EVITA

En**v**ironmental **I**ndicators for the **T**otal Road Infrastructure **A**ssets

Effective asset management meeting future challenges

Cross-border funded Joint Research Programme

by Belgium (Flanders), Denmark, Finland, France, Germany, Ireland, Lithuania, Netherlands, Norway, Slovenia, Sweden, Switzerland, and United Kingdom.

Deliverable D2.2

Assessment and evaluation of existing E-KPIs

Final version - September 2011

This joint research programme was initiated by **ERA-NET ROAD**.

Deliverable D2.2

CONTRACT N° :	
ACRONYM:	**EVITA**
TITLE:	Environmental Indicators for the Total Road Infrastructure Assets

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Date of issue of this report :	30 September 2011

road ERA net	**Project funded by the ERAnet Road 2 Programme (2010 - 2013)**

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Deliverable D 2.2 - Assessment and evaluation of existing KPIs

Abstract

Glossary

The following words are frequently used in the EVITA reports. An attempt of definition in this context is proposed below.

Road Infrastructure / road asset: All constructions (pavements, bridges, drainage structures…) and equipments (safety barriers, signs, lights…), including the land reservation which composed the facilities devoted to road transport.

Road asset management: All studies, decision makings and operations which are specifically aiming at or required to build, maintain and operate the road infrastructure/road asset.

Road Stakeholder: All people (physical or social person), all organisms, and more generally all bodies which have some interactions with road infrastructure. It should be that road infrastructure applies some constraints or, conversely, bring some facilities to them. It should also be that they exert some actions or bring some constraints on the infrastructure.

Expectation: Anything that a stakeholder is expecting from the road infrastructure. It may be some services, some returns, or it may be the reduction of some nuisances.

Road performance: Generally, ability of the road to answer expectations, to provide a stakeholder with what he is expecting from the road. More specifically, road performance is a measure of this ability to meet expectations, of the quality of the road regarding the expected service or characteristics.

Performance Indicator: A comprehensive term which quantifies the road performance. It can be expressed in the form of a technical parameter (dimensional) and/or finally in form of an index (dimensionless) evaluating the performance indicator on a predefined scale

- KPI ……..Key performance indicator for a given characteristic or parameter
- E-KPI ……Key performance indicator related to environmental aspects

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Environmental Indicators for the Total Road Infrastructure Assets

Deliverable D 2.2 - Assessment and evaluation of existing KPIs

Executive summary

The main objective of the project "EVITA – Environmental Performance Indicators for the Total Road Infrastructure Assets" aims at developing and integrating new and existing key performance indicators in the asset management process taking into account the expectations of different stakeholders (users, operators, neighbours, etc.). The first part of WP2, performed under task 2.1, was devoted to the extensive inventory of the road stakeholders and their expectations. Detailed description of this task is reported in Deliverable D2.1 "Stakeholder's categories and sub-categories – Expectations - Necessary and existing KPIs" [1]. The report included inventory of all existing E-KPIs (Environmental Key Performance Indicators) from COST 354 database, from literature and from actual research projects together with their preliminary assessment. In total 11 existing E-KPIs were selected for further assessment:

- noise (4 different E-KPIs),
- air pollution (1 E-KPI),
- water pollution (3 different E-KPIs),
- natural resources (2 different E-KPIs), and
- green house gas emissions (1 E-KPI).

This report presents summary of work performed within the task 2.2 "Assessment of Existing E-KPIs" of WP2. The selected indicators were further assessed from the following standpoints:

- meeting stakeholders' needs and expectations,
- assessing performance of the individual assets,
- asset management level of applicability,
- possible aggregation into combined index,
- data availability, indicating if measurements are performed routinely as part of standardized monitoring procedures, or data can be obtained by modeling,
- spread of use, indicating if indicator is used in corresponding European Directives or national legislatures,
- reliability, indicating If the indicator measuring/monitoring/forecasting is based on well established/standardized/recognized methods, and
- sustainability, indicating from when and for how long monitoring of environmental effect is necessary.

The report briefly describes the Drivers-Pressures-State-Impact-Responses (DPSIR) approach. The application of this approach to the use of E-KPIs in the road asset management is presented in figure EA1. The existing technical E-KPIs address either source/emissions or intensity/concentration of different environmental effects. In some cases it is easier to distinguish impact caused by road construction and maintenance from other sources (i.e. energy consumption), while in other cases it may be rather difficult (i.e. noise or air pollution).

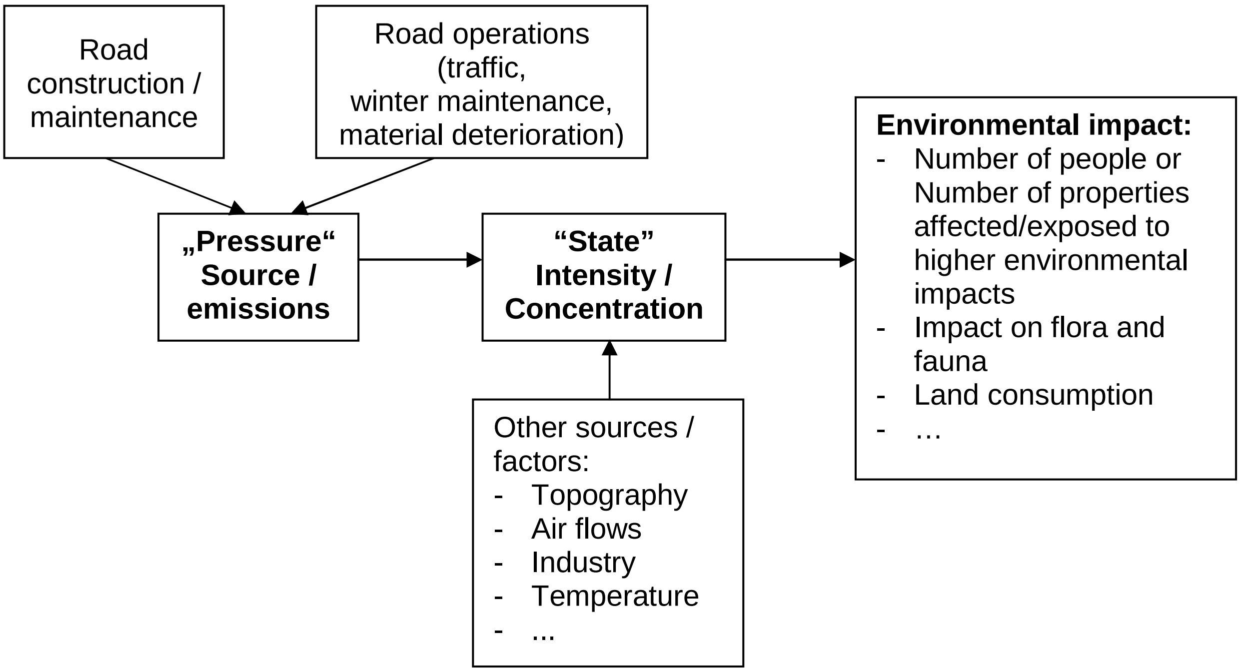

Figure EA1 – Environmental effects of roads

Therefore, two groups of possible performance indicators are identified:

- indicators based on <u>absolute value of environmental impact</u>, that are more appropriate for technical indicators based on source/emission, like energy consumption or CO_2 emission as a result of road construction/maintenance, and
- indicators based on <u>change in environmental impact</u> that are more appropriate for technical E-KPIs based on intensity/concentration of environmental effect, like noise or air pollution, and that would describe environmental impact for different road construction/maintenance alternatives.

In order to quantify or model environmental impact, additional data is needed on affected people, flora and fauna, properties or area along the roads. Depending on the available data, impact indicators can be defined based on road section/network length and density of population or characteristics or affected area. This information can also be obtained through mapping like noise mapping that is typically used to show noise impact for highly trafficked roads.

Finally, the stakeholders' needs and expectations were compared to the list of existing technical E-KPIs in order to identify missing indicators. Impact on environment preservation, as one of stakeholders' expectations, is lacking technical indicators which would describe the impact on flora and fauna and impact on land consumption that should include valuable (national habitat, domestic and recreation) area lost and/or sealed. It should be noted that indicators which address these expectations exist, but they have been mainly used at the strategic level.

This work opens the road for the development of missing E-KPIs (WP3) and their implementation in Asset Management Systems (WP4).

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En**v**ironmental **I**ndicators for the **T**otal Road Infrastructure **A**ssets

Deliverable D 2.2 - Assessment and evaluation of existing KPIs

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En**v**ironmental **I**ndicators for the **T**otal Road Infrastructure **A**ssets

Deliverable D 2.2 - Assessment and evaluation of existing KPIs

I - Introduction

The main objective of the project "EVITA – Environmental Performance Indicators for the Total Road Infrastructure Assets" is the development and integration of new and existing environmental key performance indicators (E-KPIs) in the asset management process taking into account the expectations of different stakeholders (users, operators, neighbors, etc.). It also aims at identifying the existing best practice in the implementation of E-KPIs to managing the full range of road infrastructure assets (pavements, structures, road furniture, etc.).

The primary benefit of this project is on the one hand to provide an applicable solution for the environmental assessment of different road infrastructure assets and on the other hand to describe the expectations of different stakeholders in form of objective indicators. Furthermore the results could be used as an integrated part in the asset management processes of the road owners and road operators.

The second Work Package (WP2) played a central role in the application of this stepwise approach. The first part of WP2, performed under task 2.1, was devoted to the extensive inventory of the road stakeholders and of their expectations. The starting point of this inventory was provided by the final report prepared by the PIARC D1.2 sub-committee on "Road Asset Management: High Level Management Indicators". The first list and definition of road stakeholders was taken out of its work. These stakeholders were then spread in categories and sub-categories when this classification proved to be helpful to correctly understand and identify their expectations. The expectations from each stakeholder were listed and organized and the impact on each of the sub-assets (pavements, structures, tunnels, etc.) was classified for each expectation. A special interest was given to the expression of environmental expectations and this report will provide a brief overview of stakeholders' expectations.

This report presents the summary of work performed within the task 2.2 "Assessment of Existing E-KPIs" of WP2. The inventory of all existing E-KPIs from COST 354 database, from literature and from actual research projects was provided in the report on task 2.1, together with their preliminary assessment. Within the task 2.2 the indicators of interest for EVITA project are further evaluated from the standpoint of their possible implementation in the asset management process. Based on comparison of stakeholders' needs and inventory of existing E-KPIs, the missing E-KPIs can be identified.

II – Overview of stakeholders' expectations and needs

Task 2.1 had an objective of identifying and classifying the road stakeholders and their expectations. Four different types of tools were used to list and classify them: literature study, workshops, questionnaire and interviews. Detailed description of this task is reported in Deliverable D2.1 "Stakeholder's categories and sub-categories – Expectations - Necessary and existing KPIs" [1].

The main identified stakeholders include society, neighbors, owners and road operators.

The environmental effects of road networks can be analyzed on two levels: local, which concerns a limited number of stakeholders expressing short term demands and global, that concerns society with some strategic demands, like reduction of GHG emission.

Environmental Key Performance Indicators (E-KPIs) should be used to quantify Road Operator's response to the E-expectations from the Society, the Neighbors and, to some extent, the Owners. Figure 1 displays the role and position of indicators within the relationships between the stakeholders which are primarily concerned by the environmental issues.

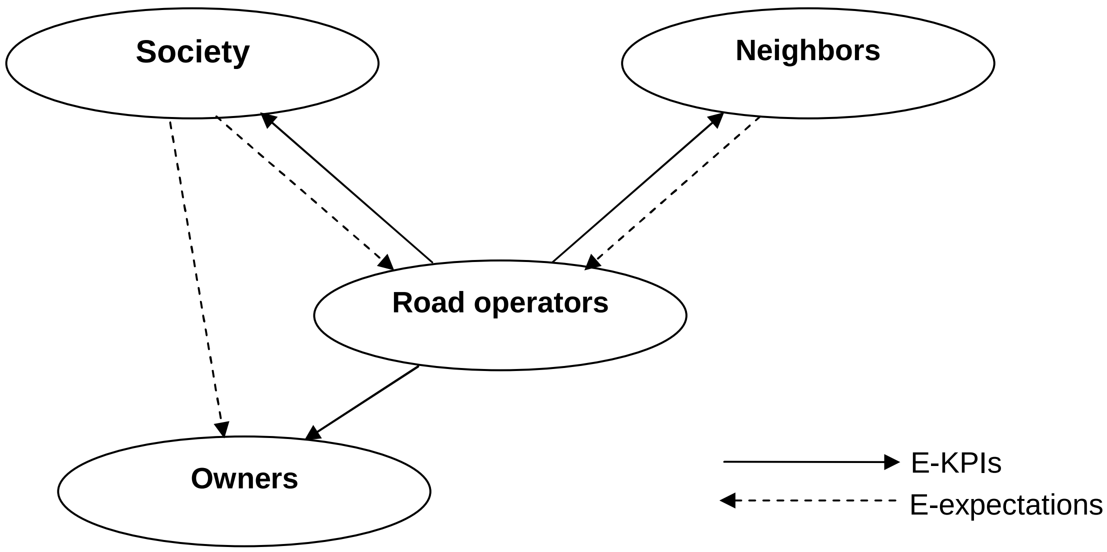

Figure 1 – Relationship between stakeholders: E-expectations and E-KPIs

For each identified E-expectation from one stakeholder, the road operators must be able to bring an answer, and an E-KPI should be able to quantify this answer. Since, very often, the expectations from the Society are sent to the Owners, the road operators should be able to report to this Owner about the measures he performed or planned, and their efficiency.

Table 1 summarizes findings and provides the initial list of required E-KPIs.

Table 1 - Initial list of required E-KPIs

From	To	Nature	Components
Road Operator	Society	• Impact on environment preservation	• Impact on water (pollutants) • Impacts on fauna, on flora?
		• Impact on natural resources consumption	• Consumption of energy • Consumption of natural building materials • Impact on oil consumption
		• Impact on contribution to climate change	• Impact on emission of GHG (CO_2…)
		• Impact on public health	• Impact on emission of particles • Impact on emission of harmful gas (NO_x…)
	Neighbors	• Impact on environment preservation	• Impact on water • Impact on land consumption
		• Impact on public health	• Impact on emission of particles • Impact on noise emissions • Impact on emission of harmful gas (NO_x…)
	Owner	• All former ones	• All former ones

III – Methodology for Task 2.2

For the assessment of existing KPIs in task 2.2, it is necessary first to define the term *indicator* which will be followed in the assessment and evaluation of existing indicators in the asset management process and second - to make a selection of criteria which will be used in the assessment of identified indicators.

III.1 Defining the term "indicator"

Performance indicators and technical parameters, terms used in COST 354, were defined as [2]:

- **Performance Indicator** is "…a superior term of technical road pavement characteristic (distress), that indicates the condition of it (e.g. transverse evenness, skid resistance, etc.). It can be expressed in the form of a Technical Parameter (dimensional) and/or in the form of Index (dimensionless)."
- **Technical Parameter** is "… a physical characteristic of the road pavement condition, derived from various measurements, or collected by other forms of investigation (e.g. rut depth, friction value, etc.)."

Following the COST 354 work, PIARC sub-committee D1.2 proposes four levels of indicators presented in Figure 2 [3]. Since the work performed within EVITA project is mainly concentrated on "technical" performance indicators used on the lower asset management levels, only the definition for 'level 1' indicators was considered in this report:

- Level 1: **Basic indicator** – or index – which directly reflects a physical property or condition of the asset. It relates to one of the several domains which composed the asset, pavement, bridges, environment…. It may also relate to asset operation. It is a characteristic of a specific element of this domain (a measurement step, a bridge component…). It is generally expressed with an International System unit.

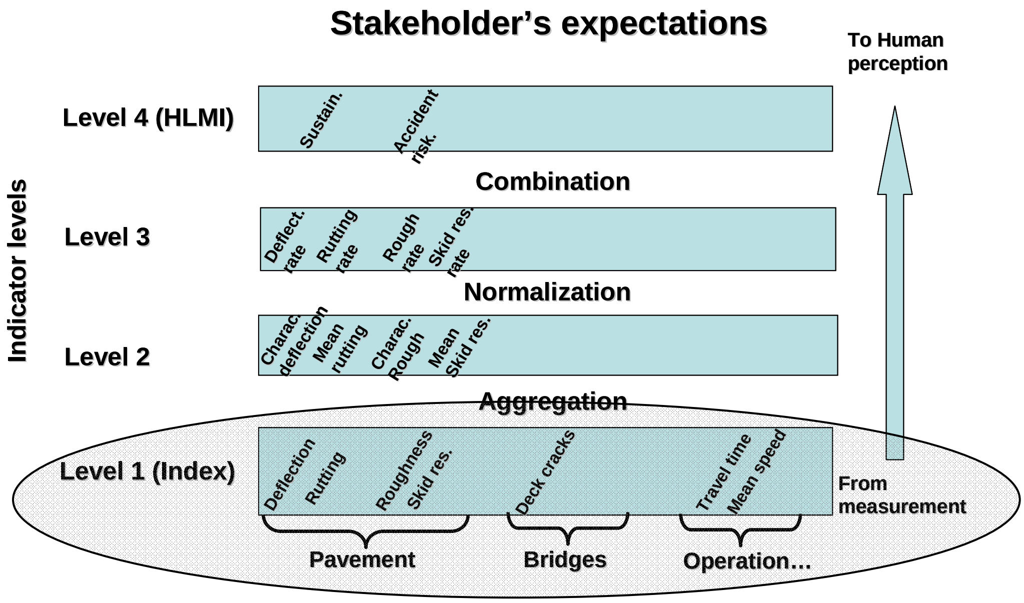

Figure 2 - Indicator levels [2]

Final report of the COST 356 project – "Indicators of Environmental Sustainability in Transport" has one chapter devoted to the establishment and justification of the term 'indicator' and how it was used in the project. Definition of the terms which were used in this project is [4]:

- An **indicator** is a variable, based on measurements, representing as accurately as possible and necessary a phenomenon of interest.
- An **environmental impact indicator** is a variable, based on measurements, which represents an impact of human activity on the environment as accurately as possible and necessary.
- An **indicator of environmental sustainability in transport** is a variable, based on measurements, which represents potential or actual impacts on the environment - or factors that may cause such impacts - due to transport, as accurately as possible and necessary.

European Environmental Agency (EEA) defines an **environmental indicator** as "... a parameter or a value derived from parameters that describe the state of the environment and its impact on human beings, ecosystems and materials, the pressures on the environment, the driving forces and the responses steering that system. An indicator has gone through a selection and/or aggregation process to enable it to steer action." [5].

Based on the presented definitions of indicators for various level of applicability, the term *indicator* which was considered in Task 2.2 for the selection of existing technical E-KPIs can be defined as follows:

- **Technical E-KPI** is a variable, based on measurement, which represents the state of the environment due to transport or physical condition of one of the several domains which compose the asset (pavement, structures, signs, etc.). It may also relate to environmental impact due to asset operation. It can be expressed in the form of a Technical Parameter (dimensional) and/or in the form of Index (dimensionless).

This definition served as the basis for the selection of existing environmental indicators from the literature review. However, since the large number of indicators was preliminary identified, criteria for the indicators evaluation and assessment were applied in order to identify E-KPIs of interest for EVITA as described in the following section.

III.2 Selection of E-KPIs for detailed assessment

The inventory and preliminary assessment of existing technical E-KPIs was based on extensive literature review. It started from previous works, such as the one done in the COST 354 action. Beyond this work, a number of sources were considered in the inventory. Other recent COST actions (350, 351, 356…), European research projects (SILVIA, SILENCE, POLMIT, HEATCO, aspect…), existing tools (ASJ RTN-Model 2008, PaLATE, BE²ST-in-Highways…) were reviewed, as well as some specific studies from COLAS, FINNRA, EEA etc.

Some of assessed E-KPIs are specific for the decision making process at network level while some are used for the assessment of properties at project level. Thus, it was decided to apply two criteria for the first screening phase: what is the level of applicability and if the indicator is technical parameter, i.e. if it can be measured. Those indicators which were identified as indicators applicable at project level and which are technical were chosen for the detailed assessment and evaluation. The list of reviewed research projects, studies and tools is presented in section VI.3, Deliverable D2.1 “Stakeholder’s categories and sub-categories-Expectations-Necessary and existing KPIs” [1].

In total 11 existing E-KPIs were selected for further detailed assessment:

- noise (4 different E-KPIs)
- air pollution (1 E-KPI)
- water pollution (3 different E-KPIs)
- natural resources (2 different E-KPIs)
- green house gas emissions (1 E-KPI).

Table 2 presents selected technical E-KPIs.

Table 2 - Selected technical environmental performance indicators for detailed assessment

Area	Technical Indicator / parameter	Assessment ID
Noise	Equivalent continuous sound level, L_{eq}, $L_{Aeq,T}$	N1
	Day-Evening-Night equivalent level L_{den}	N2
	Night time level L_{night}	N3
	Sound absorption coefficient	N4
Air pollution	Concentration of pollutants ($PM_{2.5}$, PM_{10}, NO_x, SO_2, NMVOC, CO, Hg, Pb, HC)	A1
Water pollution	Concentration of heavy metals (Cd, Cu, Pb, Cr, Zn, Fe, Ni, Na)	W1
	Concentration of total hydrocarbons (polynuclear aromatic hydrocarbons, PAH)	W2
	Concentration of de-icing salt (sulphate, calcium chloride, sodium, cyanide)	W3
Natural resources	Waste reduction (Use of recycled materials in construction)	R1
	Energy consumption	R2
GHG	Emission of CO_2 equivalent (CO_2e)	G1

IV – Assessment and evaluation of selected E-KPIs

IV.1 Notes on chains of causalities

In COST 356 final report, a causal chain is defined as "… an ordered sequence of events or issues, in which any one event or issue in the chain causes the next one" [4]. These chains of causalities can be used as an example of indicator framework, i.e. to classify indicators based on their characteristics and attributes. The most common indicator framework is Drivers-Pressures-State-Impact-Responses (DPSIR) approach. DPSIR is "…the causal framework for describing the interactions between society and the environment adopted by the European Environment Agency: *driving forces, pressures, states, impacts, responses*" [6].

DPSIR approach becomes useful in an attempt to categorize indicators based on their place in the chain of events. Figure 2 presents an example of DPSIR use in the assessment and understanding of causes and effects of impact on environment due to transport related activities. If transport is observed as a *driver*, the emission of pollutants is a *pressure* on environment caused by transport. This emission of pollutants is expressed as the concentration of pollutants in air, water or soil which defines its quality (*state*). *Impacts* which these concentrations have are various and can be expressed as impact on public health or loss of biodiversity. In order to reduce negative impacts, *responses* of the authority such as new regulations or promotion of public transport will have positive impact on whole system.

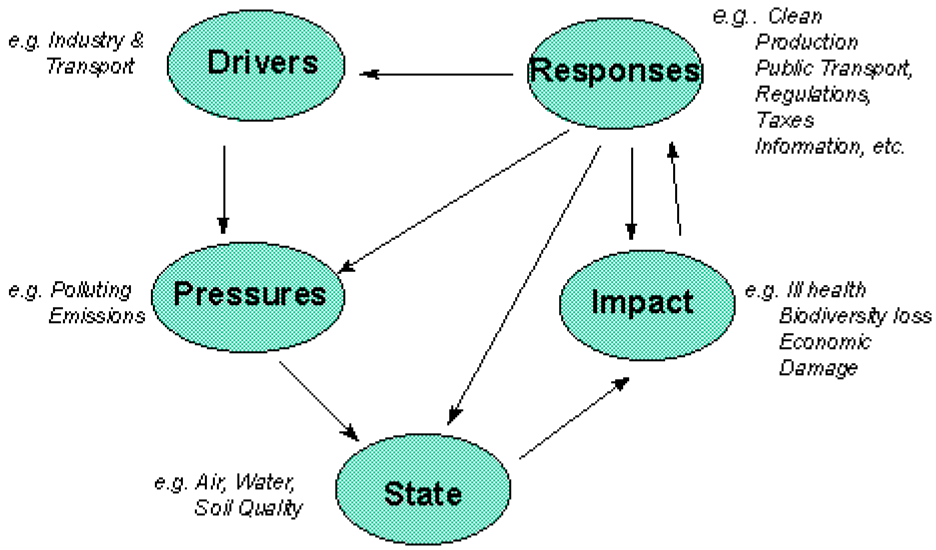

Figure 2 - DPSIR approach [7]

For example, traffic *(driver)* is the source of noise *(pressure)* [4]. The noise energy is dispersed by air which causes annoyance (*impact*).

Based on the E-KPIs definition used in task 2.2 and DPSIR context, it should be noted that, for this task, selected indicators mainly present *state* of the environment; they describe the consequences of some events or issues (*pressure*) that cause certain *impacts* on environment. There are special measurement methods and prediction models for different components, so it is possible to define indicators for Drivers, Pressures, States, Impacts, as well as Responses.

IV.2 Assessment of the existing technical E-KPIs

Initially, the description of work for task 2.2 included four main criteria for the assessment of existing E-KPIs:

- How they meet stakeholders' needs and expectations?
- How they assess performance of individual assets?
- What is level of applicability and use (strategic network or program level)?
- Is it possible to aggregate into combined performance indicators for particular type of road asset and for the entire road?

In addition, four criteria that include data availability, spread of use, reliability and sustainability of selected KPIs were also used. The short explanations about the applied criteria are presented in Table 3.

Table 3. Typical assessment form for the existing technical E-KPIs

EVITA Area: **AREA NAME**			Assessment ID **NX**
Indicator Name:	Name of the selected indicator		
Description:	Short description of the indicator.		
Technical Parameters	Technical parameters which can be used to represent the selected indicator.	**Units:**	
Indirect indicators and relations	For some indicators, there have been identified relations between the selected indicator and other physical characteristics of the road asset condition (called indirect indicators in this report). These relations can be either positive (increase in one indicator increases the other also) or negative (increase in one indicator decreases the other).		
Related/derived indicators:	Indicators that can be used to express same or similar effect on the environment.		
Measurement/ monitoring methods:	Known and established methods for measuring or monitoring the technical parameter value.		
Sources:	List of projects, standards or literature where information about the indicator can be found.		
ASSESSMENT			
Meeting stakeholders' needs and expectations	List of stakeholders and their expectations which the selected indicator addresses.		
Assessing performance of individual assets	List of individual assets for which the selected indicator can be used.		
Level of applicability and use	List of decision making levels for which the selected indicator can be used. Project phases in which the indicator is used. Brief explanation of possible indicator use based on the literature review.		
Possible aggregation into combined index	Is it possible to combine indicator with related indicators into the combined/general index?		
Data availability:	Are measurements performed based on routine, standardized monitoring procedure? Is modelling of indicator possible and what data are needed?		
Spread of use:	Is indicator used in corresponding European Directives or national legislatures?		
Reliability:	If the indicator measuring/monitoring/forecasting is based on well established/standardized/recognized methods, reliability of data.		
Sustainability:	From when it is necessary to monitor environmental effect? How long will the effect last and produce consequences?		

The output of this process is summarized and presented in section VI.4, Deliverable D2.1 “Stakeholder’s categories and sub-categories-Expectations-Necessary and existing KPIs” [1]. Detailed assessment forms for the available E-KPIs are presented in the Appendix of this report.

IV.3 Evaluation of existing indicators

The objective of project EVITA is the development and integration of new and existing environmental key performance indicators (E-KPIs) in the asset management process taking into account the expectations of different stakeholders (users, operators, neighbors, etc.). Analyzing the perspective of the asset management systems and the integration of the environmental aspect in this process, it is suggested to divide the potential impact of road related activities on environment in two categories: road (asset) construction and maintenance related activities and road (asset) operations related activities (Figure 3). In the context of DPSIR approach, these activities represent *driver* events. The part of pollution from construction and maintenance activities can be further divided on different road assets (pavements, bridges, culverts, signs etc.).

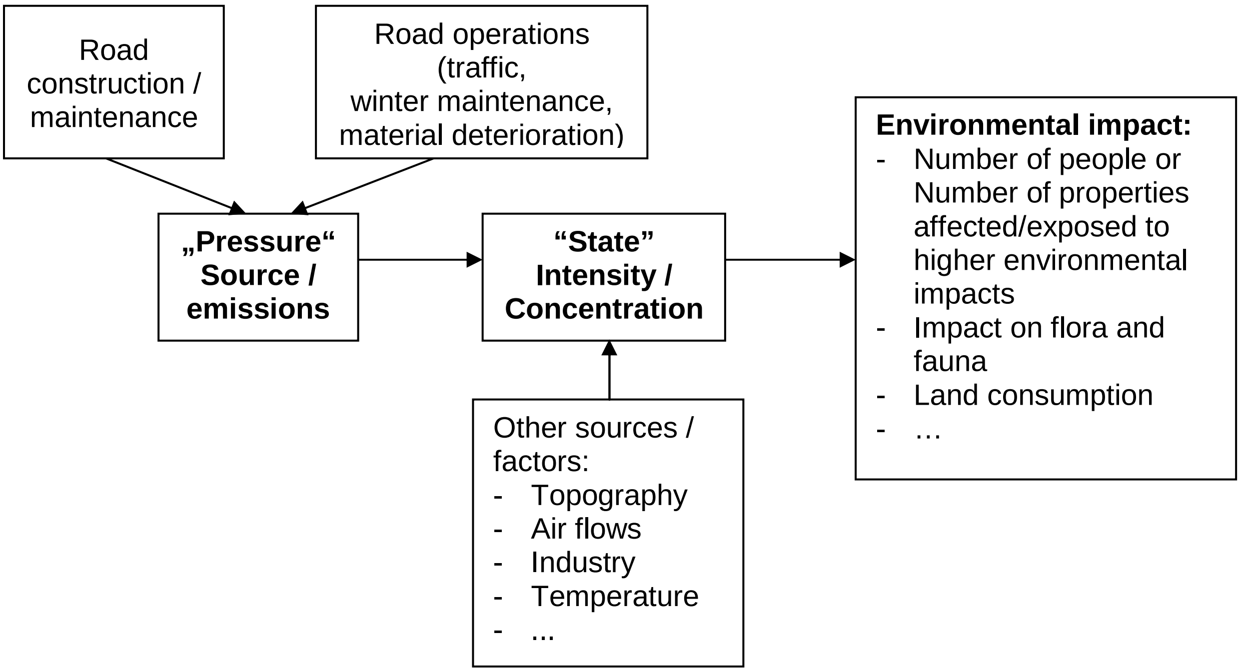

Figure 3 – Environmental effects of roads

Intensity or concentration of some environmental effects depends on many parameters and some of them are outside of control of road administration. Among others they include topography, air flows, pollution from other sources like industry, whether the project is located in urban or rural area etc.

Most of available technical indicators that were assessed are based on intensity / concentration of certain environmental effect. The classification of evaluated indicators according to their type, i.e. if they address emissions (sources) or intensity of environmental effects (concentrations) is presented in Table 4.

Finally, all environmental effects have impact on people, flora and fauna along the roads. The „impact“ indicators are tools for measuring an impact, or how an objective is achieved.

In some cases it is easier to distinguish impact caused by road construction and maintenance from other sources (i.e. energy consumption), while in other cases it may be rather difficult (i.e. noise or air pollution).

Therefore, two groups of possible performance indicators are identified:

- indicators based on absolute value of environmental impact, that are more appropriate for technical indicators based on source/emission, and
- indicators based on change in environmental impact that are more appropriate for technical E-KPIs based on intensity/concentration.

Table 4. Types of existing technical E-KPIs

Area	Technical Indicator / parameter	Assess-ment ID	Type of indicator: Source / Emission	Type of indicator: Intensity / Concen-tration
Noise	Equivalent continuous sound level, L_{eq}, $L_{Aeq,T}$	N1		X
	Day-Evening-Night equivalent level L_{den}	N2		X
	Night time level L_{night}	N3		X
	Sound absorption coefficient	N4		X
Air pollution	Concentration of pollutants ($PM_{2.5,}$ PM_{10}, NO_x, SO_2, NMVOC, CO, Hg, Pb, HC)	A1		X
Water pollution	Concentration of heavy metals (Cd, Cu, Pb, Cr, Zn, Fe, Ni, Na)	W1		X
	Concentration of total hydrocarbons (polynuclear aromatic hydrocarbons, PAH)	W2		X
	Concentration of de-icing salt (sulphate, calcium chloride, sodium, cyanide)	W3		X
Natural resources	Waste reduction (Use of recycled materials in construction)	R1	X	
	Energy consumption	R2	X	
GHG	Emission of CO_2 equivalent (CO_2e)	G1	X	

The effectiveness (i.e. „benefits“ in asset management terms) of measures taken can be evaluated based on reduction of this impact. Table 5 provides some examples of existing „impact“ indicators.

Table 5. The examples of environmental impact Indicators

Area	Impact indicator
Noise	Percentage of people (properties) exposed to certain noise level
	Number of people highly annoyed with certain noise level
Air pollution	Number of people or protected areas exposed to toxic or exotoxic pollutant emission exceeding standards of heavy metals (Cu), persistent organic compounds (POC), particulates, NO_x, SO_x
	Years in life lost (YOLL)
GHG	Social carbon cost savings

Indicator values can be also estimated by prediction models. Such models should be calibrated using actual measurements.

In order to quantify environmental impact, additional data is needed on affected people, flora and fauna, properties or area along the roads in addition to road section/network length under consideration. Depending on the available data, impact indicators can be defined based on road section/network length and density of population or properties or affected area. This information can also be obtained through mapping like noise mapping that is typically used to show noise impact for highly trafficked roads.

V – Missing E-KPIs

Part of task 2.2 was to, based on the assessment and evaluation of existing E-KPIs, for each category of identified stakeholders' expectation, select the most important KPIs and to identify the need for development of missing KPIs. In order to complete this part of task 2.2, it was decided to cross and match findings of two previously mentioned parts of WP2: initial list of required E-KPIs (presented in section II – Table 1) and summary of existing technical environmental performance indicators (presented in section III.2 – Table 2).

Table 6 presents preliminary list of missing E-KPIs. Stakeholders are grouped based on their expectations which are expressed through selected impacts on environment. In the context of DPSIR approach, it should be noted that stakeholders' expectation in fact presents *impact* in chain of causalities while selected existing E-KPIs mainly present *state*. For example, if the stakeholder's expectation is concerning the impact on contribution to climate change, expressed as the impact on emission of GHG, the indicator which is associated with this expectation, i.e. part of this causal chain is the emission of CO_2 (G1).

Impact on environment preservation, as one of stakeholders' expectations, is lacking technical indicators which would describe the impact on flora and fauna and impact on land consumption. It should be noted that indicators which address this expectations exist, but they have been mainly used at the strategic level, thus they have been omitted from the detail assessment of existing E-KPIs (see, for example, section VI.2, Deliverable 2.1 [1]). At technical level Indicators for air and water pollution partially address impact on flora and fauna.

The review of existing technical E-KPIs also showed that there is lack of indicators for individual sub-assets. However, it was considered that E-KPIs should represent environmental performance of a road section, partial or entire road network.

Grouping of indicators, as presented in Table 6, can also serve as a starting point for their combination and use at upper levels of asset management.

Expectations regarding human life framework that include “Heritage preservation” and “Natural disasters prevention and rescue” were not addressed in this section since the EVITA project is dealing only with technical indicators.

Table 6 - Preliminary list of missing E-KPIs

Expectations	Stakeholders	Impacts	Area	Assessment ID
Impact on environment preservation	Society Neighbours Owner Road operator	Impact on water (pollutants)	Water pollution	W1-W3
		Impacts on fauna, on flora	X	X
		Impact on land consumption	X	X
Impact on natural resources consumption	Society Owner Road operator	Consumption of energy	Natural resources	R2
		Consumption of natural building materials		R1
		Impact on oil consumption		R2
Impact on contribution to climate change	Society Owner Road operator	Impact on emission of GHG	GHG	G1
Impact on public health	Society Neighbours Owner Road operator	Impact on emission of particles	Air pollution	A1
		Impact on emission of harmful gas		
		Impact on noise emission	Noise	N1-N4

VI - Conclusions

This report represents the summary of work performed for task 2.2 within the WP2. This task is devoted to the assessment and evaluation of existing E-KPIs. The inventory of all existing E-KPIs (Environmental Key Performance Indicators) from COST 354 database, from literature and from actual research projects was provided in the report on task 2.1 (D 2.1), together with their preliminary assessment.

The deliverable D 2.1 also presented the preliminary assessment of existing technical E-KPIs. In total 11 existing E-KPIs were selected for further assessment and evaluation:
- noise (4 different E-KPIs),
- air pollution (1 E-KPI),
- water pollution (3 different E-KPIs),
- natural resources (2 different E-KPIs), and
- green house gas emissions (1 E-KPI).

The selected indicators were further assessed within WP2 from the following standpoints:
- meeting stakeholders' needs and expectations,
- assessing performance of the individual assets,
- level of applicability,
- possible aggregation into combined index,
- data availability, indicating if measurements are performed routinely as part of standardized monitoring procedures, or data can be obtained by modeling,
- spread of use, indicating if indicator is used in corresponding European Directives or national legislatures,
- reliability, indicating If the indicator measuring/monitoring/forecasting is based on well established/standardized/recognized methods, and
- sustainability, indicating from when and for how long monitoring of environmental effect is necessary.

The report D 2.2 briefly describes the Drivers-Pressures-State-Impact-Responses (DPSIR) approach and its application to the road asset management process. The existing technical E-KPIs address either source/emissions or intensity/concentration of different environmental effects. Based on this analysis, two groups of possible performance indicators were identified:

- indicators based on <u>absolute value of environmental impact</u>, that are more appropriate for technical indicators based on source/emission, like energy consumption or CO_2 emission as a result of road construction/maintenance, and
- indicators based on <u>change in environmental impact</u> that are more appropriate for technical E-KPIs based on intensity/concentration of environmental effect, like noise or air pollution, and that would describe environmental impact for different road construction/maintenance alternatives.

In order to quantify or model environmental impact, additional data is needed on affected people, flora and fauna, properties or area along the roads. Depending on the available data, impact indicators can be defined based on road section/network length and density of population or characteristics or affected area. This information can also be obtained through mapping like noise mapping that is typically used to show noise impact for highly trafficked roads.

Finally, the stakeholders' needs and expectations were compared to the list of existing technical E-KPIs in order to identify missing indicators. Impact on environment preservation, as one of stakeholders' expectations, is lacking technical indicators which would describe the impact on flora and fauna and impact on land consumption that should include valuable (national habitat, domestic and recreation) area lost and/or sealed. It should be noted that indicators which address these expectations exist, but they have been mainly used at the strategic level.

This work opens the road for the development of missing E-KPIs (WP3) and their implementation in Asset Management Systems (WP4).

VII - References

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IX – APPENDIX: Assessment of the existing E-KPIs

Table A1. Assessment form for the indicator N1

Area: **NOISE**			Assessment ID **N1**
Name:	Equivalent continuous sound level L_{eq}, $L_{Aeq,T}$		
Description:	Represents the average noise level (that accounts for changes in pressure level) during the measurement time T.		
Technical Parameters:	Maximum A-weighted sound pressure level $L_{AF,\max}$ Average A-weighted sound pressure level L_{Aeq}	**Units:**	dB(A)
Indirect indicators and relations	Directly proportional to: Texture, Rolling resistance, Skid resistance, Stiffness, Indirectly proportional to: Porosity		
Related/derived indicators:	Sound exposure level SEL (or $L_{A\max}$) Day-Night equivalent level L_{DN} Day-Evening-Night equivalent level L_{den} Night level L_{night}		
Measurement/ monitoring methods:	Statistical Pass-By-Method (SPB) ISO 11819-1 Close Proximity Method (CPX) ISO/CD 11819-2 Statistical Pass-By Backing Board Method (SPB-BB) Controlled Pass-By-Method (CPB) Before/After Method		
Sources:	Projects: SILVIA, SILENCE, COST356, FINNRA, TERM, Tools: HDM-4		
ASSESSMENT			
Meeting stake-holders needs and expect.	Neighbors – Public health		
Assessing per-formance of ind. assets	Pavement surface, noise screens and barriers		
Level of applicability and use	Project level; project's operational phase; it can be used for comparison of pavement surface alternatives or as a noise level indicator in urban areas.		
Possible aggre-gation into combined index	Indicator can be combined into noise indicator. Impact can be expressed in monetary terms.		
Data availability:	Noise measurements are performed as part of regular monitoring, mostly in urban areas. Modeling of noise level is possible as function of traffic volume and structure, vehicle speed, distance from highway). Measurements or modeling are used for noise mapping. However, the procedure is not harmonized at European level. Possible lack of data for less trafficked roads.		
Spread of use:	L_{Aeq} has been almost universally adopted for road noise assessment.		
Reliability:	Well established and recognized measurement/monitoring methods providing consistent and reliable data.		
Sustainability in time:	Effect is expected to demonstrate in the short-term scale, but the duration of the effect is observed in the long-term scale.		

Table A2. Assessment form for the indicator N2

Area: **NOISE**			Assessment ID **N2**
Name:	Day-Evening-Night equivalent level L_{den}		
Description:	Represents the noise indicator for overall annoyance.		
Technical Parameters	Maximum A-weighted sound pressure level $L_{AF,\max}$ Average A-weighted sound pressure level L_{Aeq}	**Units:**	dB
Indirect indicators and relations	Directly proportional to: - Texture, Rolling resistance, Skid resistance, Stiffness Indirectly proportional to: - Porosity		
Related/derived indicators:	Day equivalent level L_{day} Evening equivalent level $L_{evening}$ Night level L_{night}		
Measurement/ monitoring methods:	Statistical Pass-By-Method (SPB) ISO 11819-1 Close Proximity Method (CPX) ISO/CD 11819-2 Statistical Pass-By Backing Board Method (SPB-BB) Controlled Pass-By-Method (CPB) French NMPB-routes-96 road noise calculation method		
Sources:	Projects: SILVIA, SILENCE, COST356, COST350, FINNRA EC Directive 2002/49/EC ISO 1996-2 (1987)		
ASSESSMENT			
Meeting stake-holders needs and expect.	Neighbors – Public health		
Assessing performance of ind. assets	Pavement surface and noise screens and barriers.		
Level of applicability and use	Strategic/Program/Project level; project's operational phase; indicator is used for the strategic noise mapping; it can be used for the assessment of pavement surface alternatives noise performances.		
Possible aggre-gation into combined index	Indicator can be combined into noise indicator. Impact can be expressed in monetary terms.		
Data availability:	Noise measurements are performed as part of regular monitoring, mostly in urban areas. Modeling of noise level is possible as function of traffic volume and structure, vehicle speed, distance from highway). Measurements or modeling are used for noise mapping. However, the procedure is not harmonized at European level. Possible lack of data for less trafficked roads.		
Spread of use:	Indicator is specified in EU Environmental Noise Directive and in use in many EU countries for road traffic noise mapping.		
Reliability:	Well established and recognized measurement/monitoring methods providing consistent and reliable data.		
Sustainability in time:	Effect is expected to demonstrate in the short-term scale, but the duration of the effect is observed in the long-term scale.		

Table A3. Assessment form for the indicator N3

Area: **NOISE**			Assessment ID **N3**
Name:	Night time level L_{night}		
Description:	Represents the noise indicator for sleep disturbance.		
Technical Parameters	Maximum A-weighted sound pressure level $L_{AF,\max}$ Average A-weighted sound pressure level L_{Aeq}	**Units:**	dB
Indirect indicators and relations	Directly proportional to: - Texture, Rolling resistance, Skid resistance, Stiffness, Indirectly proportional to: - Porosity		
Related/derived indicators:	Sound exposure level SEL (or $L_{A\max}$) Day-Night equivalent level L_{DN} Day-Evening-Night equivalent level L_{den}		
Measurement/ monitoring methods:	Statistical Pass-By-Method (SPB) ISO 11819-1 Close Proximity Method (CPX) ISO/CD 11819-2 Statistical Pass-By Backing Board Method (SPB-BB) Controlled Pass-By-Method (CPB) French NMPB-routes-96 road noise calculation method		
Sources:	Projects: SILVIA, SILENCE, COST356, COST350, FINNRA EC Directive 2002/49/EC, ISO 1996-2 (1987)		
ASSESSMENT			
Meeting stake-holders' needs and expectat.	Neighbors – Public health		
Assessing performance of ind. assets	Pavement surface and noise screens and barriers.		
Level of applicability and use	Strategic/Program/Project level; project's operational phase; indicator is used for the strategic noise mapping; it can be used for the assessment of pavement surface alternatives noise performances.		
Possible aggre-gation into combined index	Indicator can be combined into noise indicator. Impact can be expressed in monetary terms.		
Data availability:	Noise measurements are performed as part of regular monitoring, mostly in urban areas. Modeling of noise level is possible as function of traffic volume and structure, vehicle speed, distance from highway). Measurements or modeling are used for noise mapping. However, the procedure is not harmonized at European level. Possible lack of data for less trafficked roads.		
Spread of use:	Indicator is specified in EU Environmental Noise Directive and in use in many EU countries for road traffic noise mapping.		
Reliability:	Well established and recognized measurement/monitoring methods providing consistent and reliable data and well developed modeling methods.		
Sustainability in time:	Effect is expected to demonstrate in the short-term scale, but the duration of the effect is observed in the long-term scale.		

Table A4. Assessment form for the indicator N4

Area: **NOISE**			Assessment ID **N4**
Name:	Sound absorption coefficient		
Description:	Information of noise absorption of porous pavements on location.		
Technical Parameters	Sound pressure wave	**Units:**	-
Indirect indicators and relations	-		
Related/derived indicators:	-		
Measurement/ monitoring methods:	In situ sound absorption measurement ISO 13472-1		
Literature sources:	Projects: SILENCE, FINNRA		
ASSESSMENT			
Meeting stakeholders' needs and expectations	Neighbors – Public health		
Assessing performance of individual assets	Porous pavements.		
Level of applicability and use	Project level; project's operational phase and maintenance; yields information about sound absorption. It can be used to monitor the effect of clogging on absorption of porous pavements to trigger maintenance actions like pore cleaning.		
Possible aggregation into combined index	Indicator can be combined into noise indicator.		
Data availability:	Limited data available on measurement/monitoring of sound absorption.		
Spread of use:	Only relevant for porous pavements.		
Reliability:	Established measurement/monitoring method providing consistent and reliable data.		
Sustainability in time:	Effect is expected to demonstrate in the short-term scale as well as the duration of the effect.		

Table A5. Assessment form for the indicator A1

Area: **AIR POLLUTION**			Assessment ID **A1**
Name:	Concentration of air pollutants		
Description:	Pollutants that have negative impact on human health, agricultural and forestry production losses, and corrosion of building materials.		
Technical Parameters	Concentration of $PM_{2.5}$ Concentration of PM_{10} Concentration of NO_x Concentration of SO_2 Concentration of NMVOC Concentration of CO Concentration of Hg Concentration of Pb Concentration of HC	**Units:**	g/km for vehicle emissions g/t, kg/t or g/m^2 for materials
Indirect indicators and relations	Directly proportional to: - fuel consumption, rolling resistance, speed, traffic volume		
Related/derived indicators:	Emission of pollutants		
Measurement/ monitoring methods:	**SO_2**: EN 14212:2005 "Ambient air quality — Standard method for the measurement of the concentration of sulphur dioxide by ultraviolet fluorescence" **NO_x**: EN 14211:2005 "Ambient air quality — Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence" **Pb**: EN 14902:2005 "Standard method for measurement of Pb/Cd/As/Ni in the PM_{10} fraction of suspended particulate matter" **PM_{10}**: EN 12341:1999 "Air Quality — Determination of the PM10 fraction of suspended particulate matter" **$PM_{2.5}$**: EN 14907:2005 "Standard gravimetric measurement method for the determination of the PM2,5 mass fraction of suspended particulate matter" **Benzene**: EN 14662:2005, parts 1, 2 and 3 "Ambient air quality — Standard method for measurement of benzene concentrations" **CO**: EN 14626:2005 "Ambient air quality — Standard method for the measurement of the concentration of carbon monoxide by non-dispersive infrared spectroscopy"		
Literature sources:	Projects: COST350, HEATCO, HDM, FINNRA, PaLATE, TERM EC Directive: 96/62/EEC - Air Quality Framework Directive EC Directive 2008/50/EC on ambient air quality and cleaner air for Europe		

Table A5. Assessment form for the indicator A1, continued

Area: AIR POLLUTION	Assessment ID A1
ASSESSMENT	
Meeting stake-holders needs and expectations	Neighbors and Society – Public health.
Assessing performance of individual assets	Roads and bridges.
Level of applicability and use	Program/Project level; project's operational phase. Indicator could be used to assess changes in the pollutant emission as a result of different maintenance activities.
Possible aggre-gation into combined index	This is the only indicator identified for this group of indicators. It can further be grouped in the general environmental indicator. Impact can be expressed in monetary terms.
Data availability	Standardized measuring methods are available and harmonized procedures for data reporting exist on European level. Measurements are being performed as part of air quality monitoring on limited number of locations, mostly in urban areas. Several modeling techniques for air pollution related to transport are available.
Spread of use:	Air quality is measured and monitored in many countries, especially in urban areas. Air pollution due to traffic is measured on experimental sites.
Reliability:	Established measurement/monitoring method providing consistent and reliable data.
Sustainability in time:	Effect is expected to demonstrate in the long-term scale as well as the duration of the effect.

Table A6. Assessment form for the indicator W1

Area: WATER POLLUTION			Assessment ID W1
Name:	Concentration of heavy metals (Cd, Cu, Pb, Cr, Zn, Fe, Ni, Na)		
Description:	Concentration of heavy metals in the highway run-off water. It affects pollution of soil, surface water and underground water.		
Technical Parameters	Concentration of the pollutant	**Units:**	mg/l – for water mg/kg – for soil
Indirect indicators and relations	Directly proportional to: traffic volume, average concentration of pollutants in the combustion gases		
Related/derived indicators:	Concentration of PAH Concentration of pesticides and salt Concentration of oil derivatives		
Measurement/ monitoring methods:	Measurement method - Atomic absorption spectrometry (AAS), Inductively Coupled Plasma (ICP), Molecule Absorption spectrometry in the UV – VIS environment (UV – VIS), Ion Exchange Chromatography (IEC) Yearly measurements in spring or summer periods during the operational phase.		
Literature sources:	Projects: COST350, POLMIT, SILVIA, FINNRA EC Directive: 2000/60/EC (Water Framework Directive) EC Directive: Proposal for a directive of the European Parliament and the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC EC Directive: 2006/118/EC on the protection of groundwater against pollution and deterioration		
ASSESSMENT			
Meeting stake-holders needs and expect.	Society – Environmental preservation/Climate change		
Assessing performance of individual assets	Roads, bridges, highway structures, traffic signs, crash barriers, drainage system		
Level of applicability and use	Project level; project’s operational phase and maintenance.		
Possible aggregation into combined index	The indicator could be aggregated to the water pollution combined index.		
Data availability:	Data available from limited surveys of water quality in the vicinity of road network. Modeling of concentration of Pollutants based on traffic volume, highway length, free-flow speed, fraction of Impervious area, rainfall history, distance from highway).		
Spread of use:	Water quality is measured and monitored in many countries. Impact is very site specific, which causes difficulties for general use. Monitoring of water pollution due to traffic is isolated to specific cases (accidents).		
Reliability:	Well established and recognized measurement methods providing consistent and reliable data.		
Sustainability in time:	Effect is expected to demonstrate in the short-term scale, but the duration of the effect is observed in the long-term scale.		

Table A7. Assessment form for the indicator W2

Area: **WATER POLLUTION**			Assessment ID **W2**
Name:	Concentration of total hydrocarbons (polynuclear aromatic hydrocarbons, PAH)		
Description:	Concentration of PAHs in highway run-off water. It affects pollution of soil, surface water and underground water		
Technical Parameters	Concentration of total hydrocarbons	**Units:**	mg/l – for water mg/kg – for soil
Indirect indicators and relations	Directly proportional to: traffic flows, average concentration of pollutants in the combustion gases		
Related/derived indicators:	Concentration of heavy metals Concentration of pesticides and salt Concentration of oil derivatives		
Measurement/ monitoring methods:	Measurement method – Gas chromatography-mass spectrometry (GC-MS) or Liquid chromatography method. Yearly measurements in spring or summer periods during the operational phase.		
Literature sources:	Projects: COST350, POLMIT, SILVIA EC Directive: 2000/60/EC (Water Framework Directive) EC Directive: Proposal for a directive of the European Parliament and the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC EC Directive: 2006/118/EC on the protection of groundwater against pollution and deterioration		
ASSESSMENT			
Meeting stake-holders needs and expectations	Society – Environmental preservation/Climate change		
Assessing performance of individual assets	Roads, bridges, highway structures, traffic signs, crash barriers, drainage system		
Level of appli-cability and use	Project level; project's operational phase and maintenance.		
Possible aggregation into combined index	The indicator could be aggregated to the water pollution combined index.		
Data availability:	Data available from limited surveys of water quality in the vicinity of road network. Modeling of concentration of Pollutants based on traffic volume, highway length, free-flow speed, fraction of Impervious area, rainfall history, distance from highway).		
Spread of use:	Water quality is measured and monitored in many countries. Impact is very site specific, which causes difficulties for general use. Monitoring of water pollution due to traffic is isolated to specific cases (accidents).		
Reliability:	Well established and recognized measurement methods providing consistent and reliable data.		
Sustainability in time:	Effect is expected to demonstrate in the short-term scale, but the duration of the effect is observed in the long-term scale.		

Table A8. Assessment form for the indicator W3

Area: **WATER POLLUTION**			Assessment ID **W3**
Name:	Concentration of de-icing salt		
Description:	Concentration of sulphate, calcium chloride, sodium and cyanide in highway run-off water. It affects pollution of soil, surface water and underground water		
Technical Parameters	Concentration of sulphate Concentration of calcium chloride Concentration of sodium Concentration of cyanide	**Units:**	mg/l – for water mg/kg – for soil
Indirect indicators and relations	Directly proportional to: - Average amount of salt annually used for winter maintenance		
Related/derived indicators:	Concentration of heavy metals Concentration of pesticides Concentration of oil derivatives		
Measurement/ monitoring methods:	Ion Selective Electrode (ISE) method. Yearly measurements in spring or summer periods during the operational phase.		
Literature sources:	Projects: COST350, POLMIT, SILVIA, FINNRA EC Directive: 2000/60/EC (Water Framework Directive) EC Directive: Proposal for a directive of the European Parliament and the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC EC Directive: 2006/118/EC on the protection of groundwater against pollution and deterioration		
ASSESSMENT			
Meeting stake-holders needs and expectations	Society – Environmental preservation/Climate change		
Assessing performance of individual assets	Roads, bridges, highway structures, traffic signs, crash barriers, drainage system		
Level of applica-bility and use	Project level; project's operational phase and maintenance.		
Possible aggregation into combined index	The indicator could be aggregated to the water pollution combined index.		
Data availability:	Data available from limited surveys of water quality in the vicinity of road network. Modeling of concentration of Pollutants based on traffic volume, highway length, free-flow speed, fraction of Impervious area, rainfall history, distance from highway).		
Spread of use:	Water quality is measured and monitored in many countries. However, monitoring of water pollution due to traffic is isolated to specific cases (accidents).		
Reliability:	Well established and recognized measurement methods providing consistent and reliable data.		
Sustainability in time:	Effect is expected to demonstrate in the short-term scale, but the duration of the effect is observed in the long-term scale.		

Table A9. Assessment form for the indicator R1

Area: NATURAL RESOURCES			Assessment ID R1
Name:	Waste reduction		
Description:	Represents the waste management method for minimizing the total waste amount to be landfill or maximizing the use of recycled materials.		
Technical Parameters	Use of recycled materials in construction	**Units:**	%
Indirect indicators and relations	Directly proportional to CO_2 emission – reducing the wase reduces the CO_2 emission.		
Related/derived indicators:	Volume of pavement waste to landfill (ton) Reduction in resource mining (%) Hazardous waste reduction (%) Water consumption during the construction activities (l)		
Measurement/ monitoring methods:	Engineering calculations based on amount of new and recycled materials used.		
Literature sources:	Projects: COST 350, COST 356 LCA Tools: BE^2ST		
ASSESSMENT			
Meeting stakeholders' needs and expectations	Society – Preservation of natural resources		
Assessing performance of individual assets	Road, bridges and highway structures.		
Level of applicability and use	Project level; it can be used for assessment of alternatives based on the cost-benefit analysis.		
Possible aggregation into combined index	Indicator can be combined into combined indicator for natural resources.		
Data availability	Tools are available that could estimate the impact of use of recycled material and waste into construction and maintenance projects.		
Spread of use:	Waste management systems are in use in many countries.		
Reliability:	Engineering calculations provide reliable data.		
Sustainability in time:	Effect is expected to demonstrate in the short-term scale, but the duration of the effect is observed in the long-term scale.		

Table A10. Assessment form for the indicator R2

Area: **NATURAL RESOURCES**			Assessment ID **R2**
Name:	Energy consumption		
Description:	Assess energy consumption for building the infrastructure as well as for vehicle operation on this infrastructure.		
Technical Parameters	Energy consumption	**Units:**	GJ TJ/km
Indirect indicators and relations	Directly proportional to: - use of construction materials, traffic volume		
Related/derived indicators:	Use of fossil fuels/renewable energy (l/100 km; kg/100 km; ton/year) Energy consumed – production, transport, placement (J/ton)		
Measurement/ monitoring methods:	Databases for specific fuel/energy consumption are available.		
Literature sources:	Projects: COST 350, COLAS, FINNRA LCA Tools: BE^{2}ST, PALATE, HDM-4		
ASSESSMENT			
Meeting stakeholders' needs and expectations	Society – Preservation of natural resources		
Assessing performance of individual assets	Road, bridges and highway structures.		
Level of applicability and use	Project level; it can be used for assessment of alternatives based on the cost-benefit analysis.		
Possible aggregation into combined index	Indicator can be combined into combined indicator for natural resources.		
Data availability	Databases with energy consumption data for construction materials are well established and mostly available. Energy consumption of vehicles can be modeled using some of existing models that are mostly based on vehicle speed.		
Spread of use:	Indicator is in use in many countries.		
Reliability:	Estimation of energy consumption due to construction works is very reliable.		
Sustainability in time:	Effect is expected to demonstrate in the short-term scale, but the duration of the effect is observed in the long-term scale.		

Table A11. Assessment form for the indicator G1

Area: **GREENHOUSE GASES**		Assessment ID	**G1**
Name:	Emission of CO_2 equivalent (CO_2e)		
Description:	Assess global warming potential for activities related to the building the infrastructure as well as for vehicle operation on this infrastructure.		
Technical Parameters	Emission of CO_2 equivalent	**Units:**	Mg
Indirect indicators and relations	Directly proportional to: - Rolling resistance, traffic volume, level of service - Energy consumption		
Related/derived indicators:	Embodied CO_2e – associated with the pavement related activities needed to bring it to the use (CO_2e per ton of asphalt per year) Operational CO_2e – associated to the pavement in operation (CO_2e per ton of asphalt per year)		
Measurement/ monitoring methods:	Spectrometer, Calculator Based Labs (CBL), Grab Sampling Tubes		
Literature sources:	Projects: HEATCO, COLAS, TERM LCA Tools: asPECT, BE^{2}ST, PALATE, HDM-4		
ASSESSMENT			
Meeting stakeholders' needs and expectations	Society – Environment preservation/Climate change		
Assessing performance of individual assets	Road, bridges and highway structures.		
Level of applicability and use	Strategic/Program/Project level; construction, operation and maintenance.		
Possible aggregation into combined index	This is the only indicator identified for this group of indicators. It can further be grouped in the general environmental indicator. Impact can be expressed in monetary terms.		
Data availability	Data on CO_2 emission due to traffic and construction works is mostly available. Modeling of CO_2 emission can be performed based on energy consumption or based on transport activity (load transported). There are several tools for estimation of the carbon dioxide saved in selecting different construction techniques and supply alternatives.		
Spread of use:	Indicator is in use in many countries.		
Reliability:	Well established and recognized measurement methods providing consistent and reliable data.		
Sustainability in time:	Effect is expected to demonstrate in the short-term scale, but the duration of the effect is observed in the long-term scale.		