Baseline

Methodological guidelines – KPI Infrastructure

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Baseline

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Any comments or feedback regarding these guidelines, should be sent to baseline@vias.be.

Version history

Version	Date	Changes
1.0	01-04-2021	First draft – not yet discussed with experts and Member States
2.0	03-05-2021	Second draft, incorporating feedback from the KPI Expert Group
2.1	18-05-2021	Incorporation of some additional remarks from experts, in particular on speed limits
2.2	14-06-2021	Addition of some clarifications following feedback by Member States and experts.
2.3	29-06-2021	Finalisation of the text on speed limits
2.4	07-07-2021	Added message on approval by the Technical Committee
2.5	12-10-20221	Incorporation of final feedback of Technical Committee

Contents

1 Introduction and aims

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

In order to gain a clearer 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 KPIs relate to main road safety challenges to be tackled, namely: (1) infrastructure safety, (2) vehicle safety, (3) safe road use including speed, alcohol, distraction and the use of protective equipment, and (4) emergency response. The aim of the KPIs is connected to EC target outcomes.

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.

The purpose of this document is to further describe the minimal methodological requirements to qualify for the BASELINE KPI for infrastructure, defined as:

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

No methodology has been prescribed by the Commission nor has any threshold been defined yet. The European Commission only specifies that the indicator should be based on a network rating or assessment methodology and take into account distance driven or another proxy for exposure.

The Commission also states: "*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.".* 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 document "*Commission Staff Working Document: EU Road Safety Policy Framework 2021-2030 - Next steps towards "Vision Zero" SWD (2019) 283 final."* – further called "SWD" – the Commission also states that temporarily, a simplified version of the KPI may be used where no 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 is 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 is left to the discretion of the Member States.

Moreover, the Commission states that in the first phase, ***urban areas could be excluded*** by Member States to reduce the overall complexity of this KPI, but the infrastructure question for urban areas should not be excluded in the future.

2 Possible formulations for the KPI on infrastructure

2.1 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 0 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.

2.2 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.

2.3 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 (ITF, 2016; SWOV, 2016; European Commission, 2020):

- 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

2.4 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.

2.5 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 4.2)
- 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 0) 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).

2.6 Optional additional/complementary KPIs on infrastructure

The following KPIs may be considered if one is looking for specific additional indicators for urban areas:

- Percentage of the road network in urban areas with speed limits no more than 30 km/h.
- Percentage of signal-controlled pedestrian crossings in relation to total number of pedestrian crossings on roads with speed limits up to 50 km/h.

3 Safety rating methods

3.1 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, 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'.

3.2 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).

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, Rajamäki & Luoma, 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.

3.3 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[2], which is similar to the French SURE approach[3]. 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.

4 Data requirements

4.1 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.

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

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

4.2 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[4] from the CARE database[5] 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.

4.3 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.

[4] Definitions are in the CaDaS glossary (see References)

[5] 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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Annex. Extracts from the SWD Document on the KPI Infrastructure

Extract from section 4.1

A KPI for road infrastructure should show the safety quality of a road network independent of road user behaviour or vehicle technology. Ahead of the network-wide safety rating required under new EU rules (with a first complete assessment expected by end 2024), and in the absence of an agreed common rating methodology, such an indicator has proved difficult to establish, and further work is needed to shape it.

The Commission services will work with Member States to define an infrastructure indicator on the following basis:

KPI for infrastructure:
Percentage of distance driven over roads with a safety rating above an agreed threshold.

The indicator will be based on a network rating or assessment methodology and take into account distance driven[6] or other proxy for exposure. This will be reviewed in ongoing work at expert level and eventually replaced by the network-wide safety rating under the new EU infrastructure safety rules.

Extract from the Annex to the document

Rationale

Layout, design (including signals) and maintenance are aspects of infrastructure that determine its 'road safety' quality.

A safety performance indicator for road infrastructure is intended to provide a quantified representation of the safety quality of a road network, which is independent of road user behaviour or vehicle technology. However, further work is needed to shape the indicator.

Definition of the KPI for infrastructure

The Commission services will work with Member States to define an infrastructure indicator on the following basis:

- **Percentage of distance driven over roads with a safety rating above an agreed threshold (still to be defined)**

leaving the rating methodology to the choice of Member States until an agreement on the threshold is reached.

However, this indicator is technically challenging. 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.

Temporarily, a simplified version of the KPI may be used where no rating methodology is available which is defined as follows:

- Percentage of 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 (limit left to the discretion of MS) in relation to total distance travelled.

Work with experts will continue in the CARE expert group or in another appropriate set-up to define the data collection procedures and the rating methodology.

In the first phase, urban areas could be excluded by Member States to reduce the overall complexity of this KPI, but we should not exclude the infrastructure question for urban areas in the future.

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[6] Many Member States do not yet have data on "distance driven". The European Statistical Office Eurostat is working on gathering such data.