EVITA

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

Effective asset management meeting future challenges

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Deliverable D4.1

Framework for implementation of Environment Key Performance Indicators

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PROJECT COORDINATORS:	Institut Français des Sciences et des Technologies des Transports, de l'Aménagement et des Réseaux (F) PMS-Consult (AT)

OTHER PARTNERS :

Laboratório Nacional de Engenharia Civil (LNEC)	P
Transport Research Laboratory (TRL)	UK
Zavod za gradbenistvo Slovenije - Slovenian National Building & Civil Engineering Institute (ZAG)	SI
DRI Investment Management, Company for Development of Infrastructure Ltd.	SI
University of Belgrade, Faculty of Civil Engineering	SR

Report coordinated by:	Contributors:	Reviewed by:	Reviewed by:
Maria de Lurdes Antunes	Philippe Lepert Julijana Jamnik Darko Kokot Vânia Marecos	J. Litzka	J. Potucek

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Abstract

Glossary

The following words are frequently used in the EVITA reports. An attempt of definition in this context is proposed below. Some of the definitions presented were developed in a previous project (COST 354) [3].

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

Single Performance Indicator (also called Individual Performance Indicator): A dimensional or dimensionless number related to only one technical characteristic of the road pavement, indicating the condition of that characteristic (for example: noise).

Combined Performance Indicator: A dimensional or dimensionless number related to two or more different characteristics of the road pavement, that indicates the condition of all the characteristics involved (for example, noise and air pollution).

Performance Index: An assessed Technical Parameter of the road pavement, dimensionless number or letter on a scale that evaluates the Technical Parameter involved (e.g. Noise, GHG, etc.) on a 0 to 5 scale, 0 being a very good condition and 5 a very poor one.

Technical Parameter (TP): A physical characteristic of the road pavement condition, derived from various measurements, or collected by other forms of investigation (for example, noise level).

Transfer Function: A mathematical function used to transform a technical parameter into a dimensionless performance index.

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Deliverable D 4.1

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 project is paying a special attention to the development of easily understandable Environmental KPIs (E-KPIs). It also aims at identifying existing best practice in the implementation of KPIs to managing the full range of road infrastructure components (pavements, structures, road furniture, etc.).

This deliverable is reporting part of the work developed under the fourth Work Package (WP 4) of the project. This WP is devoted to the development of a strategy for the implementation of Key Performance Indicators (KPIs) in optimised asset management systems and to the development of recommendations for their practical application in road management practice.

Deliverable D 4.1 aims at the presentation of a general framework for implementation of E-KPIs. A flexible system that can accommodate different types of technical parameters and indicators, different objectives and different levels of application, is recommended. The use of a unified scale to express E-KPIs is also recommended.

Based on the work previously performed under COST 354 action, some guidance is provided for the transformation of technical parameters into unified E-KPI, as well as for the combination of several E-KPIs into one Combined Index, when needed.

Finally, general recommendations are provided concerning the integration of E-KPIs in asset management practice, depending on the specific objectives.

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I - Introduction

I.1 The EVITA Project

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 key performance indicators in the asset management process taking into account the expectations of different stakeholders (users, operators, neighbours, etc.)

The project is paying a special attention to the development of easily understandable Environmental KPIs (E-KPIs). It also aims at identifying existing best practice in the implementation of KPIs to managing the full range of road infrastructure components, (pavements, structures, road furniture, etc.).

The project started with a comprehensive state of the art investigation conducted in cooperation with the client (through the PEB), with European Road Administrations and with other important road stakeholders such as Environment Agencies. This first step was completed by an inventory of the existing E-KPIs [1] and an assessment of these E-KPIs [2]. In a second step, recommendations of different E-KPIs for the environmental areas “noise”, “air and water”, “natural resources” and “greenhouse gas (GHG)” are being developed (WP 3). Finally, a recommendation for the implementation and the use of E-KPIs are included in this project as well. Therefore the investigation will be extended to the given frameworks (where, when, how, etc.) of possible users.

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 with respect to objective indicators. Furthermore the results could be used as an integrated part in the asset management processes of the road owners and road operators.

I.2 The Work Package 4

The objective of Work Package 4 is to develop a strategy for the incorporation of Key Performance Indicators (KPI) in optimised asset management systems and to develop recommendations for their practical application in road management practice. These KPIs will be applied to different road infrastructure assets (pavement structures, drainage and road furniture) and they will take into account different stakeholders’ requirements and expectations as well as environmental issues (traffic noise, air and water pollution and natural resources preservation).

The strategy for implementation of KPIs developed by WP2 and WP3 will be flexible, in order to be able to deal with different quality levels of information and to be applicable in different contexts. Task 4.1 aims at the development of a general framework for implementation of E-KPIs. Task 4.2 will address the implementation of E-KPIs in asset management practice.

This report (Deliverable 4.1) is the output of Task 4.1 and presents a concise discussion about the general framework for technical implementation/incorporation of E-KPIs, in preparation for subsequent work. Deliverable 4.1 is dealing with the Technical implementation of the KPIs. Once a detailed report on development of E-KPIs is issued by WP3 (Deliverable 3.1), task 4.2 will develop examples for the use of these indicators in asset management practice, and a comprehensive final report of WP4 will be produced (Deliverable 4.2), covering the practical implementation.

II - The Environmental Key Performance Indicators (E-KPIs)

The main objective of the EVITA project is to identify and to develop, when necessary, environment key performance indicators (E-KPIs) for implementation in road asset management, taking into account stakeholders expectations.

The work performed by Work Package 2 has identified the main expectations from different road stakeholders. From this work it was concluded that the impact of road infrastructures on the environment is mainly a concern of the road neighbours, the society in general and the road owners. This latest group is concerned with the environment in the sense that they have to manage their image to the public and the society.

WP2 performed an evaluation of existing technical environmental performance indicators or technical parameters, with respect to issues like stakeholder needs and expectations, level of applicability and use, data availability, etc [1] [2]. The indicators assessed are presented in Table 1.

Table 1 - List of indicators assessed by EVITA WP2

Area	Indicator/Technical 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

Taking into account the results of WP2, Work Package 3 is working in the development of E-KPI for noise (N), air pollution including green house gases (A), water pollution (W) and natural resources (R).

a) Noise

Noise emissions are mainly affecting the road neighbours. The E-KPIs developed by WP3 will be based on noise mapping. If possible, the theoretical modelling used for noise mapping will be verified through in-situ measurements.

b) Air and water pollution

Air pollution can be generated by traffic itself, during the whole life-cycle of the infrastructure, or by construction and maintenance activities, which take place at specific points in time. The most significant issues related to air pollution will be NOx and particles.

Green House Gas emissions can be expressed as CO_2 equivalent, but it is difficult to separate the effects that derive directly from the road from the effects of other human activities. CO_2 emissions by traffic will also be part of air pollution indicators.

Water pollution due to road infrastructure is mainly attributed to wash off pollutants from the surface of the road and can be mitigated through protective measures associated with the drainage system. Indicators can be developed as a function of the quality of the drainage system.

Air and water pollution are mainly affecting areas in the vicinity of the road. Air pollution, and specially CO_2 emissions, is also relevant for society in general.

c) Natural resources

Depreciation of natural resources in road infrastructure is mainly associated with material and energy consumption as well as waste generated during construction and maintenance. It can be considered as a global problem that affects society in general, but it is also an issue for road owners, who are responsible for these activities.

III – Framework for implementation of Environment Key Performance Indicators (E-KPI)

III.1 Strategy for incorporation

The incorporation procedure for E-KPIs must be a flexible system in order to accommodate different types of technical parameters and indicators, different objectives and different levels of application.

From the work performed in other projects and in previous Work Packages it can be concluded that some E-KPIs can be directly related to roads whereas other indicators, such as air and water pollution or GHG emissions are depending on other factors and other activities.

The selected Technical Parameters and associated E-KPIs can be relevant on different phases of the infrastructure life-cycle; for example, E-KPIs associated with natural resource consumption are only relevant during construction and maintenance operations, whereas

indicators associated with emissions are relevant during the whole life-cycle – construction, operation and maintenance phases.

An issue that must be considered when implementing and combining E-KPIs is their spatial relevance, which can also be associated with different stakeholders expectations: for example, noise emissions is a local problem and they affect mainly the road neighbours, whereas CO_2 emissions is a global problem, which affects society in general.

Therefore, a first step that should be taken for incorporation of E-KPI in asset management practice is to evaluate their relevance with respect to the infrastructure life-cycle, stakeholders and spatial distribution, depending on the context. Table 2 presents an example of this evaluation using the set of E-KPIs that were assessed by WP2 (see Table 1). .

Table 2 – Example of evaluation of relevance of E-KPIs in different contexts

Assessment ID	Infrastructure Life Cycle Phase			Stakeholder						Spacial	
	Construction	Operation	Maintenance	User	Operator	Owner	Society	Neighbours	Financing Body	Global	Local
N1	L	H	L				L	H			H
N2	L	H	L				L	H			H
N3		H						H			H
N4		H						H			H
A1	L	H	L				M	H		M	H
W1	L	H	L				H	M		H	M
W2	L	H	L				H	M		H	M
W3			H				M	L		M	L
R1	H		M				H	L	M	H	L
R2	M	H	M	H	H		H		M	H	
G1	M	H	M				H			H	

Key:
L Low relevance
M Medium relevance
H High relevance

The relevance of E-KPIs under development by WP3 will be discussed and analysed in a workshop that will be organized by WP4, in order to be taken into account in the development of procedures for use and implementation for different contexts.

For example, the energy consumption is much lower in the construction and maintenance phases compared to the operation phase. In fact, its relevance will depend on the context: if the purpose is to assess the energy consumption throughout the infrastructure's life cycle, the consumption during operation will have a major impact, compared to the other phases. On the other hand, if the purpose of a road owner or operator is to select the best construction and maintenance alternatives concerning, the energy consumption indicator should have a high relevance for construction and maintenance phases.

Given the fact that, for many road networks, the available information on technical parameters related to environment is still limited, the strategy for implementation/incorporation of E-KPIs should consider a minimum of information for development of simple, easily understandable indicators that can be complemented with more sophisticated information for a better accuracy.

Each E-KPI will use different input variables in form of Technical Parameter(s) or Single Performance Indice(s). To provide a consistent basis for quantitative analysis, each E-KPI will be expressed by a dimensionless index on a scale 0 (good condition) to 5 (poor condition), based on appropriate transformation functions. The 0-5 scale is indicated below.

Table 3 - Performance Index scale

Very Good	Good	Fair	Poor	Very Poor
0 to 1	1 to 2	2 to 3	3 to 4	4 to 5

The proposed process for developing a transformation from technical parameter (TP) to a dimensionless index (PI) is the one developed within COST 354 [3], which consists of 4 steps, briefly described below

1. Decide on TP values with corresponding Index values (PI). It is necessary to define at least two values for the technical parameter with corresponding Index values. These points can be at any point in the Index scale.
2. Plot points on graph. This allows the relationship between the technical parameter and the Index to be seen.
3. Determine the line/curve of best fit. Choose a graph which best fits the points you have chosen. The graph can be of any type, however most cases will use either a linear ($y=mx+c$) or quadratic ($y=ax^2+bx+c$) equation.
4. Calculate and check the range and sensitivity. If the transformation is unsuitable return to step one with additional and/or modified index values.

The procedure described above is illustrated in Figure 1. An example, which is taken from COST 354 report [4] is presented below.

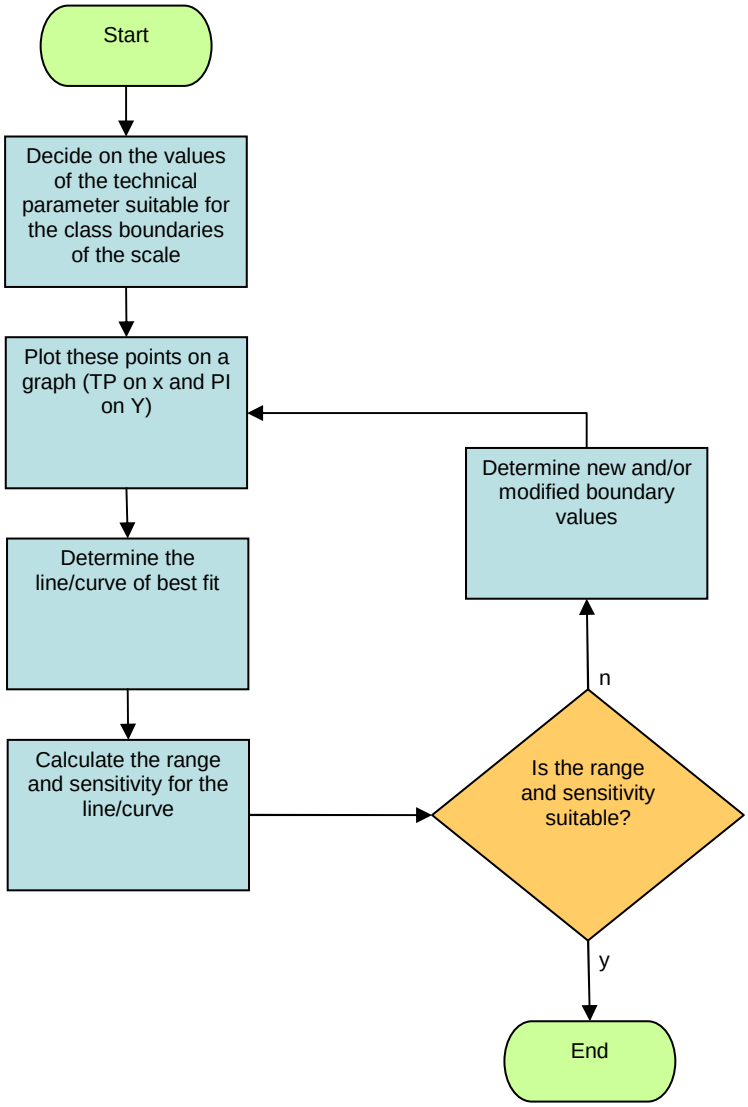

Figure 1 - Flow chart for developing transformation of technical parameters into unified KPI [3]

As an example of the use of the procedure described above the determination of the Skid Resistance index is described. It is assumed that SFC (Sideways Friction Coefficient) data is used, which runs from 0-1. The first step in developing a custom transformation is to define values for class boundaries (or other points on the Performance Index scale). In this example, the user defines the boundaries between good and fair as 0.6, and fair and poor as 0.40. These boundary points have Performance Index values of 2 and 3 respectively (see Table 3). These points are graphed in fig. 2 (along with the line of best fit).

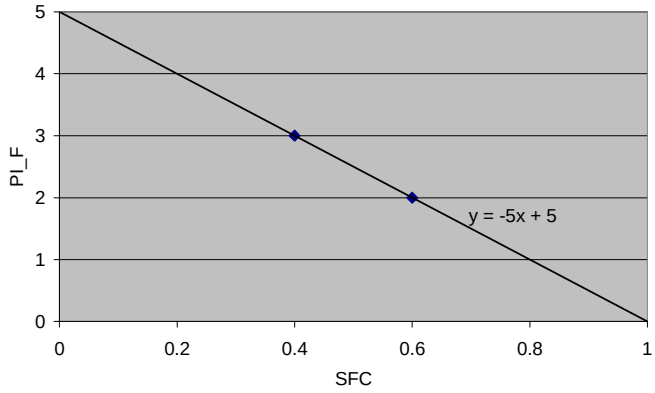

Figure 2: Example graph for developing custom transformation

For the two points given the equation calculated (i.e. the line of best fit) is PI_F=Max(0,Min(5,-5*SFC+5). This leads to the following range and sensitivity.

Table 4 Range and Sensitivity of example custom transformation

	Very Good	Good	Fair	Poor	Very Poor
Skid Resistance, PI_F	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5
SFC – Custom Transformation	1.0 – 0.8	0.8 – 0.6	0.6 – 0.4	0.4 – 0.2	0.2 – 0.0

The user would then check to see if the range/sensitivity fits with his network. If it does, then the user would use this transformation, if not, the user would revisit their boundary conditions and repeat the process.

III.2 Combination of E-KPI for different expectations

The definition of E-KPI for a given purpose can be done through a combination of several indices, for a special purpose or goal, or for a special stakeholder or interest group. In that case the user should be able to use appropriate weights/priorities in the combination procedure.

Therefore, the following issues can be considered in the implementation procedure for E-KPIs at project level:

a) Use of single E-KPI
b) Combination of E-KPIs for different phases in the infrastructure life-cycle
   b.1) the construction phase
   b.2) the road operation (including maintenance)
   b.3) the whole lifecycle
c) Combination of E-KPIs for different stakeholders / objectives
   c.1) Local (neighbours)

c.2) Global (society)

The recommended combination procedure is based on the advanced maximum criteria used in COST 354 [3]. In this procedure, the user assigns an appropriate weight (Wi) to each single E-KPI, according to the specific priorities in the network.

The combined E-KPI (C(EKPI)) takes into account the maximum weighted single E-KPI value affected by biased values of other weighted E-KPIs.

$$C(EKPI) = \min\left[5; I_1 + \frac{p}{100} \cdot \overline{(I_2, I_3, \ldots, I_n)}\right]$$

where

$$I_1 \geq I_2 \geq I_3 \geq \ldots \geq I_n$$

and

$$I_1 = W_1 \cdot EKPI_1, I_2 = W_2 \cdot EKPI_2, \ldots, I_n = W_n \cdot EKPI_n .$$

With this approach the combined E-KPI can differ from one to another, if there are other E-KPIs that can influence it, by using the mean value of the other weighted E-KPIs and combining it with a *p* factor that enables to control the total influence of those indicators according to its relevance.

The weights W_i represent the influence of the different E-KPIs and can vary from 0 (lowest importance) to 1 (highest importance). Regarding the *p* factor its value increases with the raise of the influence of the other weighted E-KPIs in relation to the maximum weighted single E-KPI.

It is recognized that road administrations differ in terms of data available, analysis methods and intervention thresholds used, local standards and priorities. Therefore, a flexible system should be used for the implementation of E-KPI, suiting different levels of application, as described below:

Minimum – the minimum input data necessary to implement a given E-KPI, normally one or more Technical Parameters that will be available in most road administrations

Standard – the normal method of implementation, using the preferred Technical Parameters.

Optimum – an advanced implementation, using additional Technical Parameters, which may not be available in all cases.

Examples of different levels of application using the indicators considered in Table 1 is presented in the figure below, where the inner circle represents the “minimum” input and the outer represents the “optimum”.

For example, the first graph on the left means that if a road administrator wants to determine an E-KPI associated with construction, the minimum information that he should use is the energy and natural resource consumption during construction (R1 and R2). If he also has information about green-house gas emissions (G1) during construction he will be able to fulfil the standard level. If he wants to use the optimum level of application, he should be able to determine also data concerning noise (N1 or N2), air (A) and water pollution (W1,2). The

picture on the right refers to the use of different levels of application during the operation, concerning neighbors.

The “minimum”, “standard” and “optimum” levels were derived based on the E-KPI relevance presented in Table 2 and they are merely illustrative. These levels of application will be reviewed during the workshop that will be organised by WP4, and recommendations will be issued in the final WP4 report.

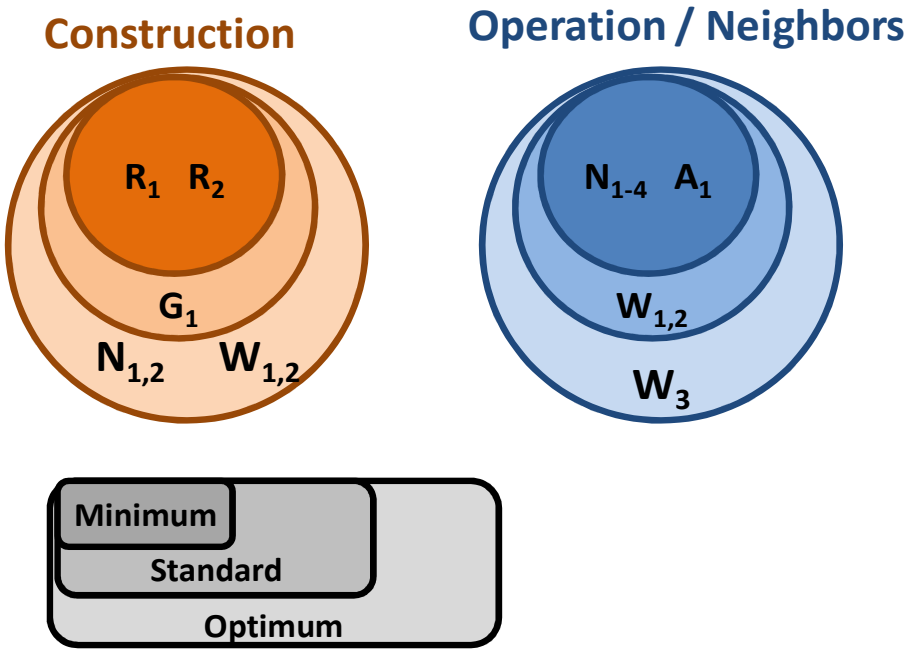

Figure 3 – Examples of different levels of application of E-KPI for different purposes (see description of E-KPIs in Table 1)

III.3 Incorporation of E-KPI in asset management practice

E-KPI can be used for different purposes in asset management practice, such as:

a) monitoring of the environmental performance of a given road network;

b) identification of sensible spots where intervention is needed to improve a certain environmental aspect;

c) assessment of environmental impacts of new infrastructures;

d) comparison of different alternative solutions for infrastructure maintenance and rehabilitation.

This section presents some general recommendations for implementation of E-KPIs in the contexts mentioned above. Once the final E-KPIs are developed by the consortium, some specific examples of practical implementation and use will be developed, as part of task 4.2.

a) Application of E-KPIs for monitoring the environmental performance of a given road network

The global use of E-KPIs for monitoring an existing road network, in the context of asset management practice is still difficult due to the fact that some of the parameters that are most relevant for a global assessment, such as green-house gas emissions or water pollution, are not exclusively attributed to road transport. On the other hand, the whole infrastructure life-cycle should be considered for this global evaluation.

The environmental performance of a given network can be evaluated in the perspectives of two groups of stakeholders: society, in general (global effects), or neighbours (local effects).

The proposed option for this purpose is to:

- select E-KPIs to be evaluated, taking into account the possibilities of the managing organisation and the recommended minimum, standard and optimum levels of application;
- select representative spots for monitoring E-KPIs along the network;
- perform periodic assessment of E-KPIs in representative spots;
- evaluate the evolution of selected E-KPIs through the infrastructure's life-cycle;
- investigate possible causes for unexpected evolution of the E-KPI, and study mitigation measures, when inacceptable evolution is attributed to the road network.

b) Identification of sensible spots where intervention is needed to improve a certain environmental aspect

The variation of E-KPI determined at a certain point of time, throughout a given infrastructure can be used for the identification of sensible spots where there is need for intervention in order to improve the situation. Noise emissions or water pollution are examples of environmental performance indices that can be evaluated in this context.

Whenever a continuous assessment of the indicator is possible, the best option is to map the indicator and identify weak points, using appropriate thresholds. Noise maps are an example of tool for the use of this approach. For some indicators, the identification of sensible spots must be made uniquely on the basis of desk studies, taking into consideration the design of the infrastructure.

Once a weak point is identified, further investigations can be performed for verification of the situation, for example, taking in situ measurements. If any mitigation measures are taken, as a consequence of this evaluation, a second measurement should be performed after the intervention, in order to assess its efficiency.

c) Assessment of environmental impacts of new infrastructures

E-KPIs can be used for the assessment of new infrastructures from an environmental perspective in two ways:

- impacts associated with construction, maintenance and rehabilitation, and

- impacts associated with operation.

The use of E-KPIs for assessment of construction, maintenance and rehabilitation impacts is mainly performed in a comparative analysis, as described in d).

E-KPIs related to the impacts of operation of a new infrastructure should ideally be evaluated in a whole life-cycle perspective, jointly with other existing infrastructures whose usage can be modified with the construction of the new element.

d) Comparison of different alternative solutions for construction, maintenance and rehabilitation

Environmental issues must be considered, together with other technical aspects, when selecting a given solution for construction, maintenance and rehabilitation of road infrastructure. E-KPIs related to energy consumption, resources, air and water pollution should be considered, according to the availability of data, taking into account their relevance. These indicators may be combined, in order to get a rating for each solution.

Ideally, the analysis must be made taking into account the durability of different solutions, in a life-cycle perspective.

IV - Conclusions

The work conducted within task 4.1 of the EVITA project aimed at the development of a framework for implementation of Environmental Key Performance Indicators (E-KPIs), which are still under development, as part of the project's Work Package 3.

The proposed framework is a flexible system that can be adapted taking into account the existence of different levels of information and different needs and expectations of road administrations and other stakeholders.

E-KPIs can be expressed in a unified scale (0 to 5), using adequate transformation functions. They can be used individually, or combined, whenever there is a need to perform a rating of a given infrastructure using one characteristic indicator. In this case, the weighting factors for combination of different E-KPIs will be established according to the specific objectives and context.

E-KPIs can be used for different purposes in the asset management practice. This report provides some general recommendations, depending on the objectives of the user.

The development of E-KPIs is still on-going in the frame of EVITA Work Package 3. Once this work is fully developed, task 4.2 will develop examples for the use of these indicators in asset management practice, and a comprehensive final report of WP4 will be produced (Deliverable 4.2), covering the practical implementation of E-KPI.

V - References

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