capital Helsinki); Lapland is the region with the lowest values.

Figure 3. Regional breakdown of KPI values in Finland



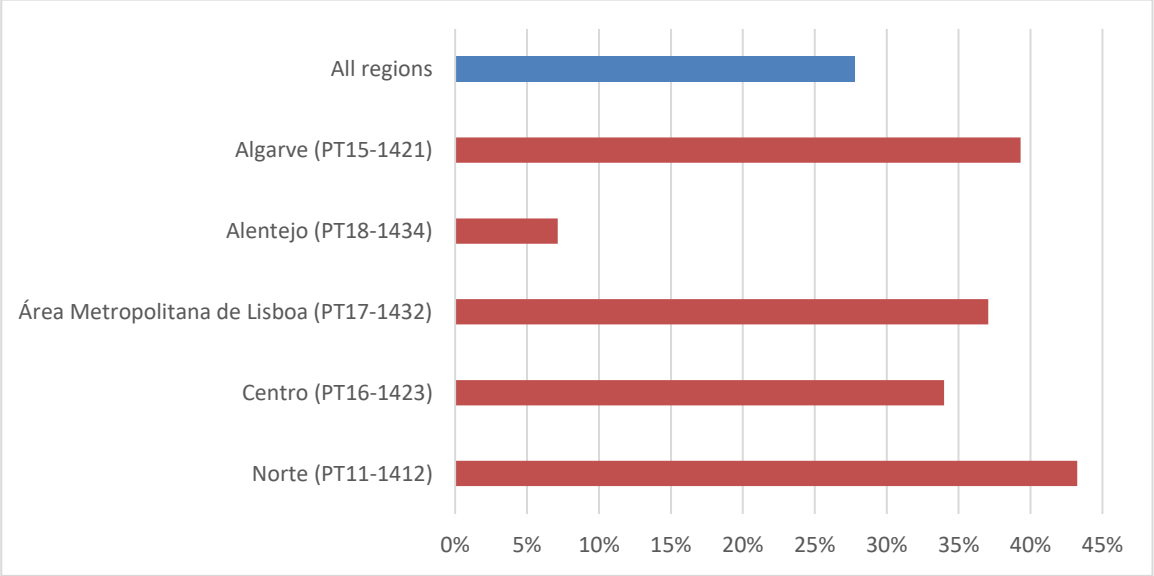
Malta made a distinction between the main island and the Gozo island (see *Figure*). As one can see, the safety level resulting from the KPI definition used, is lowest in Gozo.

Figure 4. Regional breakdown of KPI values in Malta



In Portugal, the values of KPI(4) were calculated for the five main regions of the country *Figure* . It can easily be detected that the values are similar in most regions, except in Alentejo, where the safety level of the roads appears to be much lower.

Figure 5. Regional breakdown of KPI values in Portugal



3.6 Complementary indicators

A proxy value for infrastructure safety can be obtained through the subjective safety feeling perceived by road users on different types of roads. It should be noted that subjective safety feeling is only a rough proxy for road infrastructure safety, since it may also be affected by perceived driver behaviour and other factors. But as of today, it seems to be the only indicator which allows to compare a range of European countries.

Information on subjective safety is available from the ESRA database and ESRA reports (Meesmann et al., 2022). Figure 5 and Figure 6 display the level of subjective safety for four types of road users: motorcyclist, cyclists, pedestrians and car drivers. The safety feeling is the mean score of a 11-point scale, where 0 = 'very unsafe' and 10 = 'very safe'. The reference population for each value consists of the road users who use that specific transport mode over the past 12 months.

One can observe that in most European countries the subjective safety feeling of pedestrians is the highest and the safety feeling of motorcyclists (including moped drivers) the lowest. Within the set of countries considered, the lowest scores are found in Greece and Bulgaria.

Figure 6. Subjective safety perceived by motorcyclists and cyclists

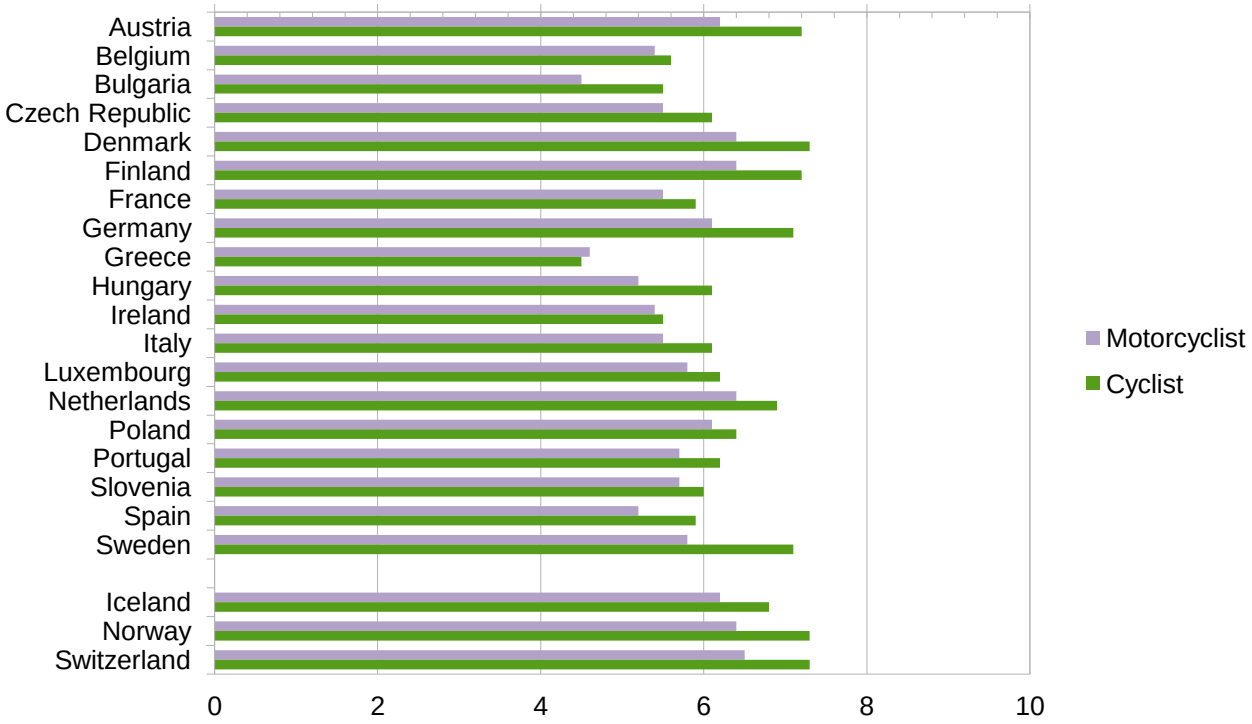
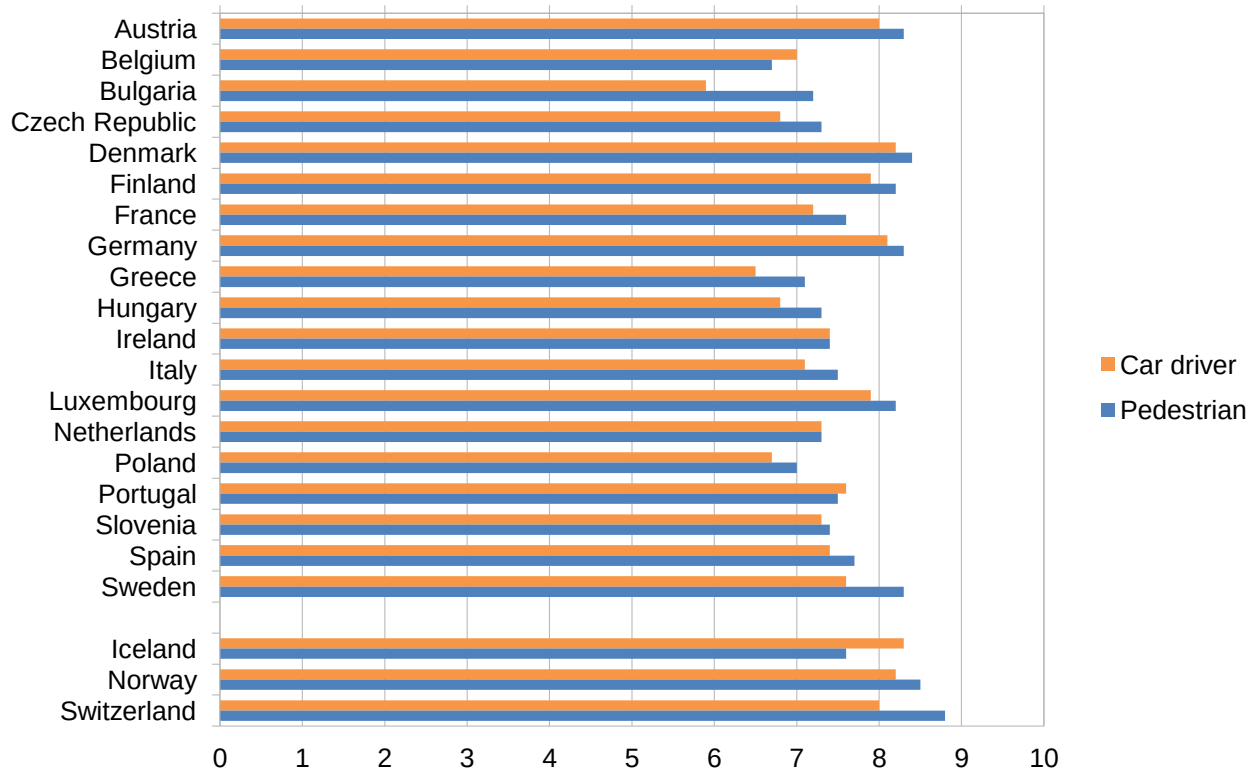


Figure 7. Subjective safety perceived by pedestrians and car drivers



4. Conclusions and recommendations

4.1 Comparability of data

Ideally, to facilitate comparison and share experience, EU Member States ought to adopt a common classification of roads, or at least would be capable of converting their data into a common classification. In particular a distinction between non-urban roads and urban roads would be required – not just for the KPIs on road infrastructure, but also for many other road safety KPIs and also for crash data itself. However, this is not the case at present.

It is also highly recommended that if the same safety assessment method is used for KPI(1) and KPI(2) in different countries, that they would agree on common safety thresholds. The results for motorways have also illustrated that there is also a need for defining safety thresholds at an appropriate level. A KPI is only useful if the threshold is ambitious but eventually feasible. If the threshold is too general, all roads will comply; if it is too strict, nothing will comply. Neither of these cases are desirable from a safety improvement perspective.

For KPI(1) and KPI(2) data is only available from one country (Finland) which makes international comparisons impossible. It should moreover be noted that only public roads in urban areas are included in the data, and not the other city streets.

Since definitions of 'rural roads' vary across countries, and speed limits vary considerably on such roads (even within a country), it is difficult to make comparisons. This is illustrated by the very large differences in values for KPI(4) between Finland, Latvia, Lithuania, Portugal and Malta, which can partially be explained by the different type of roads included. Yet, the comparison between Sweden and Finland makes sense since they are based on traffic volume and roads with similar characteristics.

For motorways, all values provided are 100%. This is understandable, given the definition of KPI(3) and KPI(4) and the threshold used by Finland for KPI(1) and KPI(2). However, this also suggests that the current definitions of these KPIs are not very useful for determining the (relative) safety level of motorways.

4.2 Towards more precise definitions

From the analyses conducted it has appeared that, if the current definitions of the KPIs are kept in the future, they need to be formulated more precisely.

For KPI(3) and KPI(4) it is suggested to replace the words "… with opposite traffic separation (by barrier or area) …" by "… with separate carriageways and/or with physical separation of the driving directions…"

For KPI(2) and KPI(4) it is suggested that the "percentage of roads" and "(total) road network length" are calculated by type of road, and that different road types are not mixed together. For instance, it would refer to "the percentage of rural roads" with particular safety characteristics as part of the "total rural road network".

4.3 Recommendations

Only six countries have provided values for one or more KPIs. This suggests that the indicator is seen as 'problematic' by many countries.

It is proposed that the current KPIs (3) and (4) would no longer be used for **motorways**. KPIs (1) and (2) could be maintained, provided that a useful and justified threshold could be defined (and agreed by several EU Member States). This threshold could also be modified over time. Alternative or complementary indicators could also be considered, such as:

- an Indicator based on crash risks (reactive approach), e.g., the number of injury crashes per 100 km over the last 5 years
- an indicator based on motorway characteristics (pro-active approach), e.g., the percentage of the motorway network that has particular safety characteristics.
- an indicator based on user perception of the safety of the motorways in their country

KPI values for **urban roads** are only available for Finland. It should be noted that the network-wide road safety assessment defined in EU DIR 2019/1936 (and the methodology under development) is, with a few exceptions, not applicable to urban roads. It is suggested to abandon the current KPIs for urban settings. It may be replaced by:

- an indicator based on crash risks (reactive approach), e.g., the number of injury crashes per million km travelled)

- an indicator based on user perception of the safety of the streets in the city they live in
- the percentage of the urban road network (excluding urban motorways) with a speed limit of 30 km/h or less.

It should be kept in mind that injury crashes with some road users, in particular cyclists and motorcyclists are often not reported to the police and hence do not appear in police records on crashes. An indicator based on crash risk should correct for that bias.

For the **rural roads**, it is suggested to maintain the four KPIs that are currently in use. As stated before, more convergence on the definition and scope of rural roads would be welcome.

Self-reported data on infrastructure road safety should also be used more. In ESRA3, new survey questions have been incorporated on road infrastructure safety, developed by a group of international experts. It will be useful to link this subjective data with data obtained through proactive and reactive approaches. An important added value of self-reported data is that the survey responses can be related to many other variables that are not available through road side observations (sociodemographic characteristics, attitudes, enforcement, context, …).

In the medium term, a new infrastructure KPI for motorways and rural roads could be based on the common European **method for assessing the safety of roads**, of which a draft proposal is now available (Yannis et al., 2022). This integrated methodology considers both the "in-built" safety characteristics of roads (proactive assessment) and historic crash data (reactive assessment), if available, and results in five classes for the ranking of roads, namely: “Very low priority”, “Low priority”, “Intermediate priority”, “High priority” and “Very high priority”, related to the prioritization for further actions leading to road infrastructure improvements. Assuming that this methodology would be adopted across Europe, a possible definition of a KPI based on this methodology could be the % of the road network classified as “very low priority” and “low priority”. Such a logic could also be applied to national road assessment methods that are currently in use in EU Member States.

Annex 1. Requirements for infrastructure safety measurements

5. A1. Possible formulations for the KPI on infrastructure

A1.1 Combination of exposure and safety rating

This concerns the 'prime' formulation of the KPI:

(1) ***Percentage of the distance driven over roads with a safety rating above an agreed threshold***

In order to be able to calculate the KPI, the following is needed:

- Exposure data for the road segments in the network. For a particular road segment "R_i" the exposure will be denoted as "E_i". The exposure data is the product of the length of the road segment and the traffic volume on that road segment.
- A safety rating method. The safety rating for a particular road segment "R_i" will be called "S_i".
- A dichotomization of the safety rating, i.e., classifying road types into roads that are above the safety threshold – called DS_i, whereby $DS_i = 1$ if the threshold is achieved or superseded, and $DS_i = 0$ if the threshold is not achieved. Please note that the threshold could vary by road category.

The formula for the KPI is the sum of the exposure on the safe roads divided by the total exposure:

$$KPI(1) = \frac{\sum_1^N E_i * DS_i}{\sum_1^N E_i}$$

(N= the total number of road segments in the network)

Please note that this KPI is expressed as a share, a value between 0 and 1. To express it in a percentage, the share should be multiplied with 100% (e.g., 0.65 becomes 65%). This also applies to the other KPIs that are discussed here.

In other words, the exposure is weighted with the (dichotomized) safety rating. Possible methods for safety ratings are discussed in Section 6 below.

As indicated in Section 1.1, urban areas can be excluded from the calculations. When doing so, this should be clearly marked when providing the KPI data and metadata.

A1.2 Combination of network length and safety rating

This concerns the following formulation of the KPI:

(2) ***Percentage of the road network length of roads with a safety rating above an agreed threshold***

Given the fact that traffic volumes are not readily available on all road segments in most countries, this is a simplified version of the previous KPI, in the sense that the road length is taken as a rough proxy of traffic exposure – in other words, the simplification is that the traffic volume is the same on all roads. Thus, if "L_i" denotes the length of a particular road section "R_i", then in the previous formula for the KPI, "E_i" should be replaced by "L_i":

$$KPI(2) = \frac{\sum_1^N L_i * DS_i}{\sum_1^N L_i}$$

As indicated in Section 1, urban areas could be excluded from the calculations. When doing so, this should be clearly marked when providing the KPI data and metadata.

A1.3 Exposure for two types of safe roads

This concerns the following formulation of the KPI:

(3) ***Percentage of the distance driven over roads either with opposite traffic separation (by barrier or area) or with a speed limit equal to or lower than xx km/h in relation to total distance travelled on all roads.***

The difference with the prime indicator (1) is that the type of safety rating is already given. The safety threshold is assumed to be achieved when either (a) the road has opposite traffic separation, or (b) has a speed limit equal or lower than a defined threshold. This speed limit threshold is not prescribed.

The following speed limit thresholds are proposed, in line with Safe System principles (European Commission, 2020; ITF, 2016; SWOV, 2016):

- 30 km/h for roads with the possibility of a collision between a vulnerable road user and a motorized vehicle (this includes all roads in built-up areas, except for roads where vulnerable road users are separated from motorized vehicles).
- 50 km/h for roads in built-up areas with facilities to separate vulnerable road users from motorized traffic.
- 50 km/h for roads with the possibility of a right angle collision between motorized vehicles (typically for interurban roads with a high density of intersections and/or where the density of accesses to private properties is high).
- 70 km/h for roads with the possibility of a head on collision between passenger vehicles (typically for interurban or rural roads with long road segments without intersections).

Please note that these speed limits are suggestions and Member States can choose other ones. These speed limits are only proposed here in the context of the KPI on infrastructure safety. They do not imply any commitment from the European Commission to these limits. If within the EGRIS[1] expert group a consensus would emerge on other or more specific thresholds, then these will be taken into account in an updated version of these guidelines.

In order to calculate this KPI, there is need for traffic exposure data and a classification of roads into three groups:

- RL: Roads on which the speed limit is equal or **lower** than the threshold (30 km/h, 50 km/h and 70 km/h, depending on the road type). We can make a further distinction in road types RL30, RL50 and RL70.
- RH: Roads on which the speed limit is **higher** than the threshold, **without** opposite traffic separation (by barrier or area). We can make a further distinction in road types RH30, RH50 and RH70.
- RS: Roads on which the speed limit is higher than the threshold, but **with** opposite traffic **separation** (by barrier or area).

The KPI is then calculated as the exposure on RL and RS roads, divided by the total exposure. The exposure on road segment i of an RL type road segment can be denoted as ERL_i, for an RH road it is ERH_i and for an RS type road segment it is ERS_i. The formula is as follows:

$$KPI(3) = \frac{\sum_1^N ERL_i + \sum_1^N ERS_i}{\sum_1^N ERL_i + \sum_1^N ERH_i + \sum_1^N ERS_i}$$

It is useful and recommended to also report the components of this indicator:

- Percentage of the distance driven over roads with opposite traffic separation (RS roads) as part of the total distance driven
- Percentage of the distance driven over roads with a safe speed limit 30/50/70 (RL roads) as part of the total distance driven

It could also be interesting to calculate the following proportions:

- Percentage of the distance driven over RL30 roads as part of the total distance driven over RL30 and RH30 roads
- Percentage of the distance driven over RL50 roads as part of the total distance driven over RL50 and RH50 roads
- Percentage of the distance driven over RL70 roads as part of the total distance driven over RL70 and RH70 roads

One should be aware that speed limits are subject to frequent changes, including work zones, constructions, etc. It is hence important to use of an inventory of speed limits that is regularly updated.

1 See https://ec.europa.eu/transparency/expert-groups-register/screen/expert-groups/consult?do=groupDetail.groupDetail&groupID=3686

A1.4 Relative network length of two types of roads

This concerns the following formulation of the KPI:

(4) ***Percentage of the road network length of roads either with opposite traffic separation (by barrier or area) or with a speed limit equal to or lower than xx km/h in relation to total road network length***

This is a simplified version of KPI (3), in the sense that the road length is taken as a rough proxy of traffic exposure. So if we define

LRL_i as the length of a road segment of the type RL,
LRH_i as the length of a road segment of the type RH, and
LRS_i as the length of a road segment of the type RS,

the formula for the KPI is as follows:

$$KPI(4) = \frac{\sum_1^N LRL_i + \sum_1^N LRS_i}{\sum_1^N LRL_i + \sum_1^N LRH_i + \sum_1^N LRS_i}$$

Clearly, this is by far the simplest (and crudest) KPI for infrastructure safety. However, it has the advantage that the data required to calculate it may be readily available with Member States.

It is highly recommended to also report the components of this indicator

- Percentage of the length of RS roads (with opposite traffic separation) in relation to the total road network length
- Percentage of the length of RL roads (other roads with a safe speed limit 30/50/70 km/h) in relation to the total road network length

It could also be interesting to calculate the following proportions:

- Percentage of the total length of RL30 roads as part of the length of RL30 and RH30 roads combined
- Percentage of the total length of RL50 roads as part of the length of RL50 and RH50 roads combined
- Percentage of the total length of RL70 roads as part of the length of RL70 and RH70 roads combined

One should be aware that speed limits are subject to frequent changes, including work zones, constructions, etc. It is hence important to use of an inventory of speed limits that is regularly updated.

A1.5 Sampling and weighting

In some cases, data on traffic and/or safety on roads may only be available for part of the road network. In cases where traffic and related data are not available, it might nevertheless be possible to derive an estimate of the KPI at national level, provided the sample is sufficiently representative and appropriate weighting factors can be defined.

If exposure data is available for the whole road network (with the possible exception of urban areas) but safety ratings for a sample only, the first question to be asked is whether this sample includes all the key types of roads in the country under consideration. In general, this requires that roads are included from all the key typologies used within the country; these typologies are often related to speed limits.

If the safety ratings still need to be undertaken the best approach is to undertake a stratified random sampling:

- In a first step, a road categorization should be defined (see Section 0)
- For each road category, at least 10 road sections are chosen at random. These road sections should be at least 1 km long (200 m in built-up areas) and have traffic volume of at least 10 vehicles per hour in each direction.
- For each of the selected road sections, the safety rating method (see Section 6) should be applied.
- Once the safety rating has been given, it should be dichotomized based on the chosen threshold, indicating whether the road can be considered safe enough.

The next steps are then:

- For each road category the safety ratings (1 or 0) are averaged, using the traffic volume on each road segment as a weighting factor. This provides an aggregated safety rating for that particular road category. This procedure is repeated for each road category.
- The national safety rating is then obtained by weighting the safety ratings for each road category with the national traffic volume on each of these road categories.

Let 'i' refer to the road category and 'j' to the road segments in that category, then we can define

R_{ij} as the road segment j of road category i,
S_{ij} as the safety rating of R_{ij}
DS_{ij} as the dichotomized safety rating of R_{ij} (1 or 0; value of 1 if the threshold is reached)
V_{ij} as the number of vehicles passing in one hour on road segment R_{ij}
S_i as the safety rating obtained for road category i
E_i as the national traffic exposure for road category i

The formula for Si is: $S_i = \frac{\sum_1^n DS_{ij} V_{ij}}{\sum_1^n V_{ij}}$

The KPI can be calculated as follows:

$$KPI(S_e) = \frac{\sum_1^N E_i * S_i}{\sum_1^N E_i}$$

If no exposure data is available but rating the safety of some road sections is available or can be undertaken, a similar but simpler procedure can be followed. The weighting factor Exposure at the end of the process is replaced by a proxy: the length of the road network for that category – which comes down to assuming that the traffic volume per km (traffic density) on the whole network of a certain road category is identical to that in the sample for that road category. Thus, if "L_i" denotes the total length of a particular road category "R_i", the formula for the KPI then becomes:

$$KPI(S_l) = \frac{\sum_1^N L_i * S_i}{\sum_1^N L_i}$$

As indicated above, traffic volumes can either be inferred from existing national mobility data or estimated by using traffic counts on the selected sample of road sections. When traffic counts are used to infer traffic volumes per stratum from traffic counts in each stratum, road network length by type of road should be taken into account.

Statistical analysis techniques and tools should be determined by each Member State and clearly described in the method section. When using sampling, project participants should indicate very clearly what principles the sampling design was based on (including justification of any deviation of the minimum sample of 10 road sections per road type) and how the exposure and traffic data were obtained for both steps in the process (weighting within each road type and weighting across road types).

6. A2. Safety rating methods

A2.1 Infrastructure based methods

One approach for safety ratings of roads is based on assessing the (geometric) characteristics of the roads. Sometimes the terms 'in-built safety method" or 'pro-active approach' are used. Such methods establish whether roads (or sections thereof) comply to road design elements that have been proven to improve road safety or that guarantee the highest road safety performance by minimizing/optimizing speeds and minimizing the risk of injury in the unlikely event of crashes. The safety components inspected can be based on national road design standards, in particular the presence of road design elements that are intended to improve road safety, or on internationally agreed requirements such as those developed under the iRAP umbrella (EuroRAP in the EU). The information needed can be derived from administrative sources (road authorities), in particular for roads that have just been designed, or collected through visual inspection. For some roads, Google Street View images maybe sufficient to undertake the safety assessments (provided they are up to date).

Defining the threshold above which a road can be considered to be "safe enough" is more complicated. International methods such as EuroRAP/iRAP use a 5 star rating system[2], whereby the minimum safety level is set at 3 stars. When national or regional methods are used, setting the safety threshold is at the discretion of the Member States. When reporting on the KPI, project partners are asked to explain on what basis the safety threshold has been defined – and possibly compare this with safety ratings and thresholds used elsewhere. In order to improve comparability across countries over time, Member States are encouraged to develop comparable ways of scoring their roads and using a common set of geometric road data.

A possible drawback of methods like EuroRAP/iRAP is that they require a lot of data. Countries starting with safety ratings for the first time, could consider to begin at a much smaller scale, for instance only using three or four road characteristics which can be used to derive a safety rating, e.g. directional separation, clear zone/obstacle distance; and number of accesses. Such a method has recently been developed in the Netherlands (Bax et al., 2017). If Member States participating in Baseline intend to use such a more simple approach, it is recommended that they would explore together whether they could use the same safety characteristics to base their safety rating on.

For project partners considering this approach, it is suggested that three threshold levels are used: a low/easy, an average and a high/difficult threshold level. For a particular type of road, the 'low' threshold could refer to for e.g. the presence of three particular safety characteristics of roads that should be present, the 'average' threshold to five and the 'high' to at least eight such characteristics. This is just an example; the numbers can vary by type of road.

An alternative approach is based on the presence of road characteristics that are known to reduce safety, e.g. obstacles on the road side, small radius of the road curve, small road width, insufficient drainage, etc. The thresholds could then be based on the presence of X unsafe road features or X % of the road segment that has these unsafe elements (e. g. due to unprotected obstacles). Depending on the presence (or absence) of these unsafe elements, three thresholds could be defined: 'very unsafe', 'unsafe' and 'likely safe'.

A2.2 Crash based methods

Crash based safety rating methods are based on the actual crash risk levels for particular road segments or types of roads. These are sometimes also called 'reactive approaches'. These crash risks are determined through statistical analysis and modelling based on the number and severity of (injury) crashes occurring on these roads at particular locations or road segments. In order to cope with statistical fluctuations, data over several years (typically 3 to 10 years) are used to calculate crash risks.

Different types of road safety outcomes can be considered such as the number of crashes, the number of injury crashes, the number of severe injury and fatal crashes, or the number of fatal crashes. In order to obtain a risk indicator, such figures should be related to a unit of measurement such as:

- the length of the road segment (crash density expressed as crashes/km)
- the traffic volume on the road (crash risk expressed as crashes/million vehicles km travelled)
- the population (mortality rate in a particular area expressed as deaths per unit population, usually million).

Such an approach is being followed in several countries and also in EuroRAP[3] .The crash risks can also be converted to an economic value (the estimated economic/human loss resulting from the road crashes on the roads), using appropriate economic estimation methods. This is already done in Finland for part of the road network (Peltola et al., 2013; Peltola & Innamaa, 2020).

Again, defining a threshold is left to the discretion of Member States. Within the Baseline project, Member States using a crash based method will, for every road type considered, seek to define a common maximum level of crash risk. At this stage it is suggested that project partners should define three levels of the threshold: a low, an average and a high threshold level. If Member States participating in Baseline intend to use a crash based safety rating method, it is recommended that they would explore together whether they could use the same risk indicators and the same threshold levels. If that proves to be difficult at this stage, it is important to keep the thresholds stable over the year, so that progress can be monitored.

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[2] EuroRAP Star Rating: https://eurorap.org/star-rating/

[3] EuroRAP Crash Rate Mapping: https://eurorap.org/crash-rate-mapping/

A2.3 Combined methods

It is possible to combine infrastructure and crash based methods, and several of such methods are also under development or being used within the countries participating in the Baseline project. One example is the German ESN approach[4], which is similar to the French SURE approach[5]. Both use the so called 'safety potential´ for the safety ranking. Using this approach an optimal threshold would be a 'safety potential' of zero. The more roads exists or distance traveled on roads with a 'safety potential´ of zero, the higher the level of road safety.

An alternative method is Empirical Bayes (EB) method where reported frequencies are combined with frequencies from a crash prediction model (which could be based on infrastructure elements). These methods predict better the safety level of road segments, in particular on road segments where no crashes have taken place yet.

Portugal is considering the development and implementation of the so-called 'HARS'-method. This method starts from six road categories and identifies within each class two distinct elements: (a) major nodes (intersections/ interchanges) and (b) road segments between nodes (20-30 km maximum length). For each road class and element, crash prediction models for each road class and element are developed, using data collected over a 5 year period.

At the request of the European Commission there is also a European project, led by NTUA from Greece, aimed at the development of an integrated (infrastructure-based and crash-based) methodology for network-wide road safety assessment in the EU, according to the provisions of EU DIR 2019/1936.

7. A3. Data requirements

A3.1 Data needed

Baseline project partners can provide data for one or more of the four KPI definitions presented in this document. If feasible, project partners are encouraged to provide values for several of the KPI definitions and to do so for three threshold values (low, average, high). This will facilitate comparisons between types of KPIs and may encourage other Member States to add their KPIs to the Baseline database.

Member States providing data on one or more KPIs should clearly state:

- which of the KPI definitions has been used
- what type of road classification has been used
- what method has been used for the safety rating (if applicable)
- what thresholds have been used (if applicable)
- what sampling design principles were used and how the weighting variables were defined (if applicable)
- whether urban areas are excluded or not from the KPI calculations
- how total traffic exposure in the country is measured/estimated.

When using a sampling based method, participants should both give a point estimate for the KPI and the 95% confidence interval.

[4] See https://www.bast.de/BASt_2017/EN/Traffic_Safety/Subjects/analysen.html?nn=1497202

[5] See http://www.sure.equipement.gouv.fr/IMG/pdf/GANNEAU-E_NSM_Paris2007_PIARC_anglais_cle211132.pdf

A3.2 Road categories

Since the safety requirements differ between types of roads, is necessary to make a distinction between these roads. Both the safety ratings methods and the safety thresholds can differ between road categories.

All Member States (or regions within Member States who are responsible for design and maintenance of roads) have their own road classification system. They can use this for the calculation of the KPIs. When communicating the KPI data it is recommended that project partners show how their national road classification corresponds with one or more of the following road typologies[6] from the CARE database[7] on road crashes in Europe (all EU Member States already undertake such conversions when providing crash data to the CARE database):

- Classification by area of the road:
  - Urban roads
  - Rural or non-urban roads (excluding motorways)
  - Motorways
- Classification by functional class:
  - Principal arterial
  - Secondary arterial
  - Collector
  - Local
  - Other
- Classification by speed limits:
  - < 30 km/h
  - 30-50 km/h
  - 51-80 km/h
  - 81-100 km/h
  - 101-120 km/h
  - > 120 km/h
  - No speed limit
- Classification by type of carriageway:
  - Single carriageway - one way street
  - Single carriageway - two way street
  - Single carriageway – not specified
  - Dual carriageway

Ideally, safety ratings are provided for all these types and then weighted in order to arrive at a national indicator for the safety of roads.

A3.3 Urban areas

When excluding urban areas in the data, it is useful to know that within the CARE database 'Urban areas' are defined as 'Areas within the urban boundary signs'. It is recommended that the same definition is used as adopted by the Member States when they upload their crash data to the CARE database.

[6] Definitions are in the CaDaS (Common Accident Data Set) glossary version 3.7. of the European Commission, DG MOVE.

[7] All EU Member States provide crash data to the CARE database. When providing this data they need to convert their classification into the categorisations used within CARE, so this conversion of national road typology to the CARE typology exists already.

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