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

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Deliverable D2.1

Stakeholder's categories and sub-categories - Expectations - Necessary and existing KPIs

Final version - June 2011

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Deliverable D2.1

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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:
Ph. Lepert	G. Mladenovic A. Weninger-Vycudil NevenaVajdic	J. Litzka	J. Potucek
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EVITA

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

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 2.1

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.). After a comprehensive state of the art review, the project conducts an inventory of the existing E-KPIs. Later, recommendations of different E-KPIs for the environmental areas "noise", "air and water" and "natural resources and greenhouse gas (GHG)" will be given. It will be completed by recommendations for the implementation and the use of E-KPIs.

This deliverable is reporting on the second Work Package (WP 2) of the project. This WP was devoted to the extensive inventory of the road stakeholders, of their expectations and to the inventory of existing E-KPIs. A large number of documents were reviewed (PIARC, COST, European FWP…).

A first list and definition of road stakeholders is proposed. These stakeholders are spread in categories and sub-categories when this classification proved to be helpful to correctly understand and identify their expectations. Figure EA1 summarizes this inventory.

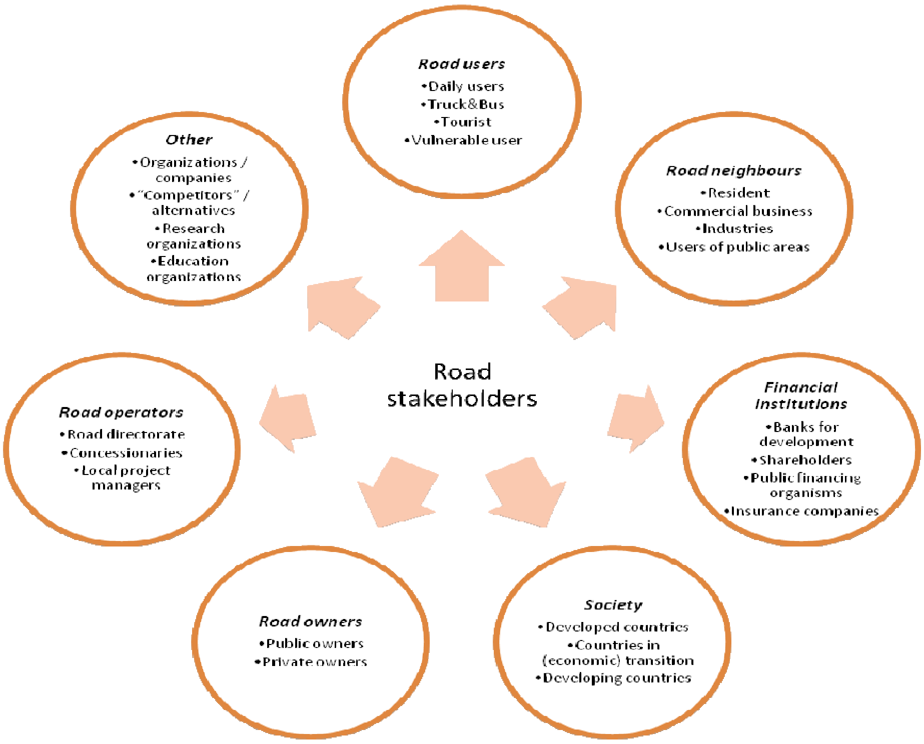

Figure EA1 – Inventory of road stakeholders

Then, the expectations from each stakeholder are listed and organized as displayed in Figure EA2.

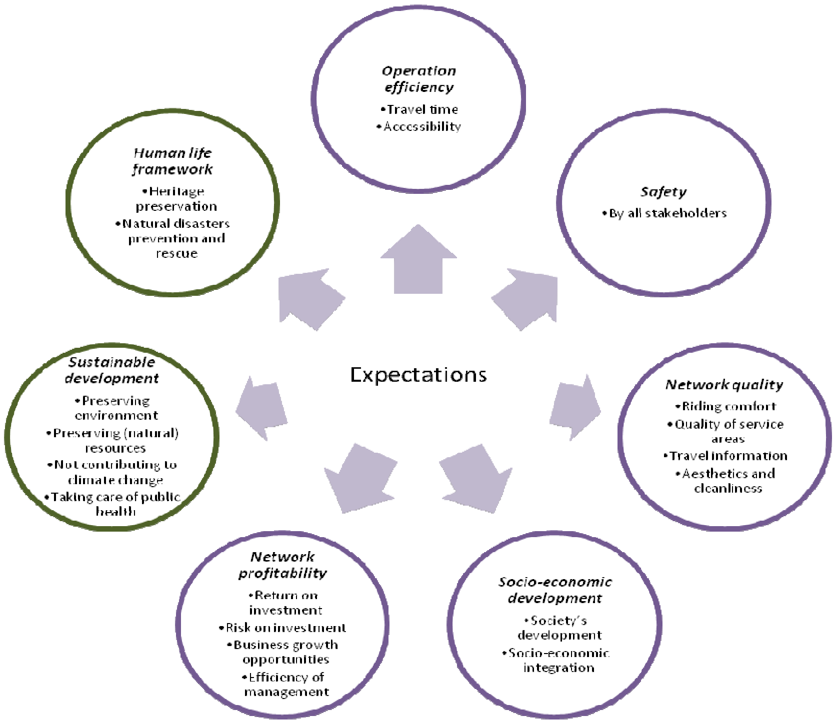

Figure EA2 – Inventory of road stakeholder's expectations

A more comprehensive analysis made it possible to assess the relative importance of the different expectations for the different stakeholders. Figure EA3 qualitatively expresses this link.

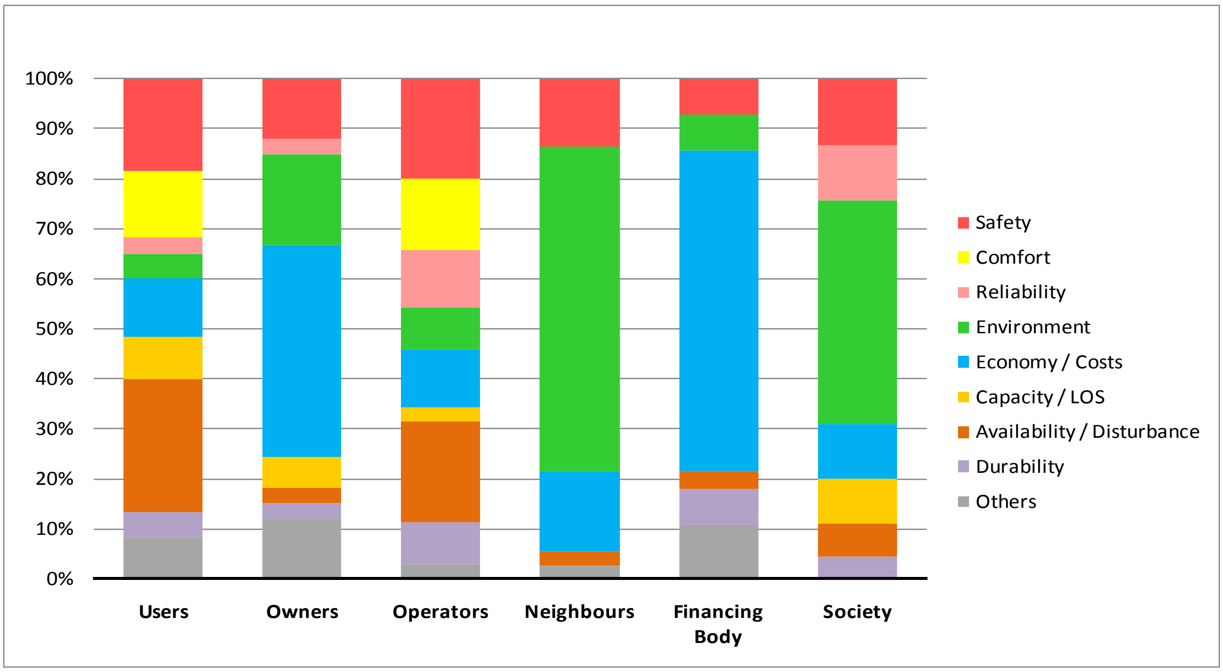

Figure EA3 - Who expects what?

And the last investigation was conducted to assess the channels used by the different stakeholders to express their expectations. Figure EA4 provides a synthesis of the answers.

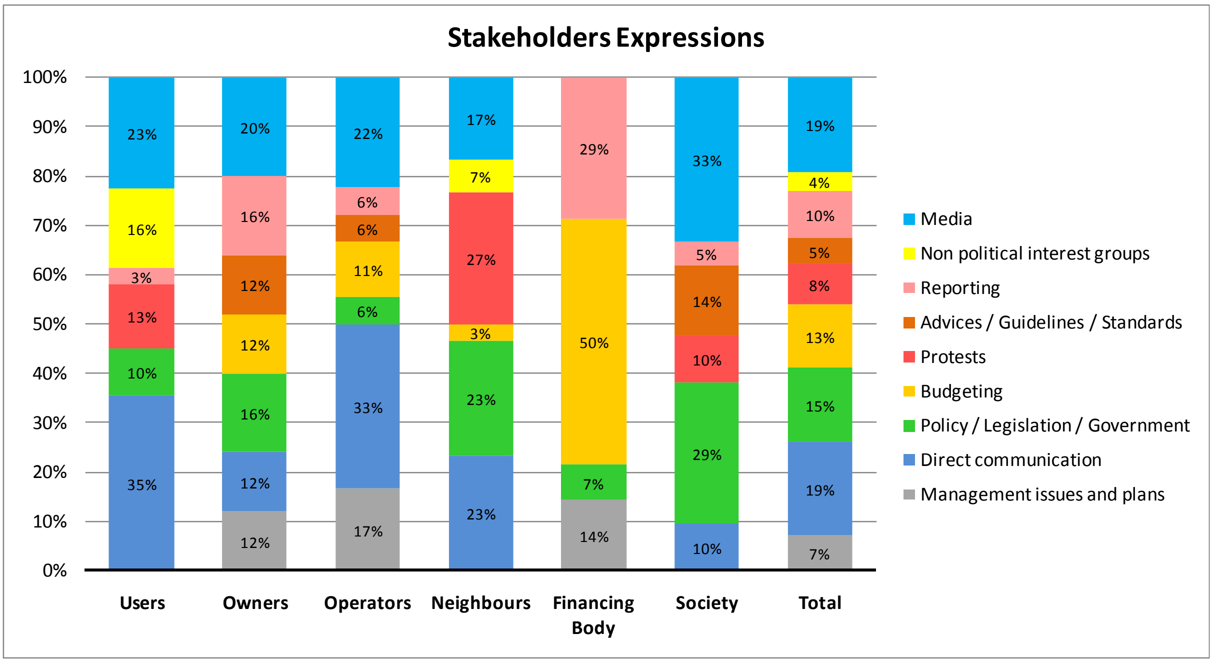

Figure EA4 – Channels of expression of the road stakeholder's expectations (numbers are not strictly accurate)

As far as environmental expectations are concerned, it appears that three channels are mainly used most often: 1) The media (TV and radio news, news papers, magazines…) regularly and rather systematically address the general subject of environment preservation; 2) Public policy and regulations certainly reflect this common concern. 3) Another important channel to express neighbor's expectations consists in the protests. This type of expression is generally more devoted to urgent, punctual (in time) and local problems. A fourth channel is identified as direct communication between the neighbors and the road authorities.

The need for environmental related E-KPIs was derived from the former inventory. The inventory of existing indicators 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, and some specific studies too, from COLAS, FINNRA, EEA… Based on this investigation a detailed assessment of existing E-KPIs was conducted comprising information about the topics

- 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 (1 E-KPI)

This work opens the road for the development of missing E-KPIs (WP3) and the implementation of them in Pavement and Asset Management Systems (WP4), which will be able to develop their contribution to EVITA.

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Environmental Indicators for the Total Road Infrastructure Assets

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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 starts 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 is completed by an inventory of the existing E-KPIs. In a second step, recommendations of different E-KPIs for the environmental areas "noise", "air and water" and "natural resources and greenhouse gas (GHG)" will be given. Beside the definition of E-KPIs for these three main categories, a recommendation for the implementation and the use of E-KPIs will be 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 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.

I.2 The Work Package 2

The second Work Package (WP) played a central role in the application of the stepwise approach proposed for EVITA: it 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 will be listed and organized and the impact of each of the asset types (pavements, structures, tunnels, etc.) will be classified for each expectation. The main contribution of the EVITA WP2 consisted in checking and completing the PIARC analysis, and in allocating each identified expectation to the stakeholder(s) that were mostly expressing it. A special interest was given to the expression of environmental expectations.

The need for environmental related E-KPIs was derived from the former inventory. These E-KPIs were spread in two categories: the existing E-KPIs and the lacking E-KPIs not dealt with later in the report. The inventory of existing indicators started from previous works, such as the one done in the COST 354 action, which was updated, for instance via complementary literature studies, questionnaires or interviews.

II - The different tools used in Work Package 2

Three different types of tools were used to inventory and classify the road stakeholders and their expectations: literature study, workshops, questionnaire and interviews.

II.1 The literature study

Surprisingly, there were not so many attempts made, in the past, to rationally and extensively inventory all road stakeholders and their expectations. Since decades and decades, road operators had been considered, and considered themselves, as the central actors of the road management, collecting and processing more or less informally the needs and expectations of all people concerned by road operations. The road users were recognised as primary and almost only road stakeholders. In France, where users associations such as Touring Club, were not very active, the expectations and requirements of users were mainly expressed by politicians, often under the pressure of media. Even fleet operators and other professional users (taxi and bus companies) met some difficulties to be directly ear by road operators, except when they were expressing via the two former channels (politician and media).

As a consequence, and until recently, road stakeholder's identification was not largely addressed in literature. The work initiated and conducted by PIARC, in the 2000's, appears to be one of the first rational and extensive approach of this problem. The last Technical Committee D1, on "Road Asset Management", specially addressed this problem from 2007 to 2011. The second Working Group of this TC ("Management Indicators") was in charge of identifying the so-called "High Level Management Indicators" (HLMI). A HLMI is an indicator which directly measures the quality of the answer a road asset is providing to a given stakeholder's expectation. In other words, it measures the level of service (in the broad meaning) of the network.

The final report of the TC D1.2 working group [1] proposes a methodology that every road authority can apply to identify the indicators it actually needs to correctly and efficiently report on the level of service of its network, and to build these indicators if they are not available in the literature or from other authorities. The two first steps of this methodology consist in 1) identifying all the stakeholders in road asset management and 2) analyzing, for each stakeholder, what are his concern(s) and his expectations in road asset management. Furthermore, in order to help the road authorities to apply this methodology, the report introduces detailed inputs, such as the definition of each category and sub-category of stakeholders and the list of their expectations.

II.2 The workshop

In February 2011, the EVITA team organized a workshop aiming at checking the findings from the literature study and, beyond that, at enlightening which expectations are expressed by which stakeholder(s), and how (by which channel). According to EVITA objective and program, the final goal of the workshop was to know which stakeholders are expressing environmental needs, requirements or expectations.

1 The workshop took place at the French Ministry of Ecology and Transport, in Paris - La Défense, France, on 2 February 2011. It was open to road

laboratories, operators (including toll motorway operators) and owners, road users (fleet operators), and governmental organizations that are dealing with the impact of transport on environment.

The workshop shortly addressed the SBAKPI project, a project conducted under the same ERAnet program. SBAKPI is complementary to EVITA, the former dealing with the socio-economic key performance indicators at the technical level, and all KPIs at the strategic level, when the latter is dealing with the environmental KPIs at the technical level. This EVITA workshop was an opportunity to inform the attendees about these complementarities. This opportunity was also seized to inform the participants about the PIARC D1.2 work and report, and the COST 354 action as well, to achieve a common level of understanding of these projects which bring some interesting inputs to EVITA and therefore, to the workshop.

During the items 5 and 7, a brain storming process was organized in two rounds: 1) What are the expectations of the different stakeholders and 2) How do the stakeholders express their expectations? Everybody, acting individually, listed on stickers the expectations – 1st round – he or she has (as a stakeholder) or he or she knows (from his or her contacts with stakeholders), and the way they expressed them – 2nd round –. The stickers were placed on a board under the stakeholders type they were concerning. At the end of the brainstorming, all the stickers were collected. They were processed later. The result of this work, including the process of the sticker, is given in appendix A.1. After the brain storming, a 3rd question was discussed: what is the role of road operators in the process of stakeholder expectation expression?

II.3 The questionnaire and interviews

To enlarge and strengthen the findings from the literature study and the workshop, a questionnaire was prepared. Using questionnaires is a somehow random process. A number of questionnaires are sent every year to road operators and other stakeholders. Only a few of them are answered, and the sample which answers is not necessarily representative of the full population of stakeholders. However, questionnaires may be useful if they are correctly interpreted: to collect new data or information; to check the completeness of those already gathered; to guide interview (see next paragraphs).

It was decided to use a questionnaire with these two objectives. In order to get more answers, the questionnaire was short and open. It consisted of two questions:

1 What environmental indicators are used in your country?
2 Please list, according to your opinion, environmental indicators for which there is a need

A framework was proposed to organise the answer per type of components of the road asset: pavement, bridge, equipments… The questionnaire was completed, after the workshop, by a third question. One histogram which composed the synthetic findings of this workshop was inserted in the questionnaire, and comments were asked about the results expressed by these figures. The questionnaire was sent to all PEB members. The questionnaire is attached to this report in appendix A.1.

Beside the collection of basic information in the context of workshops and the investigation of the actual literature, the Consortium decided to carry out interviews on national level with the environmental departments of the road administration authorities. This should help on the one hand to get detailed information about E-KPIs in use and on the other hand to find the areas where E-KPIs are missing at the moment. It was decided that the interviews will be carried out by the Project Team of the Consortium based on the former questionnaire. The output of these interviews was supposed to be an additional basis for the following up work in the context of the E-KPIs evaluation and selection process.

III - Identification and categorization of road stakeholders

After consideration of different sources, a first attempt for definition of stakeholders is suggested.

Road users

- **Daily users:** Persons who use road infrastructure very frequently as driver or passenger of a vehicle; its journey purpose may be: work, education or business.
- **Truck & Bus:** Transport service operators using road infrastructure. This sub-class identifies the public or private companies, whose aims are the transport of goods and persons.
- **Tourist:** This sub-class identifies persons that use road infrastructure occasionally for tourism purpose as drivers or passengers of vehicles.
- **Vulnerable user:** Cyclists using road infrastructure occasionally or frequently. Their journey purpose may be: work, education, entertainment, etc. Pedestrian, meaning persons moving by walking on road infrastructure occasionally or frequently.

Road neighbors

- **Resident:** Any person who lives along a road or a street.
- **Commercial business:** Any shop, any retail building which is located along a road or a street, whose entrances and exits are directly opened to the street.
- **Industries:** Any industrial facility, plant or other production site which have direct connection (entrances, exits) to the road network.
- **Users of public areas:** People who go or work in public place like schools, hospitals, administrative buildings, and more generally buildings which are opened to public

Financial institutions

- **Banks for development**: Financial organisms which provide the (generally developing) countries with loans to develop their economy. A part of these loans are allocated to the improvement, the development, even to the reconstruction of their road network, considered as an unavoidable tool for the economic development. The loans are decided after appropriate studies demonstrate the relevance of the investment which are planned with these budgets.
- **Shareholders**: Stakeholders which gather financial resources and invest them in a (road, in the present case) concession. Two categories of road shareholders can be identified:
    - Those who are only expecting a financial return on their investment, and manage this asset as any other investment;
    - Those who also expect an industrial return, especially the large Public Works companies which are looking for some synergy between their financial and industrial activities.
- **Public financing organisms**: Public organisms which invest financial resources in the development, the maintenance and the operation of road networks.
- **Insurance companies:** Companies involved in the business of providing protection against road accident risk.

Society

- **Developed countries:** The national community in all countries with a high level of prosperity.
- **Countries in (economic) transition:** The national community in all countries currently transforming drastically their economic organization.
- **Developing countries:** The national community in all rapidly transforming countries aiming at a global progress and rising prosperity.

Road owners

- **Public owners:** Strictly speaking, the owners of a public road network are the citizens. Practically, the owners are the legal representatives of these citizens. In accordance to this definition, the owners may be different entities, bodies, organizations depending on the road network they own. Usually for the national road networks the owner would be government or one of its bodies (e.g. Ministry for Transport), whereas in case of local road networks that would be local authority (e.g. municipality or one of its bodies, local council).
- **Private owners:** These stakeholders own the roads in the traditional sense of the word: they owned the ground on which the roads are constructed and the roads themselves since they entirely paid for their construction and maintenance. Forest and mining companies are private road owners. In some housing estates, the house holders may also own the streets.

Road operators

As previously said, the Road operators are also road stakeholders, but have no expectation from the network. Their role is to ensure the satisfaction of the other stakeholder's expectations. For completion of the work, the three sub-categories identified amongst road operators are listed below.

- **Road directorate**: Any service which assumes the management of a public road network. This means that it makes, in the name and with the agreement of the owner, all decisions regarding construction, extension, development, maintenance and operation on this network; its role is central, e.g. there is only one Road Directorate for a given network. This service reports to the network owner, the medium and long terms decisions of which it is preparing, including decisions dealing with the budget
- **Concessionaries:** Private and/or public organism to which the public authority delegates all or part of the financing, construction, extension, development, maintenance and operation of a road network, and which is allowed, in return for it, to directly collect toll near the Users or near the Owners. The respective missions and duties of the public authority and the concessionary are defined in a (long term) contract, which especially mentions the conceded network characteristics, the end of the concessionary, the level of toll and the rules to update it.
- **Local project managers**: Local services which locally execute the maintenance and operation decisions made by the Road Directorate (on public networks) or by the concessionary (on conceded networks). Districts may operate their own pieces of equipment, especially for the road operation missions.

The Road Operators are in charge of up dating all the functional and technical indicators. The Road Owners are using these indicators to inform all other stakeholders about the performance of the network regarding their different expectations.

Other road stakeholders

There are, in reality, other stakeholders that could be mentioned in the former inventory:

- **Organizations / companies** involved in road maintenance / construction / design
- **“Competitors” / alternatives**: other traffic branches: railways/air/water transports
- **Research organizations** on road & traffic
- **Education organizations** on road & traffic.

However, all these stakeholders are expecting “something” from the road management, but not from the road infrastructure itself. They expect to make businesses, to capture some traffic, some clients, to get some data or to learn some findings from road maintenance management. They are not expecting services from road networks. This is justifying the choice not to consider them in the present analysis.

This list of stakeholders is summarized in Figure 1, below.

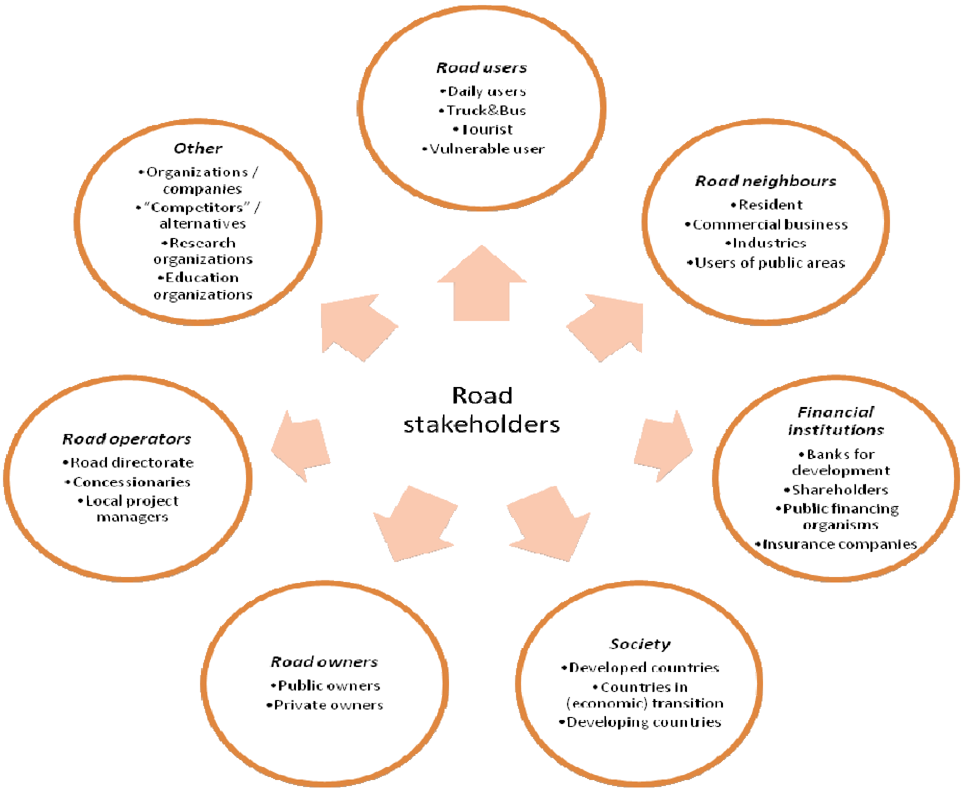

Figure 1 – Inventory of road stakeholders

IV - Expectations of road stakeholders

Basically, the road networks aim at constantly contributing to society development. In order to achieve this objective, they must efficiently operate. However, the experience proves that further requirements apply to road operations too: be safe, environment respectful and if possible, comfortable, cleanness and aesthetic. More and more often, some other aspects are considered in asset management, e.g. the respect of cultural or natural heritage.

As a part of EVITA project, the present report should mainly be focused on expectations related to environment preservation. However, considering all stakeholders’ expectations is the only possible approach to assess the diversity of the expectations that road operators are facing. It is therefore a basic requirement to situate the environmental expectations in the general context of road management, to assess their relative importance and priority.

Therefore, this chapter is organized in two parts:

- Expectations not dealing with environment preservation (e.g. operation efficiency, safety, road quality, socio-economic development, profitability), which are in the periphery of EVITA;
- Expectations dealing with environment preservation (sustainable development, human life framework), which are the core subject of EVITA.

IV.1 Expectations not dealing with environment

Expectations regarding operation efficiency

Operation efficiency is the basic, primary expectation from most road stakeholders, since it is the "reason of being" of the network. This efficiency clearly covers two main expectations: the travel time and the accessibility

- **Travel time:** Most users expect to spend as little time as possible from their origin to their destination (the so-called travel time). They would like to be able to run at maximum allowed speed always and everywhere. For that, road operators 1) regularly survey their infrastructures and perform maintenance roadworks, and 2) constantly look after the measures of traffic management which can maintain the traffic flow at the highest level, in any place at any time. The reliability, the regularity of travel time is also a significant component of users' expectation. This refers to the ability of road system to perform (level of service) and maintain its functions (traffic flow) in routine circumstances, as well as in unusual circumstances (e.g. accident, roadworks…).

- **Accessibility[1]:** Accessibility refers to the ease of reaching other zones or being reached from other zones (for road users). It also refers to the ease of accessing the road from private sites (homes, shops, industries) or reaching private sites from the road (for road neighbors). The settlement of economic activities is chosen taking into account the accessibility from potential clients or suppliers (Society expectation). Road operators have to consider these expectations in managing their network.

Expectations regarding safety

A safe road is a road with no harms (deaths, injuries and property damage). All stakeholders are expecting safe roads; all stakeholders are expecting "road safety". However, under this common and global wording, these stakeholders express different expectations, e.g.:

- **Road users** are potentially the first victims of harms. They expect that the road operators will take all appropriate measures on their networks to reduce the risks of accident, at least when they are driving "normally";
- **Neighbors** expect that the public domain (road) which is surrounding their homes, shops, offices, facilities will not constitute a danger for their relatives or for themselves;
- **Road operators** aim at avoiding on their network any accident in which their responsibility could be involved;
- The same applies to the **road owners**; but these ones are also sensitive to the pressure of public opinion (media, politicians) to reduce road accidents.

[1] "Accessibility" is preferred to "mobility" as it implies that all displacements have another objective than moving itself.

- The **financial institution** (mainly insurance companies) expects that the amount paid for damages of road accidents will decrease.
- Finally, road safety is a strong expectation of **Society** since the consequence of accident represents a significant economical loss.

Expectations regarding network quality

Road network must primarily offer an efficient and safe travel service. Comfort is also an expectation of users, who are ready to pay for that. Comfort, in the broad meaning, covers different expectations:

- **Riding comfort:** Travel comfort influences the perceptions of drivers regarding the Quality of Service. It is indirectly connected to level of service concept which was introduced in the Highway Capacity Manual.
- **Quality of service areas:** The frequency and quality of services areas along a route is more and more often integrated in the perception of the level of services by the users.
- **Travel information:** It is dealing with weather forecast, congestion, accident, on going interventions, etc. Quality of travel information depends on their actuality, reliability, clearness and usefulness. Guiding information is a special aspect of travel information.
- **Aesthetics and cleanness:** This comprise: quality of road side amenity and vegetation, aesthetic and architectural look, integration of infrastructure in its environment, cleanness, quality of street furniture, etc. In towns, neighbors are sensitive to the aesthetic and cleanness of the street they are using several times a day or they can see from their windows.

Expectations regarding Socio-economic development

- **Society's development:** Societies expect that roads contribute to the progress of social and economic activities, aiming at rising prosperity and the aggregation of satisfaction felt by all.
- **Socio-economic integration**: The road network should be more and more efficiently inserted and integrated in the whole network of ground transport (water born, rail, bicycle and walking). Development of intermodality is a growing expectation in terms of socio-economic development.

Expectations regarding network profitability

- **Return on investment (ROI)**: Private shareholders who invest in road network construction, maintenance and operation are expecting a return on their investment. The ROI is the benefit (return) of the investment divided by its cost. The benefit of the investment is the sum of the dividends produced by the investment and the potential proceed obtained from reselling the investment. This last term is in direct relation with the asset value which is related, to some extent, with the condition of the asset.
- **Risk on investment**: Before the investment is realized, the ROI (see above) is the result of a probabilistic estimate. The probability to get a certain level of ROI decreases as this level increases. The risk on investment is defined as the risk not to get the expected return.
- **Business growth opportunities**: Financial institutions investing in road network businesses (for instance, banks) are generally involved in other industrial and financial activities. Beside the direct financial incomes (toll incomes), the road networks may generate indirect returns, such as those resulting from a growth in the industrial businesses, or from a more cost-effective industrial activity. Financial institutions expect that investing in road network will maximize their overall profit.
- **Efficiency of management**: The efficiency of managers, on the view of the investing financial institutions, is a measure of their ability to produce the higher return on

investment, which is to produce the higher dividend and preserve the capital (the road condition) with the minimum expenses.

IV.2 Expectations dealing with environment

Expectations regarding sustainable development

- **Preserving environment:** A rather general definition of environment is provided by the PIARC dictionary: "The circumstances, objects, or conditions by which one is surrounded". Preserving the natural context consisting of avoiding that the road transport modifies in a negative and (quasi-) irreversible way air, water, noise, fauna, flora. In other words, it aims at limiting the direct and negative influence of human activity – here, road transport – on the environment.
  It is noted that the environment tends to be perceived differently by the administrations, which often give priority to the technical aspects (water, air, waste, nuisance, ecosystems) and by the community-at-large which tends to think of the quality of life and nature. These differences in perception of the environment concept have been reported in a number of countries. A study by the Euro-Mediterranean Centre for Environment shows that the word environment means living environment for executives and professionals, towns and traffic for artisans and traders, nature for salaried workers, pollution for industrialists, and neighborhood for farmers.
- **Preserving (natural) resources:** Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs, which in particular includes the preservation of (natural) resources such as quality aggregates, bitumen, but also water...
- **Not contributing to Climate change:** Climate change is defined as "alteration due to human activity, of the complex web of systems that allow life to thrive on earth, such as cloud cover, rainfall, wind patterns and ocean currents, also influencing the distribution of plant and animal species." (This is rather the indirect influence of human activity on the environment).
- **Taking care of Public Health:** Care for the global level of health of the whole population. The impact of road transport on public health is an important component of the impact on environment. This is why it is explicitly mentioned here.

Expectations regarding human life framework

- **Heritage preservation:** It expresses the new worry of actual generation to transmit to the next generation a direct access to their historical asset including the local social and cultural patrimony. In other words, it expresses the expectation that the negative impacts of human activity on the patrimony generated by previous and current human generations will be contained at an acceptable level.
- **Natural disasters prevention and rescue:** Natural disasters are defined as situations or events arising from nature, which overwhelms local capacity, necessitating a request to national or international level for external assistance, an unforeseen and often sudden event that causes great damage, destruction and human suffering. Road network have an active and passive role in natural disasters; on one hand anarchic development of infrastructures may destabilize natural equilibrium, and contribute to generate natural disasters such as water flooding in cities, land slides… Conversely, roads play a major part in rescue organization as they allow the relief to arrive at disaster areas. Therefore vulnerability (i.e. how much natural disaster may effect road operating conditions) of key road itineraries to natural disasters is a key point of road management.

This inventory of stakeholder's expectations is summarized in Figure 2, next page.

V - Expression of expectations by stakeholders

The EVITA project objective is to identify – or develop when necessary – Environmental-KPIs. To meet this objective, the EVITA consortium had to answer several questions, which should provide a first basis for the definition of the E-KPIs. These questions, which are listed below, focus on the one hand to the different stakeholders and on the other hand to different expectations for a modern road infrastructure asset in Europe. In accordance with the discussions in the ENR project SBAKPI the following questions were raised within EVITA

- Which stakeholders are strongly expressing this type of expectations?
- How do they express them?
- Which kind of answer are they expecting?

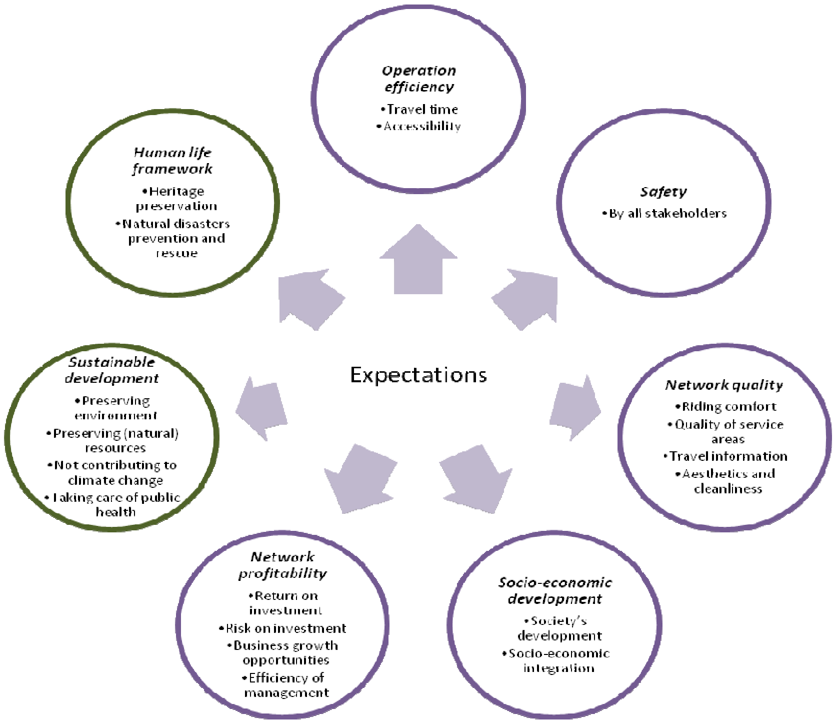

Figure 2 – Inventory of road stakeholder's expectations

All three questions were provided and discussed with different stakeholders from different European countries within a workshop on the 2nd of February 2011 in Paris. This was an opportunity for the EVITA partners to meet road operators, industrial fleet operators, environment and socio-economic experts. The minutes of this workshop are attached in appendix A.2. The detailed outputs of this workshop are listed in appendix A.3.
In the following chapters the answers of these questions and the following up discussions are explained in detail.

V.1 Which stakeholders are expressing what expectations?

The first question focuses directly to the expectations of the different stakeholders for the road infrastructure assets. All answers were collected within the workshop and categorized afterwards into 9 different areas or objectives respectively. These areas / objectives are as follows:

- Safety
- Comfort
- Reliability
- Environment
- Economy / Costs
- Capacity / LOS (level of service / HCM)
- Availability / Disturbance
- Durability
- Others

The main findings of the answers are displayed in Figure 1. It can be seen that the environmental aspect of the road infrastructure is mainly related to the expectation of the Neighbors and the Society. The results underline the importance of the environmental theme for the Neighbors, which are directly affected by environmental impacts caused by traffic. Furthermore, Figure 3 shows that environment is a main topic for the whole Society.

For the other stakeholders, who are listed and described above, the environmental aspect exists, but is not the main topic according to their expectations.

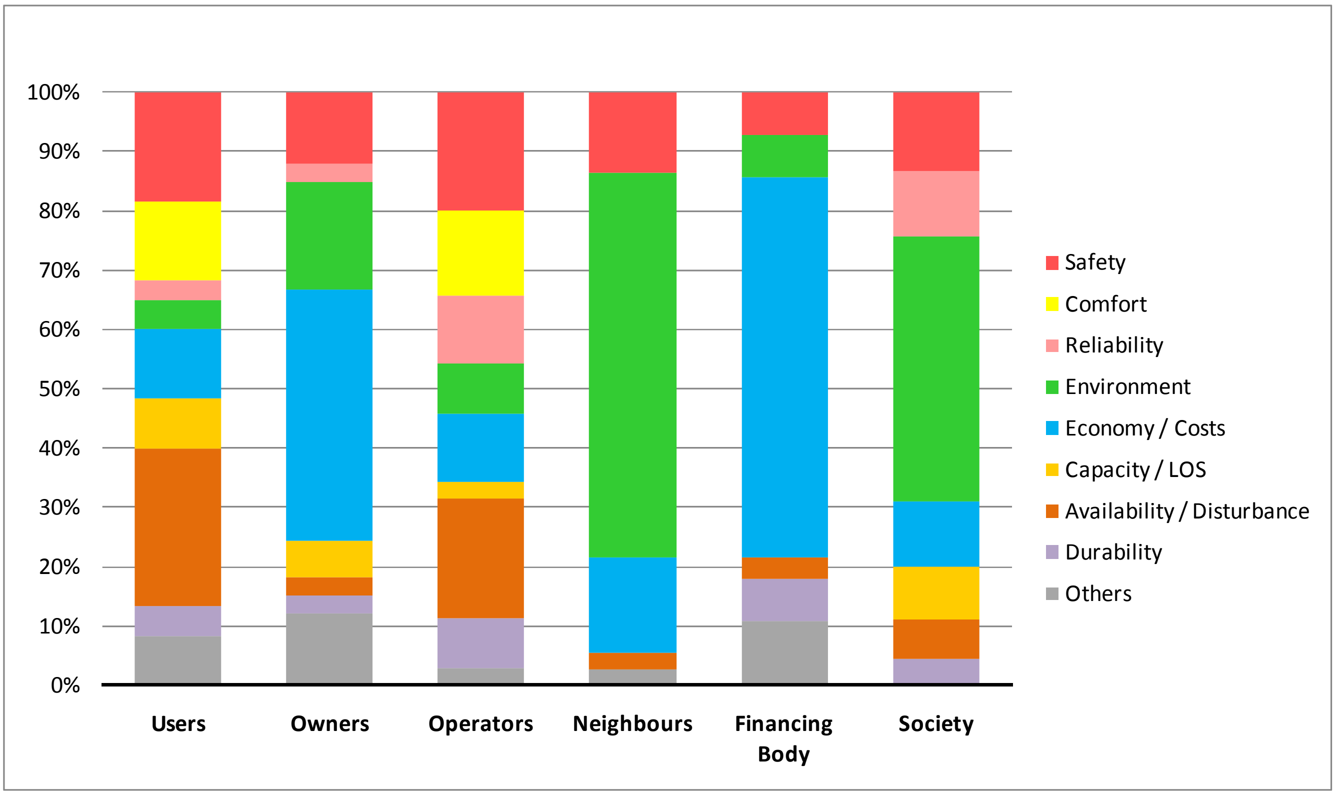

Figure 3 - Stakeholders Expectations Distribution

Information about the expectations expressed by the stakeholders can also be found in the literature, especially in the PIARC report D1.2 [1]. According to this report, the stakeholders express in priority the following expectations:

Road users

- **Daily users**: Safety, travel time, reliability, accessibility, parking facilities, riding comfort
- **Truck & Bus**: Travel time, reliability, consumption, quality of service
- **Tourist**: quality of service, information, aesthetic and cleanness
- **Vulnerable user**: Safety, riding comfort

Road neighbors

- **Resident**: Accessibility, parking facilities, information, environment preservation, public health
- **Commercial business**: Accessibility, parking facilities
- **Industries**: Accessibility
- **Users of public areas**: Safety, accessibility, parking facilities, environment preservation, public health

Financial institutions

- **Banks for development**: Socio-economic efficiency, business growth opportunities
- **Shareholders**: Return and risk on investments
- **Public financing organisms**: Socio-economic efficiency, business growth opportunities
- **Insurance companies**: Safety

Society

- **Developed countries**: Society development, Socio-economic efficiency, environment preservation, natural resources preservation, no contribution to climate change, public health
- **Countries in (economic) transition**: Society development, Socio-economic efficiency
- **Developing countries**: Society development, Socio-economic efficiency

Comparing these two sources of information it is clear that the impact of road infrastructures on environment is mainly a worry of 1) the neighbors; 2) The society and 3) the owners

1. Neighbors (mainly residents) are mainly worrying about the noise emissions, the preservation of the environment, of the frame of life, and about the compliances with the requirements of public health (their health).
2. Society (mainly the industrialized countries) are concerned by several aspects of environment preservation: natural resources preservation, no contribution to climate change, public health
3. Public owners feel concerned by environment preservation in the sense that they have to manage their image to the public and the Society.

As already mentioned, the Neighbors are the main affected stakeholders for negative environmental impacts, followed by the Society and the (public) Owners. Thus, the selection of adequate E-KPIs will be strongly related to their expectations. Especially for the combination of single indices to combined and finally to a global E-KPI these results will influence the combination procedures and algorithm respectively (e.g. weighting factors).

The output of this investigation clearly underlines the necessity for the definition of E-KPIs of the total road infrastructure asset.

V.2 Complement from questionnaire and interviews

Although the questionnaire was spread into the whole consortium, there were only very few answers received. It was then decided to conduct additional personal interviews in the countries of the consortium members. For time reasons these could not be included into this report, but will be evaluated within the WP3-report.

The German Road Directorate indicated that (as far as environment is concerned, of course) they are using indicators to quantify noise emissions, air pollution, soil and water pollution, and GHG emissions. Furthermore, as far as GHG emissions are concerned, the indicators are oriented towards Society, users, operators and financing institutions. More generally, demands based on European Legislation are taken into account by national regulations.

The Slovene DDC Company provides some answers too. They are focusing on air pollution and GHG emissions. Regarding air pollution, the structure of emissions is indicated by individual substances:

- Acidifying substances: sulphur dioxide (SO2), nitrogen oxides (NOx) and ammonia (NH3)
- Ozone precursors: They are substances contributing to the formation of ground-level (tropospheric) ozone. The ozone precursors include: nitrogen oxides (NOx), carbon monoxide (CO), methane (CH4) and non-methane volatile organic compounds (NMVOC).
- Particles: Particulate emissions can be subdivided into primary particulates PM10 (particulates with a diameter of 10 μm or less, which are directly emitted to air) and secondary particulates PM10 or particulate precursors (part of emissions of NOx, SO2 and NH3, which are as a result of photochemical reactions transformed into particulates with a diameter of 10 μm or less).

Regarding GHG emissions, the Kyoto Protocol considers six pollutants from the GHG group; namely carbon dioxide (CO_2), methane (CH_4), dinitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF_6). Due to comparability, the GHG amounts are calculated to a CO_2 equivalent that considers the differences between the global warming potential of individual gases.

The Irish Road Directorate provided the consortium with answers too:

- Noise emissions are quantified by the 60 dB L_{den} indicators at nearest noise sensitive location; the stakeholders concerned are neighbours;
- EU Air quality standards for Nitrogen Dioxide and Fine particulates (PM10 and PM2.5); the stakeholders concerned are neighbours;
- For water pollution, drinking water quality standards are applied; the stakeholders concerned are neighbours, Society and operators;
- For GHG, NRA is using monetised CO_2 concentrations; the stakeholders who are targeted are users, operators, Society and financing organisms (the same as in Germany).

The Portuguese Road Administration indicates the use of environmental indicators related to noise (L_{den} and L_n), air pollution (NO2 and PM10), soil and water pollution (heavy metals and other pollutants) and GHG emissions (CO). Non-renewable resource consumption is considered in construction works, through the percentage of recycled materials and the consumption of energy, fuel and water.

The French Ministry provided some information, according to which some organisms such as CITEPA (http://www.citepa.org) are contracted by the Public Authorities to follow up the air pollution level and issue some periodical report. They are measuring a lot of indicators and their evolution (Figure 4). However, there is no evidence that the proportion of pollutant generated by the traffic itself can be assessed.

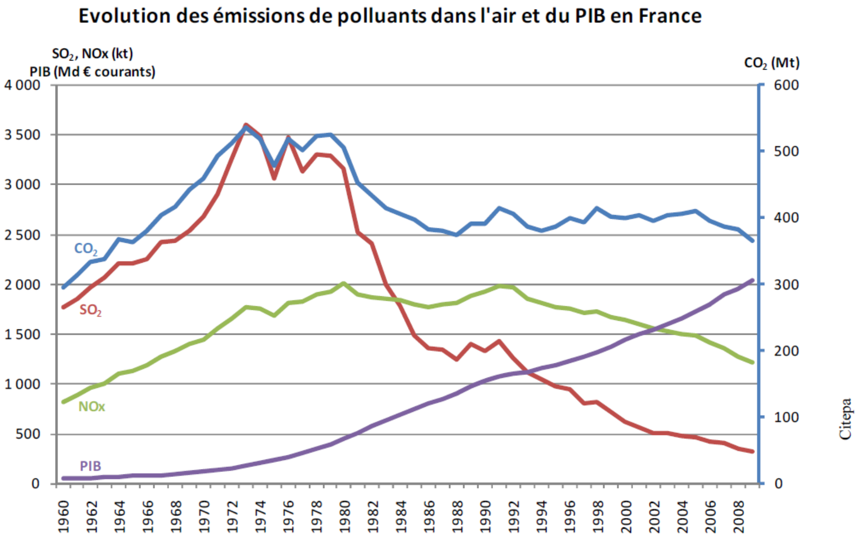

Figure 4 – Indicator followed by CITEPA

There are too few answers to draw very general conclusions from this first inventory of indicators – except that the road operators are several time mentioned instead of the road owners, but this can be understood as a confusion between both wordings –, but the answers seem quite consistent with the first statements derived from the first EVITA workshop and the PIARC report.

V.3 How these stakeholders express their expectations?

This question was also discussed during the first workshop in detail. Figure 5 reflects the answers which were collected at that time. The answers were categorized into 9 different groups, which represents the methods how the different stakeholders express their expectations. These are as follows:

- Media
- Non political interest groups
- Reporting
- Advices, guidelines, standards
- Protests
- Budgeting
- Policy / legislation / government
- Direct communication
- Management issues an plans

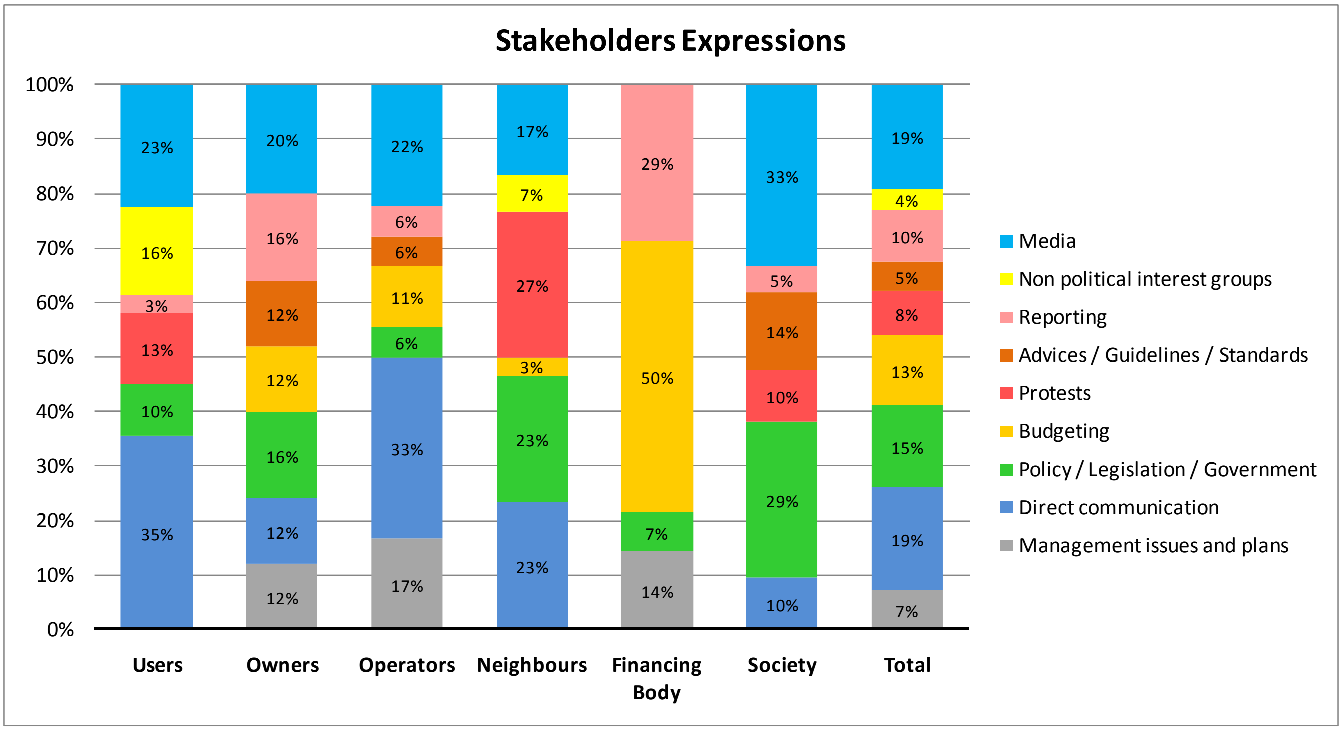

Figure 5 – Stakeholders expression

As far as environment expectations are concerned, and specifically their expression by Society and neighbors, three channels are clearly used most often:

- The media (TV and radio news, newspapers, magazines…) regularly and rather systematically address the general subject of environment preservation. The impact of road infrastructure on environment is one of the recurrent questions – but not the first one - of these types of news and analysis, beside renewable energies. One can think that this subject is regularly addressed in the media because Society (all of us together) feel concerned.
- Public policy and regulations certainly reflect this common concern. To some extent, they are answers brought by the Society to its own expectations, as expressed by media. But they can also result from more direct expression, such as the percentage of votes collected by the ecologic parties at elections, or simply the discussions between citizens and politicians in pre-election meetings.
- Another important channel to express neighbor's expectations consists in the protests. This type of expression is generally more devoted to urgent, punctual (in time) and local problems. Protests organized by neighbors against road infrastructures are mainly triggered by safety problems or health risk. Noise generated by road transport is also a core message of public protests. Such expression is very often relayed by media.

A fourth channel is identified as direct communication between the neighbors and the road authorities. This consists in letters, mails and phone calls from the neighbors to the road authorities, to protest against a specific disturbance due to the traffic on their daily life.

In correlation with the results of the stakeholders expectations the answers from the Neighbors, the Society and the Owners are the essential input for the following up work. E-KPIs should help these stakeholders to express their expectations in a more objective and finally effective way. Harmonized E-KPIs should simplify the communication between the different stakeholders and help to understand and assess the local but also the strategic situation. E.g. for non-technicians an index on a scale from 0 (very good) to 5 (very poor) is easier to understand in comparison to a technical parameter with a complex unit (e.g. ppm). Thus, an objective of EVITA is to define representative E-KPIs as an understandable and reproducible value for the communication between and to the different stakeholders on both, strategic (see also SBAKPI) and local level.

V.4 Which kinds of answers are expected?

As a general statement, the environmental effects of road networks should probably be handled at least in two different ways:

- Local effects: They mainly concern a limited number of stakeholders, the neighbors, which expressed very practical demands, expecting some short term answers. Reducing traffic noise, reducing air and water pollutions, are the main example of this type of expectations;
- Global effects: They concern the Society as a whole, with more theoretical demands, but not "here and today". GHG reduction illustrates this type of expectations.

However, when neighbors are protesting against a too dense and noisy traffic crossing a town, they are asking for the construction of a diversion, which is a medium or long term project.

As previously indicated, the answers to Society expectations, which are expressed or relayed in media, consist of policy and regulation. Reduction of Green House effect can only be managed at the higher political levels, at least at the continental level, but more efficiently by worldwide agreements. The Kyoto protocol illustrates the agreement that can result from the wishes of developed country governments to answer the Society expectations. At the same time, it illustrates the difficulties encountered by these governments to progress on these topics. Reductions of noises as well as preservation of public heath are treated at national or continental level. The European directive on noise maps is one of the measures that comply with this type of expectations. Reduction of gas and particles emissions can be managed at the local or national levels. The bonus given to greener vehicles, the restrictions of circulation to green cars are some examples of this type of measures. Therefore, a general statement about these long term answers to Society expectations is that they are much more relevant from political authorities than from road authorities.

Neighbors expressed through protests and/or direct communications some requirements which are more punctual, more local. If the construction of a diversion to avoid transit traffic in the center of a town – a medium term measure – is a decision shared by political and road authorities, the installation of noise protection walls or more silent wearing courses, for instance, is mainly under the responsibilities of the road administrations.

V.5 Synthesis and consequences on the indicators

Environmental Key Performance Indicators (E-KPIs) should be designed to quantify the quality of the answers which are brought to the E-expectations from the Society, the Neighbors and, to some extent, the Owners. Figure 6 displays the role and position of indicators within the relationships between the stakeholders which are primarily concerned by the environmental issues.

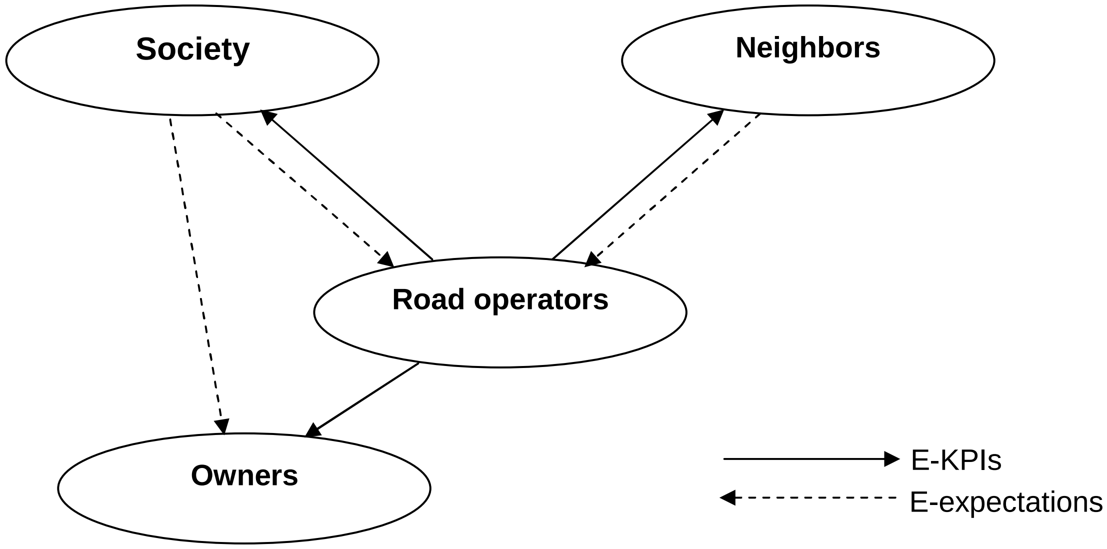

Figure 6 – Relationship between stakeholders: E-expectations and E-KPIs

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 planed, and their efficiency. Finally, a first list of necessary E-KPIs can be derived from the previous chapters (see table 1).

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

As a final note of this paragraph, it is important to underline that, since indicators are basically a scale on which the answers to stakeholders expectations are measured, they can be used to meet different objectives:

- Specification of measurable goals / standards
- Evaluation of difference (backlog) between goals/standards and actual condition
- Forecasts connected to allocation of resources & planning of measures
- Monitoring and reporting of the development.

The use of the indicators should be carefully considered when selecting or proposing new indicators.

VI - The existing E-KPIs

VI.1 Recommended definitions and general approach

As already described in the previous chapters the E-KPIs, which will be defined in the EVITA project, should provide an objective and comprehensive basis for the technical assessment of the environmental situation of road infrastructure assets, but also to improve the communication between the different stakeholders on different decision levels (local/technical to strategic).

Based on the positive experiences within the COST354 project [2] and the possibility to integrate the environmental aspect into a full holistic assessment process, the recommended general approach will be based upon the method of COST354. In the following Figure 7 the process for the assessment of characteristics of road infrastructure assets is schematically shown.

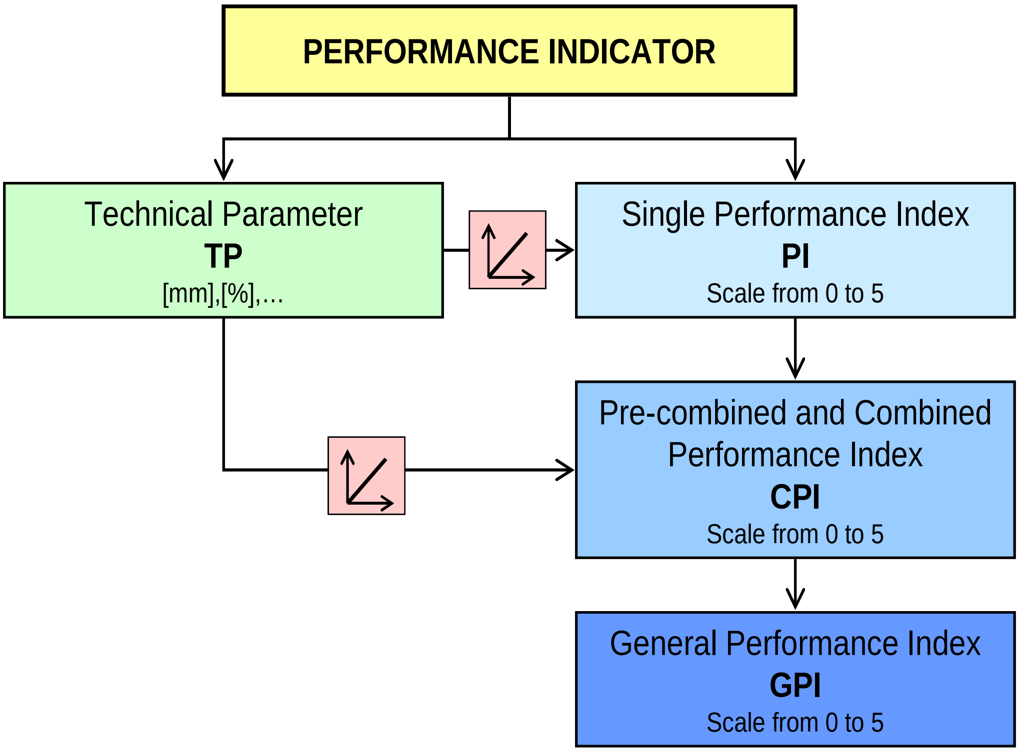

Figure 7 – Overview of the development of performance indicators in the COST 354 action [2]

With regard to COST354, **Performance Indicator** is used as a superior term of a technical road characteristic that indicates the condition / situation of it. It can be expressed in the form of a **Technical Parameter (TP)** (dimensional) and/or in the form of an Index (dimensionless). The Technical Parameter is a physical characteristic of the road, derived from various measurements, collected by other forms of investigation, or calculated from theoretical models (e.g. noise propagation calculation). For the transformation of the Technical Parameter into the dimensionless **Performance Index (PI)**, **Transformation Functions** or Transformation Processes will be used. The methods or types for the transformation are explained in detail below. The output of the Transformation will be the Performance Index, which can be defined as an assessed Technical Parameter of the road in the form of an dimensionless number, or letter on a scale that evaluates the Technical Parameter involved on a 0 to 5 scale, 0 being a very good condition/situation and 5 a very poor one.

Based on a unified classification it is possible to combine different indices into **Combined Indices (CPI)** and finally into a **General Performance Index (GPI)**.

Within COST354 the critical step in the assessment process was the transformation of the Technical Parameter into the dimensionless Index. Many Performance Indicators for pavements use a simple linear function to transfer the Technical Parameter into the Index. The functions to be used are usually dependent on the type of the Technical Parameter and the field of application (e.g. stronger assessment on roads with higher importance). Nevertheless, this simple method enables the user to create or apply an assessment process without complex analysis of the input parameters.

In comparison to pavements the assessment of Technical Parameters for environmental aspects can be an easier, but also a more complex approach. In many cases only a yes/no or fulfilled/not-fulfilled answer is the output of the full assessment process. In these cases it will not be possible to set an Index to 1, 2 or 3. It will only be 0 or 5. In other cases more than one Technical Parameter must be used for the assessment process, so that the transformation is an n-dimensional problem. The most complex situation will be where beside Technical Parameters, an (engineering) assessment of a complex situation must be taken into consideration.

Based on the investigations and the experiences of the experts in the Consortium the following transformation types of E-TPs (Environmental Technical Parameters) into an Index could be found.

- **Discrete Transformation Function**
  The transformation is based on a discrete (discontinuous) correlation between the Technical Parameter and the Index.

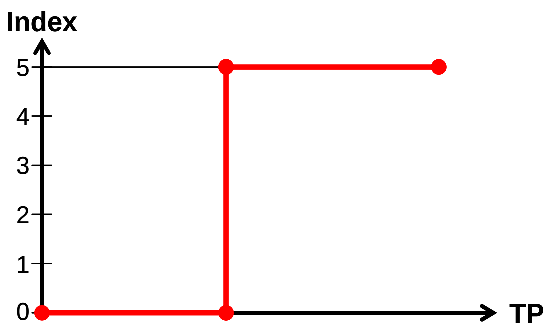

Figure 8 – Discrete Transformation Function (schematic)

- **Continuous Transformation Function**
  The transformation will be carried out by a continuous mathematical function representing the correlation between the Technical Parameter and the Index.

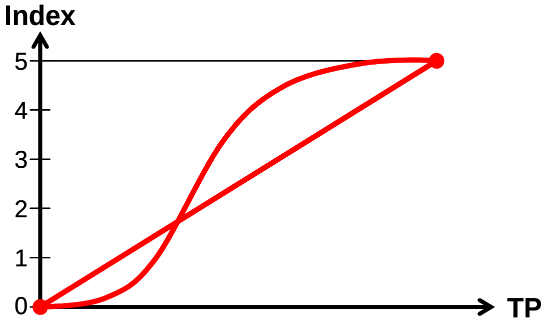

Figure 9 – Continuous Transformation Function (schematic)

- **Complex Transformation Function**
  The transformation will be carried out by a complex n-dimensional correlation between n different Technical Parameters / Coefficients and the Index.

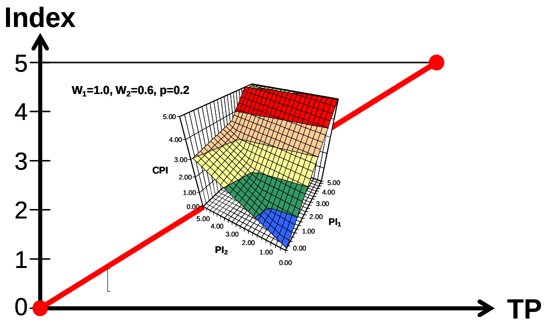

Figure 9 – Continuous Transformation Function (schematic)

- **Spatial Transformation Function**
  The transformation will be carried out in form of a spatial assessment of the correlation between 1 or n different Technical Parameters / Coefficients and the Index.

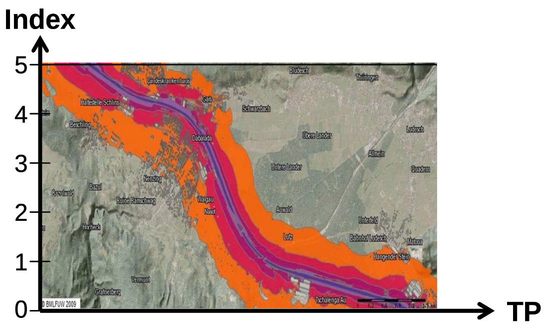

Figure 9 – Continuous Transformation Function (schematic)

The next step in the process is the definition of Combined Performance Indices, derived from the single PIs. The objective of each Combined Environmental Performance Index (E-CPI) is to characterize the contribution of each environmental area to the total environmental situation or performance respectively of the road infrastructure asset.

At the highest level in the assessment of the environmental performance is the calculation of the General Environmental Performance Indicator (E-GPI). The GPI is a mathematical combination of single and/or combined indicators which gives a first impression of the overall environmental situation at network level, and enables badly performing sections to be identified. By using this information a general design or maintenance strategy can be derived. Consequently the general indicator is a useful tool for decision-makers to assess the environmental condition of the network and to evaluate future strategies

In comparison to COST354 where the Technical Parameters and Indices have been related to the pavements only, the E-KPIs will and must go beyond the reference to single sub-asset. E-KPIs should represent the environmental performance of a road section, of a partial road network or of the whole road network. Of course, the environmental performance is strongly dependent on the number and types of different sub-assets. But the E-KPIs should represent the overall situation in form a cumulated value of all single parameters to be found on the section, the partial road network or the total road network.

Independently from the environmental area the described general assessment process will be the recommended approach for the use of technical E-KPIs for the total road infrastructure assets and thus the basis for the following up work in this project.

VI.2 Identification of the existing E-KPIs

Identification of the existing E-KPIs was conducted in two steps. In the first phase a comprehensive literature review is conducted to identify existing technical E-KPIs from COST 354 database, from literature and from actual research projects. In the second phase those indicators which were identified as parameters of interest for EVITA are assessed according to the set of criteria.

The first step included a review of the FP7 and COST research projects, Life Cycle Assessment (LCA) tools and rating systems, European Environmental Agency (EEA) reports and other projects and available documents. The objective was to identify technical environmental indicators and corresponding technical parameters.

The review is presented through a set of tables where indicators are sorted by area and domain. Area of interest for EVITA project related to the environmental issues are identified in the project proposal and they are marked as follows: noise (N), air pollution (A), water pollution (W), natural resources (R), and Greenhouse gases (G). Since the EVITA's environmental areas can be different from those specified in the selected projects in terms of terminology, project's selected environmental domains are presented in the column "Domain" next to the associated column with EVITA "Area". Only indicators which are related to the project level and are technical, i.e. can be measured and monitored, are selected for the further assessment (grey area). Column "Assessment ID" specifies the code under which the indicator is labeled and assessed later in the report. First letter defines the environmental area, as mentioned above, followed by the associated number.

Several literature sources with redundant information are omitted from this review.

COST 350 - Integrated assessment of environmental impact of traffic and transport infrastructure

COST Action 350 [3] gathered scientists, engineers and biologists from 20 European countries. Project has been started in 2001 and completed in 2006. The objective was to develop a framework for the assessment and integration of environmental impacts that traffic and transport infrastructure has. The target level of decision making process is the planning phase related to the four geographical levels: national, regional, local and corridor. Environmental indicators were used as impact parameters for evaluation of effects of transport plans and programs. In total, 17 impacts were considered in the projects and each one is associated with one indicator (table 2).

Table 2. Summary of environmental indicators from COST 350

EVITA Area	Domain	Indicator/Parameter	Level of applicability			Technical	Assessment ID
			Strategic	Program	Project		
N/A	Biodiversity, Fauna and Flora, Landscape, Population	Natural habitat area lost Domestic and recreation area lost Sealed area	X	X	X		
		Threats to populations of (representative) target species	X	X	X		
		Emission of photochemical pollutants	X	X			
		Number of people or protected areas exposed to toxic or exotoxic pollutant immission exceeding standards of heavy metals (Cu), persistent organic compounds (POC), particulates, NO_x, SO_x		X	X		
		Number of killed, seriously or slightly injured persons due to accidents	X	X	X		
		Claim of valuable areas x impact magnitude	X	X	X		
		Emission of pollutants with eutrophication potential		X	X		
		Area affected, species lost, people affected, cost of water supply		X	X		
Air pollution	Air, Soil and Water	Emission of pollutants with acidification potential	X	X	X		
		Sensitive pollution		X			
Natural resources	Material resources	Consumption of non-renewable raw materials and recycling of waste in construction	X	X	X	X	R1
		Use of fossil fuels/renewable energy	X		X	X	R2
Water pollution	Soil and Water	Concentration of lead, PAH, pesticides, and salt in soil		X	X	X	W1 W2 W3
		Concentration of oil derivatives, pesticides and salt in surface water	X	X	X	X	W1 W2 W3
		Probability of accidents causing ecological catastrophes within vulnerable areas	X	X			
Noise	Population	Number of people affected by noise level oversteps or proximity of sensitive habitats	X	X	X		
Greenhouse gases	Climate change	CO_2 emission	X	X		X	G1

COST 351 – WATMOVE – Water Movements in Road Pavements and Embankments

COST Action 351 [4] dealt with different aspects of water impact on pavement and embankment structures. One part of the project dealt with sources of water pollution and different techniques to estimate the concentration of pollutants. This includes measurement of electrical conductivity, ph, and water chemical analysis. However, no specific indicators are used in the project that can be used in the road asset management.

COST 354 - Performance Indicators for Road Pavements

COST Action 354 [2] dealt with functional and structural performance indicators for road pavements. One of basic objectives was to identify suitable performance indicators for noise and air pollution and based on them develop combined environmental performance indicator. However, based on the extensive questionnaire on the state of practice in participating countries there was insufficient data at the moment for their use in this COST action. It was concluded that these indices may be added at a later date, once more research has been carried out.

COST 356 - Indicators of Environmental Sustainability in Transport

Research activities in the COST 356 Action [5] involved scientists from 20 European countries from 2005 till 2010 when the project was completed. Main objective of the COST 356 Action was to provide assistance to the methods of the designing process for building better environmental impact indicators based on the existing knowledge and to integrate those indicators into the decision making processes related to the transport sector.

A summary of the environmental indicators used in COST Action 356 are presented in table 3.

Sustainable Road Surfaces for Traffic Noise Control – SILVIA

Project SILVIA [6, 7] was initiated by FEHRL with the purpose of investigating low noise road surfaces as a mean of road traffic noise reduction and deriving the full benefit from this type of noise control. From 2002 till 2005, 15 partners with the leadership of the Belgian Road Research Centre worked on the project which objective was to develop a tool for decision-makers which will allow rational planning of traffic noise control measures with the focus on low-noise road surfaces. The final product was the “Guidance Manual for the implementation of Low-Noise Road Surfaces” with the associated excel based tool for the cost-benefit analysis. The final report summarizes different domains of traffic noise topics starting from the sources of vehicle and tire/road noise, existing and, at the time, surfaces under development, performance specifications of low-noise surfaces and cost benefit analysis.

Assessing the advantages and disadvantages of porous asphalt compared with the standard dense asphalts or concrete pavements, water pollution was one of topics covered within the SILVIA project. In the report regarding this issue, main pollutants from highways which appear in the run-off water were identified as well as their primary sources.

The summary of environmental indexes used in SILVIA is presented in table 4.

Table 3. Summary of environmental indicators from COST 356

Area	Domain	Indicator/Parameter	Level of applicability: Strategic	Program	Project	Technical	Assessment ID
Air pollution	Air pollution	Pollutant emissions PM_{10}		X			
Natural resources	Non-renewable resources	Indicators based on energy and mass	X				
		Indicators based on the relationship between use and deposits	X				
		Indicators based on the future consequences of resource extractions	X				
		Indicators based on energy consumption and entropy production	X				
		Indicators based on the marginal increase in costs due to the extraction of a resource	X				
	Waste	Waste from road vehicles (number and treatment of used tires)	X				
		Physical composition (%)	X			X	
		Tons of waste products used for biofuel or biodiesel production	X			X	
		Waste generated in the process (ton/ton)	X			X	
		Waste water generated by the biofuel process (m^3/ton)	X			X	
		BOD loadings to land or water (ton/year)	X			X	
		Tons of waste generated per ha cultivated (pertaining to the biofuel production)	X			X	
		Volume of pavement waste to landfill			X	X	R1
		Number of vehicles scrapped, quantity of various materials in vehicle	X			X	
		Quantity of used motor oil improperly disposed	X			X	
		Quantity of used tires landfilled or stockpiled	X			X	
		Quantity of lead-acid batteries discarded into municipal waste stream	X			X	
		Amount of waste produced by scrap cars	X			X	
		Number of vehicles scrapped, quantity of various materials in vehicle, percentage of mass landfilled	X			X	
		Number of motor vehicles disused annually (number of end-of-life vehicles)	X			X	
		Quantity of waste disposed (tone or m^3 per day or year)	X			X	
		Volume of waste illegally dumped per year	X			X	
		Volume of waste entering unpermitted landfills per year	X			X	

Table 3. Summary of environmental indicators from COST 356 (cont'd)

Area	Domain	Indicator/Parameter	Level of applicability: Strategic	Program	Project	Technical	Assessment ID
Noise	Noise	Equivalent Level $L_{eq,h}$			X	X	N1
		Maximum level $L_{\max}$			X	X	N1
		Minimum level $L_{\min}$			X	X	N1
		Statistical level L_{xx}			X	X	N1
		Sound exposure level SEL			X	X	N1
		Traffic noise index TNI			X	X	*
		Noise pollution level NPL			X	X	*
		CRTN			X	X	N1
		Day-Night equivalent level DNL	X	X	X	X	N2
		Day-Evening-Night equivalent level DENL	X	X	X	X	N2
		Night level L_{night}	X	X	X	X	N3
		km^2 of territory with $L_{den} > L_{den,\lim it}$	X				
		km of infrastructure with $L_{den} > L_{den,\lim it}$	X				
		km^2 of territory with $L_n > L_{n,\lim it}$	X				
		km of infrastructure with $L_{den} > L_{den,\lim it}$	X				
		% of people exposed to $55 < L_{den} < 65dB(A)$	X				
		% of people exposed to $65 < L_{den} < 75dB(A)$	X				
		% of people exposed to $L_{den} > 75dB(A)$	X				
		Population having access to quiet areas (within 500m of residence)	X				
Greenhouse gases	Greenhouse effect	Global Warming Potential (GWP)	X				
		Global Damage Potential (GDP)	X				
		Global Cost Potential	X				
		Global Temperature Change Potential (GTP)	X				
		Carbon Dioxide Equivalent Warming Number (CEWN)	X				
		Indicator of health impact due to greenhouse effect	X				

* - not in use

Table 4. Summary of environmental indicators from SILVIA

Area	Domain	Indicator/Parameter	Level of applicability			Technical	Assessment ID
			Strategic	Program	Project		
Noise	Noise	Equivalent continuous sound level $L_{Aeq,T}$			X	X	N1
		Day-Evening-Night level L_{den}	X	X	X	X	N2
		Night level L_{night}	X	X	X	X	N3
Water pollution	Highway run-off water	Concentration of hydrocarbons (petroleum)			X	X	W2
		Concentration of heavy metals and salt (Cd, Cr, Cu, Pb, Zn, Fe, Ni, Cl, Na, Ca and sulphates)			X	X	W1 W3
		Concentration of nutrients – nitrogen and phosphorus			X	X	W2
		Concentration of sedimentation – particulates			X	X	W2

Quieter Surface Transport in Urban Areas – SILENCE

Project SILENCE [8] was funded by European Commission under Sixth RTD Framework Program in the period of three years, from 2005 till 2008, involving 46 European partners from 14 countries. The main objective was to develop a methodology and technology for control of surface transport noise in urban areas, focusing on noise propagation and emission, noise source control and people's noise perception.

Various noise indicators were used as a benchmark for the assessment of accomplishments that different policies or road surfaces can achieve in noise reduction with the respect to the current state or the reference material. Also, noise indicators were used for the establishment of the relation between noise perception and annoyance and actual noise levels.

Table 5 presents a summary of the noise indicators used in SILENCE.

Table 5. Summary of environmental indicators from SILENCE

Area	Domain	Indicator/Parameter	Level of applicability			Technical	Assessment ID
			Strategic	Program	Project		
Noise	Noise	Day-Evening-Night equivalent level L_{den}	X	X	X	X	N2
		Night level L_{night}	X	X	X	X	N3
		Maximum sound level $L_{A\max}$			X	X	N1
		Sound absorption coefficient			X	X	N4

Noise Prediction Model ASJ RTN-Model 2008

Continuing the research activities related to the road traffic noise prediction, a research committee, organized by the Acoustical Society of Japan in 1974, continually worked on the development and revisions of the noise prediction model from its first version ASJ Model 1975 to the latest version ASJ RTN-Model 2008 [9]. This latest model is used not only for road traffic noise prediction, but also for design of environmental preservation measures and for the estimation of the current state of noise during environmental monitoring. The equivalent continuous A-weighted sound pressure level L_{Aeq} is used as the noise index for road traffic assessment (table 6).

Table 6. Summary of environmental indicators from ASJ RTN-Model 2008

Area	Domain	Indicator/Parameter	Level of applicability			Technical	Assessment ID
			Strategic	Program	Project		
Noise	Noise	Equivalent continuous sound level L_{Aeq}			X	X	N1

Pollution of Groundwater and Soil by Road and Traffic Sources: dispersal mechanisms, pathways and mitigation measures – POLMIT

Project POLMIT [10] was conducted in the period of two years, from 1997 till 1999, under the 4th RTD Framework Program, involving seven European countries. The project's main objectives were to:

- Analyze current information about road and vehicle emissions and identify their relative importance as a source of terrestrial pollution,
- Screen the annual loading of pollutants into the monitoring sites roadside environment, and identify potential impact of the environment pollutants,
- Identify pathways of road and vehicle pollutants transport mechanism into the local roadside environment, and any factors that may have influence and the relative importance of each pathway,
- Establish the proportion of each pollutant that enters the terrestrial environment, and
- Recognize the targets of mitigation measures so they can be most effective.

14 locations in participating European countries were selected as case studies for field monitoring over a period of 30 months. Water pollution indicators used in POLMIT are presented in table 7.

Table 7. Summary of environmental indicators from POLMIT

Area	Domain	Indicator/Parameter	Level of applicability			Technical	Assessment ID
			Strategic	Program	Project		
Water pollution	Soil and groundwater pollution	Concentration of polycyclic aromatic hydrocarbons (PAH)			X	X	W2
		Concentration of heavy metals (Cd, Cr, Cu, Pb and Zn)			X	X	W1
		Concentration of chloride (Cl)			X	X	W3

Developing Harmonized European Approaches for Transport Costing and Project Assessment - HEATCO

The objective of the HEATCO project [11] was to develop harmonized guidelines for project assessment for trans-national projects in Europe which includes a consistent framework for monetary valuation. Among other direct and indirect project's costs, assessment of environmental costs included three main impacts: air pollution, noise, and global warming. Other impacts such as vibration, severance, visual intrusion, loss of important sites, resource consumption, and impairment of landscape, soil and water pollution were not included in the report since there was lack of information regarding their monetary valuation.

Table 8. Summary of environmental indicators from HEATCO

Area	Domain	Indicator/Parameter	Level of applicability			Technical	Assessment ID
			Strategic	Program	Project		
Air pollution	Air pollution	Pollutant emissions ($PM_{2.5}$, NO_x , SO_2, NMVOC)		X	X	X	A1
Noise	Noise	Number of persons highly annoyed		X	X		
Greenhouse gases	Emission of greenhouse gases	CO_2 equivalent	X	X	X	X	G1

Asphalt Pavement Embodied Carbon Tool – asPECT

Project asPECT [12] was conducted from 2008 till 2011 within Collaborative Research Program which is a joint initiative of the Highways Agency, Minerals Products Association, Refined Bitumen Association and TRL. The objective of the project was to develop a framework for measuring the greenhouse gas emissions of highways related activities as the contribution to climate change. The asPECT tool consists of guidance document, protocol and software and provides necessary formulae, emission factors and default data for GHG emissions calculation of asphalt products. Life cycle GHG emissions assessment of asphalt includes ten steps from acquisition of raw materials to end of life (cradle-to-grave).

Table 9. Summary of environmental indicators from asPECT

Area	Domain	Indicator/Parameter	Level of applicability: Strategic	Program	Project	Technical	Assessment ID
Greenhouse gases	Emission of greenhouse gases	CO_2 equivalent			X	X	G1

PaLATE - Pavement Life-cycle Assessment Tool for Environmental and Economic Effects

PaLATE [13] is a tool for life-cycle assessment of environmental and economic effects of pavements and roads. Based on input that the user provides about design, construction, maintenance, equipment use and costs specification, this excel-based tool calculates costs and environmental results as output.

Environmental results are presented for phases like initial construction and maintenance which are further sub-divided into three categories: (i) materials production, (ii) materials transportation and (iii) processes (equipment).

The environmental indicators used in PaLATE are presented in table 10.

Table 10. Summary of environmental indicators used in PaLATE

Area	Domain	Indicator	Level of applicability: Strategic	Program	Project	Technical	Inventory No
Air pollution	Air pollution	Pollutant emissions (NO_x, PM_{10}, SO_2, CO, Hg, Pb)			X	X	A1
Greenhouse gases	Emission of greenhouse gases	CO_2 emission			X	X	G1
Natural resources	Energy	Energy use			X	X	R2
	Water consumption	Water consumption			X	X	R1
	Waste generation	RCRA Hazardous Waste Generated			X	X	R1
Other	Health	Human Toxicity Potential (Cancer)			X		
		Human Toxicity Potential (Non-cancer)			x		

Building Environmentally and Economically Sustainable Transportation-Infrastructure-Highways - BE²ST-in-Highways

BE²ST-in-Highways [14, 15] is a rating system which provides a quantitative methodology for the sustainability ratings of highway construction alternatives. The system assesses sustainability of a project based on the quantitative comparison between a reference design and proposed alternative designs. The system is divided into two phases – mandatory screening and judgment indicators. A project needs to meet the terms of the first phase, mandatory screening, in order to be evaluated based on the judgment indicators.

Mandatory screening:

- Social requirements including regulation and local ordinances

Judgment indicators:

- Greenhouse gas emission
- Energy use
- Waste reduction (Including Ex situ materials)
- Waste reduction (Recycling In situ materials)
- Water consumption
- Hazardous waste
- Life Cycle Cost
- Traffic noise
- Social carbon cost savings

Assessment of project's sustainability considers material production, transportation of materials and construction of highway structures. A summary of environmental performance indicators used in BE^{2}ST-in-Highways is presented in table 11.

Table 11. Summary of environmental indicators from BE^{2}ST-in-Highways

Area	Domain	Indicator/Parameter	Level of applicability			Technical	Assessment ID
			Strategic	Program	Project		
N/A	Economic assessment	Life Cycle Cost		X	X		
	Social benefits	Social carbon cost savings	X	X	X		
Natural resources	Waste generation	Waste reduction			X	X	R1
		Hazardous waste			X	X	R1
	Water consumption	Water consumption			X	X	R1
	Energy	Energy use			X	X	R2
Noise	Traffic noise	Traffic noise			X		
Greenhouse gases	Emission of greenhouse gases	CO_2 equivalent			X	X	G1

COLAS study "The Environmental Road of the Future"

The Colas report [16] deals with the impact on environment during road construction. The report analyzed flexible and rigid pavement construction and compared energy consumption and greenhouse gas emissions for production of constitutive materials and final products.

Environmental parameters used in Colas study are presented in table 12.

Table 12. Summary of environmental indicators used in Colas report

Area	Domain	Indicator/Parameter	Level of applicability			Technical	Assessment ID
			Strategic	Program	Project		
Natural resources	Energy	Energy consumption			X	X	R2
Greenhouse gases	Emission of greenhouse gases	GHG emissions			X	X	G1

FINNRA report „Life-Cycle Assessment of Road Construction"

FINRRA report [17] is another document that deals with road construction. The model includes production and transportation of materials and their placement. The most important environmental impacts were included, like use of natural raw materials and secondary products, energy and fuel consumption, emissions of carbon dioxide, nitrogen oxides, sulphur dioxide, VOC, carbon monoxide and particles, dust emissions, compounds leaching into the soil and noise.

Table 13 presents environmental parameters considered in the FINNRA study.

Table 13. Summary of environmental indicators considered in FINNRA study

Area	Domain	Indicator/Parameter	Level of applicability			Technical	Assessment ID
			Strategic	Program	Project		
Natural resources	Resource use	Use of natural resources			X	X	R1
		Industrial by-products			X	X	R1
		Energy			X	X	R2
		Fuels			X	X	R2
		Land use			X		
	Waste	Inert waste			X	X	R1
Water pollution	Effluents to soil and waters	Leaching of metals (e.g. As, Cd, Cr, Cu, Mo, Ni, Se, Pb, Zn)			X	X	W1
		Leaching or migration of organic compounds from materials			X		
		Cl, SO_4			X	X	W3
Air pollution	Emissions to air	CO_2 NO_x SO_2 VOC CO Particles			X	X	A1
Noise	Other loadings	Noise			X	X	N1 N2 N3 N4

Water usage, land use, waste – and nitrogen effluents and accident risks were also analyzed during the first phase. It was, however, concluded that either the significance of these loadings is low or the data available is insufficient for the analysis.

European Environmental Agency Indicators

European Environmental Agency (EEA) regularly publishes reports with several environmental indicators that are observed in 32 member states. However, most of these indicators are strategic indicators used at network level.

The EEA has established a Transport and Environment Reporting Mechanism (TERM) which main aim is to monitor the progress and effectiveness of transport and environment integration strategies on the basis of a core set of indicators [18]. The TERM indicators were selected and grouped to address seven key questions:

1. Is the environmental performance of the transport sector improving?
2. Are we getting better at managing transport demand and at improving the modal split?
3. Are spatial and transport planning becoming better coordinated so as to match transport demand to the need for access?
4. Are we optimizing the use of existing transport infrastructure capacity and moving towards a better balanced intermodal transport system?
5. Are we moving towards a fairer and more efficient pricing system, which ensures that external costs are internalized?
6. How rapidly are cleaner technologies being implemented and how efficiently are vehicles being used?
7. How effectively are environmental management and monitoring tools being used to support policy-making and decision-making?

The TERM indicator list covers the most important aspects of the transport and environment system (driving forces, pressures, state of the environment, impacts and societal responses — the so-called DPSIR framework). It represents a long-term vision of the indicators that are ideally needed to answer the above questions.

Table 14, next pages, provides summary of indicators used in TERM reporting system.

In addition to indicators presented in table 11, EEA web-site [19] provides several other indicators. However, all of them are non-technical indicators used at network level and therefore they are not presented in this report.

In addition, EEA in its Environmental Policy Review (EPR) that is published annually provides general environmental indicators for EU 27 member states [20]. Some of them are technical indicators related to transport in general, but applicable only at network level and therefore they are not presented in the review.

Table 14. Summary of environmental indicators used in TERM system

Area	Domain	Indicator/Parameter	Level of applicability: Strategic	Level of applicability: Program	Level of applicability: Project	Technical	Assessment ID
Noise	Traffic noise	TERM 05 - Exposure to and annoyance by traffic noise	X				
Air pollution	Air pollution	TERM 03 - Transport emissions of air pollutants	X			X	A1
		TERM 04 - Exceedances of air quality objectives due to traffic	X			X	A1
		TERM 28 - Specific air pollutant emissions	X			X	A1
Natural resources	Waste generation	TERM 11 - Waste oil and tires from vehicles	X			X	N1
		TERM 11a - Waste from road vehicles (ELV)	X			X	N1
	Energy	TERM 01 Transport final energy consumption by mode	X			X	N2
		TERM 27 - Energy efficiency and specific CO_2 emissions	X			X	G1
Greenhouse gases	Emission of greenhouse gases	TERM 02 - Transport emissions of greenhouse gases	X			X	G1
		TERM 27 - Energy efficiency and specific CO_2 emissions	X			X	G1
Other		TERM 06 - Fragmentation of ecosystems and habitats by transport infrastructure	X				
		TERM 07 - Proximity of transport infrastructure to designated areas	X				
		TERM 08 - Land take by transport infrastructure	X				
		TERM 09 - Transport accident fatalities	X				
		TERM 10 - Accidental and illegal discharges of oil at sea	X				
		TERM 11 - Waste oil and tires from vehicles	X				
		TER M11a - Waste from road vehicles (ELV)	X				
		TERM 12a/b - Passenger transport volume and modal split (CSI 035)	X				
		TERM 13a/b - Freight transport volume and modal split (CSI 036)	X				
		TERM 14 - Access to basic services	X				
		TERM 15 - Regional accessibility of markets and cohesion	X				

Table 14. Summary of environmental indicators used in TERM system (cont'd)

Area	Domain	Indicator/Parameter	Level of applicability			Technical	Assessment ID
			Strategic	Program	Project		
		TERM 15 - Regional accessibility of markets and cohesion	X				
		TERM 16 - Access to transport services	X				
		TERM 18 - Capacity of infrastructure networks	X				
		TERM 19- Infrastructure investments	X				
		TERM 20 - Real change in transport prices by mode	X				
		TERM 21 - Fuel prices and taxes	X				
		TERM 22 - Transport taxes and charges	X				
		TERM 23 - Subsidies	X				
		TERM 24 - Expenditure on personal mobility by income group	X				
		TERM 25 - External costs of transport	X				
		TERM 26 - Internalization of external costs	X				
		TERM 29 - Occupancy rates of passenger vehicles	X				
		TERM 30 - Load factors for freight transport	X				
		TERM 31 - Uptake of cleaner and alternative fuels (CSI 037)	X				
		TERM 32 - Size of the vehicle fleet	X				
		TERM 33 - Average age of the vehicle fleet	X				
		TERM 34 - Proportion of vehicle fleet meeting certain emission standards	X				
		TERM 35 - Implementation of integrated strategies	X				
		TERM 36 - Institutional cooperation	X				
		TERM 37 - National monitoring systems	X				
		TERM 38 - Implementation of SEA	X				
		TERM 39 - Uptake of environmental mgt. systems by transport companies	X				
		TERM 40 - Public awareness	X				

Highway Design and Management Model HDM- 4

HDM-4 Model [21] is one of first pavement management tools that use environmental indicators in the evaluation of different pavement maintenance alternatives. The indicators include:

- Vehicle emissions
- Noise emissions
- Energy balance consideration

Table 15 presents environmental indicators used in HDM-4.

Table 15. Summary of environmental indicators used in HDM-4

Area	Domain	Indicator/Parameter	Level of applicability			Technical	Inventory No
			Strategic	Program	Project		
Air pollution	Air pollution	Pollutant emissions (HC, NO_x, CO, SO_2, Pb, PM)			X	X	A1
Greenhouse gases	Emission of greenhouse gases	CO_2 equivalent			X	X	G1
Noise	Traffic noise	L_{eq}, L_{10}			X	X	N1
Natural resources	Energy	Energy use			X	X	R2

Models used in HDM-4 are developed for different vehicle categories and relate vehicle emissions primarily to fuel consumption and vehicle speed. The noise model is related to traffic flow.

VI.3 Review of the existing environmental performance indicators

Based on literature review it was concluded that only technical environmental parameters are currently available. In the following chapter the short description of the identified technical parameters is presented. The goal is to provide basic information about parameters that can be further used in the development of technical E-KPIs. The review is organized by the area of interest: noise (N), air pollution (A), water pollution (W), natural resources (R) and greenhouse gases (G).

<u>Noise</u>

From the literature review, in Europe the most commonly used noise scale for assessing the noise impact from road traffic is the equivalent continuous sound level, $L_{Aeq,T}$,(N1), which is an energy based measure represented by a steady sound level which, over a defined period of time *T*, has the same A-weighted acoustic energy as the time varying noise level that is typically associated with traffic noise.

$$L_{Aeq,T} = 10\log_{10}\left[\frac{1}{T_2 - T_1}\int_{T_1}^{T_2} 10^{L_A(t)/10}\,dt\right] \quad [1]$$

where $L_A(t)[dB(A)]$ is A-weighted sound pressure level, i.e. weighting filter that accounts for the fact that human hearing is less sensitive at very low and very high frequencies.

For the assessment of the impact of environmental noise on communities including the road traffic noise, EU recommended two noise indicators: L_{den} (N2) and L_{night} (N3) [22]. Beside the noise scale as a basic metric, both indicators have additional factors to account for the time of the day and length of exposure.

$$L_{den} = 10\times\log_{10}\left(\frac{1}{24}\right)\left(12\times10^{L_{day}/10} + 4\times10^{(5+L_{evening})/10} + 8\times10^{(10+L_{night})/10}\right) \quad [2]$$

where[2]:

- L_{day} is the A-weighted equivalent sound level for the 12-hour daytime period from 07:00 to 19:00 hours, determined over all of the day periods of a year;
- $L_{evening}$ is the A-weighted equivalent sound level for the 4-hour evening period from 19:00 to 23:00 hours, determined over all of the evening periods of a year;
- L_{night} is the A-weighted equivalent sound level for the 8 hour evening period from 23:00 to 07:00 hours, determined over all of the night periods of a year.

European Directive 49/2002/EC [22] proposed that every country should, due to subjective perception and attitude of people to traffic noise, draw noise maps, i.e. how many people are annoyed at different level of L_{DN}, L_{den} or L_{night}. It is acknowledged that the threshold of annoyance is 55dBA and the threshold of unacceptability is 65dBA [23, in 24].

In addition to the selected indicators, one more indicator has properties of being technical and used at the project level – sound absorption coefficient (N4). However, this indicator can be used only for the assessment of acoustical properties of porous pavements. His potential application in the asset management process is in its use to monitor the effect of clogging on absorption of porous pavements to trigger maintenance actions like pore cleaning

Air pollution

The air pollution can be the result of road construction and maintenance activities, or road traffic due to vehicle emissions. The first part of air pollution is described in LCA tools, like PaLATE [13] an FINNRA report [17], while the second part is used in HDM-IV [21].

There are several indicators that are used for the description of air pollution independently from its source:

- Concentration of particulate matter $PM_{2.5}$ and PM_{10}, where number denotes the size of particulates
- Concentration of nitrates (NO_x)
- Concentration of sulfates (SO_2)
- Concentration of carbon monoxide (CO)
- Concentration of hydrocarbons (HC)
- Concentration of heavy metals (Pb, Hg)

[2] In some countries, different time periods of the day possible

- Concentration of NMVOC (non-methan volatile organic compounds) as precursor of ozone.

In this report all these parameters are grouped into one air pollution indicator A1.

Water pollution

As the indicator of the water pollution, concentration of the specific pollutant is chosen. It should be recognized that the concentration of pollutants in the highway runoff water is one approach for the indicator measurement, while the pollution of ground water and soil could be also used for the indicator assessment. In this report, three indicators were selected: concentration of heavy metals (W1), concentration of PAHs (W2) and concentration of de-icing salts (W3). From the literature, it is recognized that these three indicators provide sufficient information about the impact of traffic and winter maintenance activities on water pollution.

Below the list of some pollutants from highways which appear in the run-off water as well as their primary sources is provided [7].

- Particulates – pavement wear, vehicle, atmospheric deposition
- Nitrogen and Phosphorous – atmosphere, roadside fertiliser application
- Lead – tyre wear, vehicle exhaust
- Zinc – tyre wear, motor oil, grease
- Iron – vehicle body rust, steel highway structures, moving engine parts
- Copper – metal plating, brake lining wear, moving engine parts, bearing and bushing wear, fungicides and insecticides
- Cadmium – tyre wear, roadside insecticide application
- Chromium – metal plating, brake lining wear, moving engine parts
- Nickel – diesel fuel and gasoline, lubricating oil, metal plating, brake lining wear, asphalt paving
- Manganese – moving engine parts
- Cyanide – anti-caking agent used in de-icer salt
- Sodium and Calcium Chloride – de-icing salts
- Sulphate – roadway beds, fuel, de-icing salts

Natural resources

For the assessment of the impact on natural resources, two indicators are selected: waste reduction (R1) and energy use (R2). There are five basic transport related activities that are considered to affect the environment by the waste generation: infrastructure construction, maintenance and abandonment; vehicle parts and manufacture; vehicle travel; vehicle maintenance and support, and disposal of used vehicles and parts. Road construction and maintenance are primary activities of interest for EVITA project thus the waste reduction indicator relates to these activities. An example is the volume of pavement waste to landfill which can be expressed as "percentage of waste circulated" with the unit "weight of recycled waste as a percentage of total waste produced per year". Another example is to use weight percentage of waste divided in classes such as "reused", "recycled", "extracted for energy retrieval" and "deposited on land-fill".

Energy uses assess energy consumption for building the infrastructure as well as for vehicle operation on this infrastructure. Related indicator is the fuel consumption, which is use of fossil fuels and renewable energy.

Greenhouse gases

CO_2 equivalent (G1) - emission of greenhouse gases is usually expressed as CO_2 equivalent which is derived by multiplying the amount of the gas by the associated Global Warming Potential. Global Warming Potential (GWP) is an indicator which represents the contribution of greenhouse gases to the global warming through a weighted sum of the emissions. For example, the GWP for methane is 23, for nitrous oxide 296 and for CO_2 is 1.

Table 16 presdents the summary of existing technical environmental performance indicators that are assessed in this report.

Table 16. Summary of existing technical environmental performance indicators

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

VI.4 Assessment of the existing environmental performance indicators

The assessment of the existing technical parameters was performed according to the set of criteria that is presented in table 17.

Table 17. Typical assessment form for the existing E-KPIs

<table>
<tr><td colspan="3">EVITA Area:
AREA NAME</td><td>Assessment ID
NX</td></tr>
<tr><td>**Indicator Name:**</td><td colspan="3">Name of the selected indicator</td></tr>
<tr><td>**Description:**</td><td colspan="3">Short description of the indicator.</td></tr>
<tr><td>**Technical Parameters**</td><td>Technical parameters which can be used to represent the selected indicator.</td><td>**Units:**</td><td></td></tr>
<tr><td>**Indirect indicators and relations**</td><td colspan="3">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).</td></tr>
<tr><td>**Related/derived indicators:**</td><td colspan="3">Indicators that can be used to express same or similar effect on the environment.</td></tr>
<tr><td>**Measurement/ monitoring methods:**</td><td colspan="3">Known and established methods for measuring or monitoring the technical parameter value.</td></tr>
<tr><td>**Sources:**</td><td colspan="3">List of projects, standards or literature where information about the indicator can be found.</td></tr>
<tr><td colspan="4">**ASSESSMENT**</td></tr>
<tr><td>**Meeting stakeholders needs and expectations**</td><td colspan="3">List of stakeholders and their expectations which the selected indicator addresses.</td></tr>
<tr><td>**Assessing performance of individual assets**</td><td colspan="3">List of individual assets for which the selected indicator can be used.</td></tr>
<tr><td>**Level of applicability and use**</td><td colspan="3">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.</td></tr>
<tr><td>**Possible aggregation into combined index**</td><td colspan="3">Is it possible to combine indicator with related indicators into the combined/general index?</td></tr>
<tr><td>**Data availability:**</td><td colspan="3">What data are needed for the assessment of the indicator?</td></tr>
<tr><td>**Spread of use:**</td><td colspan="3">Where the indicator is used.</td></tr>
<tr><td>**Reliability:**</td><td colspan="3">If the indicator measuring/monitoring/forecasting is based on well established/standardized/recognized methods, reliability of data.</td></tr>
<tr><td>**Sustainability:**</td><td colspan="3">When it is expected for the indicator effect to occur? How long will the effect last?</td></tr>
</table>

Detailed assessment forms for the available E-KPIs are presented in the following tables.

Table 18. 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 stakeholders needs and expectations	Neighbors – Public health		
Assessing performance of individual 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 aggregation into combined index	Indicator can be combined into noise indicator.		
Data availability:	Regular measurement/monitoring of noise emission levels.		
Spread of use:	Indicator is specified in EU Directive and in use in many EU countries.		
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 19. Assessment form for the indicator N2

<table>
<tr><td colspan="2">Area:
NOISE</td><td colspan="2">Assessment ID
N2</td></tr>
<tr><td>**Name:**</td><td colspan="3">Day-Evening-Night equivalent level L_{den}</td></tr>
<tr><td>**Description:**</td><td colspan="3">Represents the noise indicator for overall annoyance.</td></tr>
<tr><td>**Technical Parameters**</td><td>Maximum A-weighted sound pressure level $L_{AF,\max}$
Average A-weighted sound pressure level L_{Aeq}</td><td>**Units:**</td><td>dB</td></tr>
<tr><td>**Indirect indicators and relations**</td><td colspan="3">Directly proportional to:
- Texture, Rolling resistance, Skid resistance, Stiffness
Indirectly proportional to:
- Porosity</td></tr>
<tr><td>**Related/derived indicators:**</td><td colspan="3">Day equivalent level L_{day}
Evening equivalent level $L_{evening}$
Night level L_{night}</td></tr>
<tr><td>**Measurement/ monitoring methods:**</td><td colspan="3">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)</td></tr>
<tr><td>**Sources:**</td><td colspan="3">Projects: SILVIA, SILENCE, COST356, COST350, FINNRA
EC Directive 2002/49/EC
ISO 1996-2 (1987)</td></tr>
<tr><td colspan="4">**ASSESSMENT**</td></tr>
<tr><td>**Meeting stakeholders needs and expectations**</td><td colspan="3">Neighbors – Public health</td></tr>
<tr><td>**Assessing performance of individual assets**</td><td colspan="3">Pavement surface and noise screens and barriers.</td></tr>
<tr><td>**Level of applicability and use**</td><td colspan="3">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.</td></tr>
<tr><td>**Possible aggregation into combined index**</td><td colspan="3">Indicator can be combined into noise indicator.</td></tr>
<tr><td>**Data availability:**</td><td colspan="3">Measurement/monitoring of noise emission levels.</td></tr>
<tr><td>**Spread of use:**</td><td colspan="3">Indicator is specified in EU Directive and in use in many EU countries.</td></tr>
<tr><td>**Reliability:**</td><td colspan="3">Well established and recognized measurement/monitoring methods providing consistent and reliable data.</td></tr>
<tr><td>**Sustainability in time:**</td><td colspan="3">Effect is expected to demonstrate in the short-term scale, but the duration of the effect is observed in the long-term scale.</td></tr>
</table>

Table 20. 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)		
Sources:	Projects: SILVIA, SILENCE, COST356, COST350, FINNRA EC Directive 2002/49/EC ISO 1996-2 (1987)		
ASSESSMENT			
Meeting stakeholders needs and expectations	Neighbors – Public health		
Assessing performance of individual 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 aggregation into combined index	Indicator can be combined into noise indicator.		
Data availability:	Measurement/monitoring of noise emission levels.		
Spread of use:	Indicator is in use in many EU countries		
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 21. 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:	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 22. Assessment form for the indicator A1

Area: **AIR POLLUTION**			Assessment ID **A1**
Name:	Concentration of 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:	NO_x- two sided Ogawa passive sampler, Palmes tubes $PM_{2.5}$-Harvard impactors PM_{10} and $PM_{2.5}$-filter based samplers		
Literature sources:	Projects: COST350, HEATCO, HDM, FINNRA, PaLATE, TERM EC Directive: 80/779/EEC EC Directive: 82/884/EEC EC Directive: 85/203/EEC EC Directive: 96/62/EEC		
ASSESSMENT			
Meeting stake-holders needs and expectat.	Neighbors – Public health.		
Assessing per-formance of in-dividual 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.		
Data availability	Distance to a major road, total length of road within certain area, traffic volume.		
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 23. 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. 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		
ASSESSMENT			
Meeting stakeholders needs and expectations	Society – Environmental preservation/Climate change		
Assessing performance of individual assets	Roads, bridges, highway structures, traffic signs, crash barriers.		
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:	Types of soils in the vicinity of infrastructure, average range of pollution of different types of soils, traffic volume, road type, natural recipient's distance from the road centre-line.		
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 24. 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) 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		
ASSESSMENT			
Meeting stakeholders needs and expectations	Society – Environmental preservation/Climate change		
Assessing performance of individual assets	Roads, bridges, highway structures, traffic signs, crash barriers.		
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:	Types of soils in the vicinity of infrastructure, average range of pollution of different types of soils, traffic volume, road type, natural recipient's distance from the road centre-line.		
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 25. 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:	Measurement method – Hach Test. 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		
ASSESSMENT			
Meeting stakeholders needs and expectations	Society – Environmental preservation/Climate change		
Assessing performance of individual assets	Roads, bridges, highway structures, traffic signs, crash barriers.		
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:	Types of soils in the vicinity of infrastructure, average range of pollution of different types of soils, traffic volume, road type, natural recipient's distance from the road centre-line.		
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 26. 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	-		
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		
Literature sources:	Projects: COST 350, COST 356 LCA Tools: BE^{2}ST		
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	Some data are available, but it is difficult to get reliable data.		
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 27. 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.		
Spread of use:	Indicator is in use in many countries.		
Reliability:	Estimation of energy consumption due to construction worls 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 28. 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		
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^2ST, 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.		
Data availability	Data on CO_2 emission due to traffic and construction works is mostly available.		
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.		

VII - Conclusions

The work conducted within the second Work Package (WP) of EVITA focused on the extensive inventory of the road stakeholders and of their expectations. Starting from the final report prepared by the PIARC D1.2 sub-committee on “Road Asset Management: High Level Management Indicators”, the analysis was completed by a workshop in Paris, the dissemination of a questionnaire and the evaluation of the responses.

The first significant findings from this approach are that the expectations about environment preservation are mainly expressed by three categories of stakeholders: the neighbours who are primarily concerned by local impact of road traffic on their own environment, well-being and health (noise, NOx, particles); the Society which is more concerned by the global impacts, such a the emission of GHG; the owners, who are reporting to public authorities about the performance of their network on these topics.

A special interest was also given to the expression of environmental expectations. It appears that three channels are mainly used most often: 1) The media (TV and radio news, news papers, magazines…) regularly and rather systematically address the general subject of environment preservation; 2) Public policy and regulations certainly reflect this common concern. To some extend, they are answers brought by the Society to its own expectations, as expressed by media. But they can also result from more direct expression, such as the percentage of votes collected by the ecologic parties at elections, or simply the discussions between citizens and politicians in pre-election meetings; 3) Another important channel to express neighbor’s expectations consists in the protests. This type of expression is generally more devoted to urgent, punctual (in time) and local problems. A fourth channel is identified as direct communication between the neighbors and the road authorities.

The need for environmental related E-KPIs was derived from the former inventory. The inventory of existing indicators 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, and some specific studies too, from COLAS, FINNRA, EEA…

Finally, performances of these existing KPIs were assessed as far as the available information made it possible. This work opens the road for the development of missing E-KPIs (WP3) and the implementation of them in Pavement and Asset Management Systems (WP4), which will be able to develop their contribution to EVITA.

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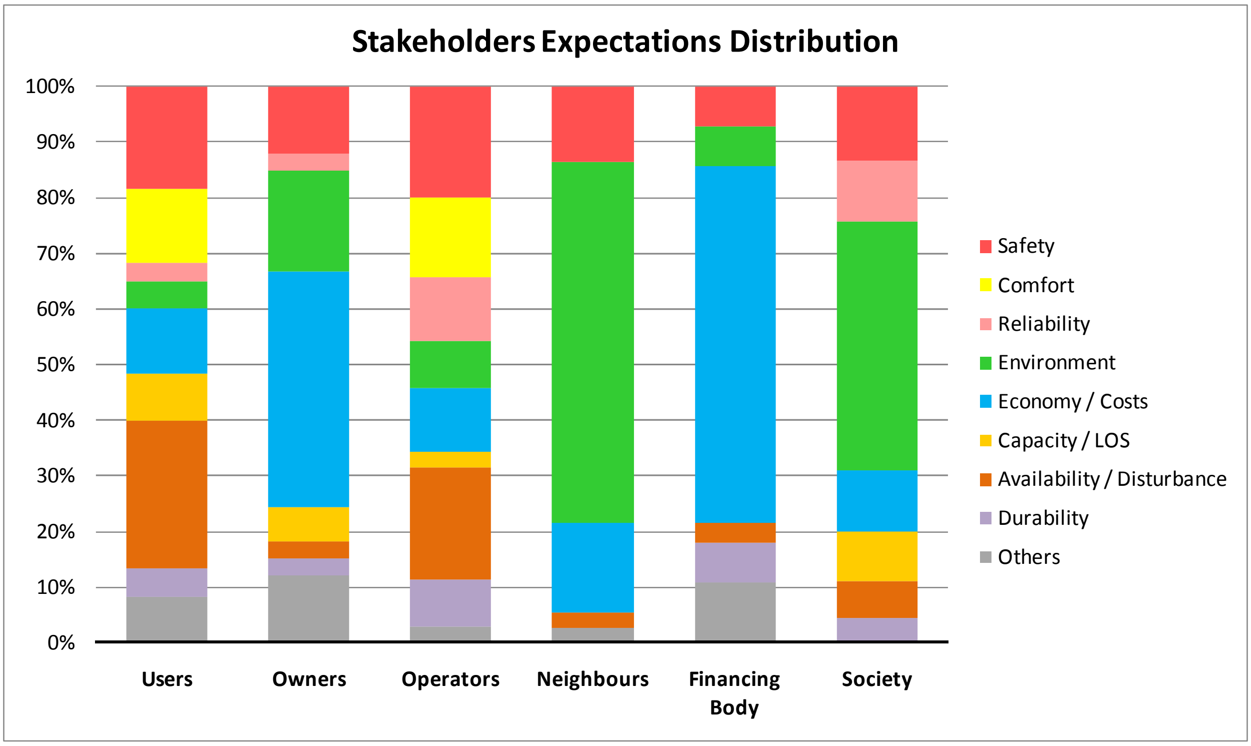
IX - APPENDIX

IX.1 APPENDIX A.1: Questionnaire prepared by the EVITA project

The main objective of the project EVITA is the development and integration of new and existing technical environmental key performance indicators (E-KPIs) in the asset management process taking into account the expectations of different stakeholders (users, operators, neighbors, etc.). Project 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 following questionnaire is a support-tool for interviews with road administration and other infrastructure agencies dealing with E-KPIs

1. How do you assess the following expectations of the different stakeholders according to the road infrastructure in general?



Comment: the figure is a result already, how was it used for answers during the workshop??

2. What environmental indicators are used in your country?

Type of <u>EXISTING</u> E-KPI that is used in your agency/country	**List of EXISTING E-KPIs**
Noise and vibrations (for Users)	
Noise and vibrations (for Neighbors)	
Air pollution	
Soil and Water pollution	
Use of non-renewable Resources	
Greenhouse Gas Emission	
Other for Users	
Others for Neighbors	
Other for Owners	
Other for Society	

3. Please list, according to your opinion, environmental indicators for which there is a need, or mark in the following table:

Type of <u>MISSING</u> E-KPI which you propose to use/apply in the future	Stakeholder concerned	MISSING E-KPIs
Noise and vibrations	Users	
	Operators	
	Neighbors	
	Society	
	Financing	
	Other	
Air pollution	Users	
	Operators	
	Neighbors	
	Society	
	Financing	
	Other	
Soil and Water pollution	Users	
	Operators	
	Neighbors	
	Society	
	Financing	
	Other	
Use of non-renewable Resources	Users	
	Operators	
	Neighbors	
	Society	
	Financing	
	Other	
Greenhouse Gas Emission	Users	
	Operators	
	Neighbors	
	Society	
	Financing	
	Other	
Other	Users	
	Operators	
	Neighbors	
	Society	
	E Financing	
	Other	

IX.2 APPENDIX A.2: 1st EVITA Workshop, Paris, 2 February 2011

Participants

Tom CASEY	National Roads Authority	Ireland	
Christian CREMONA	Ecology Minister	France	(Project Manager)
Kajsa LINDSTROM	Transport Administration	Sweden	
Stefan POELZLBAUER	ASFINAG	Austria	
Emmanuel de Verdalle	VEOLIA	France	
Jean-Loup MADRE	INRETS	France	
Irving VILLARREAL	INRETS	France	
Juliana JAMNIK	DDC Consulting	Slovenia	
Darko KOKOT	ZAG	Slovenia	
Goran MLADENOVIC	University of Belgrade	Serbia	
Johann LITZKA	Consultant	Austria	
Alfred WENINGER-VYCUDIL	Office-PMS	Austria	(Project coord)
Jaro POTUCEK	Consultant	Sweden	
Duncan BOND	TRL	UK	
Maria de Lurdes Antunes	LNEC	Portugal	
Philippe LEPERT	LCPC	France	(Project coord)

Context

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 consideration the expectations of the different stakeholders. This objective will be met by conducting a comprehensive state of the art investigation in close co-operation with representatives of the different road stakeholders and road authorities in Europe.

PIARC, the world road association, is presently conducting a larger action, dealing with the identification of road infrastructure stakeholders, their needs and expectations. The Technical Committee D1 "Road Asset Management" is especially in charge of this work. In a preliminary report, the committee identifies six groups of stakeholders: users (incl. trucks or bus operators), neighbors, road operators (inc. private), network owners; financing organisms and Society (incl. gov. environment agency). Various expectations were categorized in Society's developments, operation efficiency, safety, sustainable development, comfort, information, cleanliness, aesthetic, human life framework technical management and asset condition financial management. EVITA intends to review and strengthen this analysis, to start identification and construction of "E-KPIs" on strong bases.

In that context, the workshop aimed to check and complete the stakeholders' expectations identification and KPIs inventory already available from existing groups (PIARC and COST). It was open to road laboratories, operators (including toll motorway operators) and owners, road users (fleet operators), and governmental organizations that are dealing with the impact of transport on environment.

Workshop venue and time table

The workshop took place at the French Minister of Ecology and Transport, in Paris - La Défense, France, on 2 February 2011. The time table was structured as follows:

1 – Welcome address
2 - Introduction of the ERAnet Road 2 call
3 - Presentation of SBAKPI and EVITA projects
4 - Work on a list of selected items or questions
5 - Lunch time
6 - Work on a list of selected items or questions
7 - General discussion – Conclusions

Important note: The workshop shortly addressed the SBAKPI project, a project conducted under the same ERAnet program. SBAKPI is complementary to EVITA, the former dealing with the socio-economic key performance indicators at the technical level, and all KPIs at the strategic level, when the latter is dealing with the environmental KPIs at the technical level. This EVITA workshop was an opportunity to inform the attendees about these complementarities.

General information

All participants are welcomed by Philippe Lepert, project coordinator) and Christian Crémona (project Manager). A short tour de table is made (see list of participants). Christian Crémona then gives a brief overview ERANET Road 2 program, of the organization of the program, the role of Program Executive Board (PEB), and his own role within this PEB. He mentions the connection between EVITA and the SBAKPI project as well. Finally, he indicates that the next PEB meeting is planned for 17th March.

The presentation of the EVITA (Ph. Lepert) and SBAKPI (D. Bond) was an opportunity to give some precisions about the articulation between both projects.

- EVITA works on road segment level / low level (road links, projects), called "project level". It works with selected environmental impacts: Noise, air & water, natural resources & GHG emissions.
- SBAKPI works on road network level / high level (comprehensive road networks). It works with all socio-economic impacts (safety, health, etc.). D. Bond mentions that the next SBAKPI meeting is planned on 5th April 2011, in Brussels.

Performances indicators

A. Weninger-Vycudil introduces the notion of performance indicators, and the definition that was provided by the COST action 354. He mentions that the final report of this action is available, and the web site as well.

Identification of stakeholders

According to the analysis made by the D1 PIARC Technical Committee, EVITA is considering six categories of stakeholders and is stating a hierarchical relation between four them: Society ➔ Financing body ➔ Owner ➔ Operator. The two other stakeholders, Users and Neighbors, are outside this hierarchy. The relation is less strong in case of concession companies. On this base, an attempt was made to identify expectations of the stakeholders and ways for expressing the expectations.

A brain storming process was used to reach this goal, and organized in two rounds:

- 1st round: What are the expectations of the different stakeholders
- 2nd round: How do the stakeholders express their expectations?

Everybody, acting individually, listed on stickers the expectations – 1st round – he or she has (as a stakeholder) or he or she knows (from his or her contacts with stakeholders), and the way they expressed them – 2nd round –. The stickers were placed on a board under the stakeholders type they were concerning. At the end of the brainstorming, all the stickers were collected. They were processed later.

After the brain storming, a 3rd question is discussed: what is the role of road operators in the process of stakeholder expectation expression process?

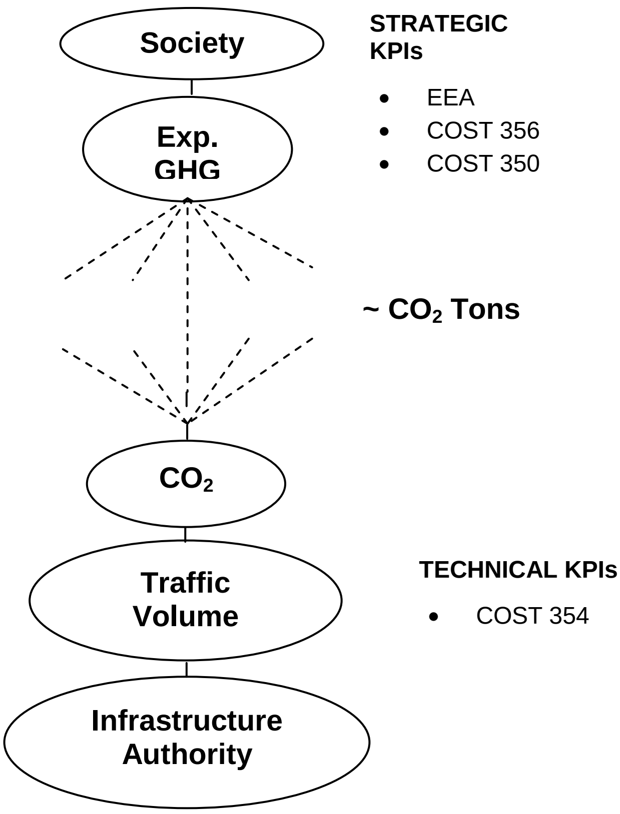
The draft result of this work, including the process of the sticker, is given in appendix.

The Environmental KPIs

The audience was invited to react on a list of selected items based on existing / distributed questionnaire.

- <u>Gases emissions</u>: Regarding Green House Gases (GHG) and other gases, it appears that only indirect indicators can be used, as no direct measurements are possible; modeling of congestion is an example of these indirect indicators. The combination of these technical indicators in some global warming strategic indicator(s) is illustrated in figure 1. It is also noticed that indicators on Energy and Green House Gas Emissions are closely interlinked.

Figure 1: From technical to strategic GHG indicators



- <u>Health indicators</u>: A (contribution to) health indicator is certainly much more complex to build than a (contribution to) global warming indicator. Therefore, it is stated that, within the EVITA project, we should deal with parameters which are known as health related, but we cannot build relationships between these indicators (for instance "particles emission") and "health", since we have neither the relevant competencies nor the inputs to set up such relationships.
- <u>Environmental indicators</u>: It is mentioned that there is a list of environmental indicators published by European Environmental Agency (EEA) and that the COST action 356 uses it for a matrix of importance (qualitative assessment). It is

recommended to be in touch with the EEA (Gorm Dige). It is also indicated that the environmental indicators should be:

  - not too many, but rather a few (maximum 15 per project) good ones
  - linked to and in line with transport and environmental objectives
  - linked to indicators in other sectors and other modes of transport
  - preferably, the same as used elsewhere
  - Indicators from European Environmental Agency
  - Focusing the essential – for instance they should show the impact on the environmental (and health) values, not on material values.
  - possible to measure, relevant, robust and possible to communicate

- Particles emissions: EU Legislation should be a starting point, from which we should identify most significant indicators and explain any exclusion; Note that the project should not be in the business of changing set EU limits.
- Water quality: If the expectation is rather clear, the required indicators are not so clear. It is agreed to restrict the work to water quality. Water quality is affected by vehicle run off, spreading of salt for winter maintenance, pollution resulting from accidents…, which all are EVITA's issues. Flood or hydraulic problems are not considered as relevant issues for EVITA.
- Noise, nuisance and tranquility: The KPIs should be – and can be – based on clear measurements; use European knowledge; calculations are possible and in use in different countries.
- Non renewable resources: Recycling waste is an issue for EVITA and should be primarily addressed. A provisional decision was made to deal with all other questions and related indicators in a later step.

Finally, it is agreed that each parameter/indicator which is on the list has to be evaluated at least with respect to its outcome from road traffic and operation.

IX.3 APPENDIX A.3: Stakeholders expectations and expression – Draft results from Brainstorming

A.3.1 The stakeholder's expectations

Users	Owners	Operators	Neighbors	Financing body	Society
High level of availability	Low costs (construction and maintenance)	Low operating costs	Noise protection	Low maintenance cost	Good accessibility
Accessibility	Durable + if possible no intervention	Good surface condition	Low pollution	Low construction cost	Safety
Reliability	Pay as you drive or similar	Good structural situation	No disturbance of privacy	Durability	Good public transport possibilities
Comfort	Safe transport + low liability	High functionality	Big distance from road/rail	Economy (good use of resources, allocated to construction and maintenance)	Health
Safety (for drivers)	No emissions + cleanness	Safe infrastructure	No congestion	Value for money (VFM)	Contribute to society environmental & transport objectives (CO_2, air, water, noise)
Flexibility	Safe working environment (Traffic safety, Use of chemicals)	Easy to operate	Health	Reducing asset management development costs	Safety of users
Economy	Min. LCC	Easy to maintain and repair	Environment	Satisfied society	Low accident rates
Safety	No budget restrictions	High intervention periods	Safety (to neighbors)	Cheap transport	Well working system
Efficiency (travel time, reliability)	Rapid intervention for maintenance and after accident	Zero problems with users and residents (neighbors)	Accessibility	Low environmental impact	Sustainability
Riding quality	Better	High quality of	Coupling	Cheap	Effectiveness of

	network performance (econ., soc., env.)	transport system	between economic and traffic roads		transport system
Max. safety	Lower costs	Smooth traffic/few/no problems	Tranquillity in the neighborhood (less noise)	Value for money	Reduced (minimised) impact on environment and landscape
Max. comfort	Safety	Operation performances (average speed, time table, travel time, vehicle type – size, weight)	Road door to door (working place)	Earn some money	Health impact
Availability	Reliability	Environment (energy consumption, gas emissions, noise)	noise and air pollution abatement measures	PPP	Accessibility
No congestion	Environment	Passenger comfort, safety - linked to the users (accelerations, vibrations)	Clean and nice environment	High income of toll	Good management + high level of operating KPI's
Clear guidance (signs and signals)	Health	Vehicle maintenance (impact on critical/key parts)	Good signalization to industrial, working, sleeping, touristic areas	Efficient use of money/funds	Low construction and maintenance cost
Quality of service (passengers comfort and travel time)	Durability	Low maintenance cost & operation cost	Safe roads	Low LLC	No pollution
Public transport	Good use of resources (natural and economic)	Safety	"Quiet" road	Adequate user costs? (contribution from users)	Economic growth equals traffic growth?
Available all the time	They want to meet society's	Reliability	As little pollution as possible from	Clear budget planning	Better roads = better quality of

	expectations		traffic		life of citizens
Cheap traffic (low road user costs, time, fuel, vehicle…)	Cheap	Durability	Local traffic only	Clear prioritisation of measures	Safety to users and neighbors
Comfort, accidents	Cheap transports	Accessibility	Safety (for children, old people)	Durable constructions	Environment and health
If really needed quick intervention when I am not there	? financing body	Low maintenance cost	Noise reduction	Low invest	Natural resources (best use)
Nice looking surrounding	Low life cycle costs	Easy to preserve	Air pollution reduction	High return	Economic resources (best use)
Resting stations	Transport efficiency	Quick intervention	Low noise	Safe transport	Accessibility
High road capacity or level of service	No complaints from any other stakeholder	Durable intervention	Low pollution	Low liability (no accidents)	Reliability
Everything at no cost	Cheap maintenance	Safe working environment	Safety	Return on investment (economic, political, financial)	Impact on health
Contribute to society objectives (environment)	High usage factor	Low noise	low level of impact	Contribute to objectives (could be environmental) transport	Safety (cost of accident)
Safe road	Meeting National/ European regulations	No emission (clear air)	Health (noise, air, water)	Low LCC = higher profit	Preservation of non-renewable resources
Smooth road	Reducing risk of litigation	Better performance from “supr?chain” ie management of env/soc/econ.	Public transport accessibility		Limitation of GHG

Reliable	Give a nice “image” of their network	Satisfied owner	Minimising (road) nuisance ie. litter/noise		Sustainability of road network
No maintenance disruptions	Improve economic activity	Safety and security in the roads	Not necessarily top scientific env/soc risks but ones of local impact		Low energy consumption
High level of service – capacity	Contribute to a consistent multimodal transport system	Easy access to work sites	Less noise		Low raw materials consumption
Good comfort	Low LCC (construction + maintenance + operation)	No complains from other stakeholders	Less emissions		Low impact on environment (noise, pollution – air & water)
High level of service (no traffic)	Low impact on environment	Safe working environment	Improve my local environment		Low impact on climate change
Well maintained infrastructure	Sustainable use of resources – energy & materials		Safety		Cheap infrastructure
Less congestion			Less noise		Cheap transports
Shared roads between modes (bikes etc.)			Less air pollution		Low environmental impact
High level of safety			Biking possibilities		Low impact on environment
No construction sites					Improved network performance
Low disturbance of traffic flow					Reduced env/soc impact of road network
Less congestion (economic)					Safe transport

Safe journeys (society)					Efficient transport
Good road facilities (society)					No damage to environment
Less visual blight (environment)					People not affected by roads and traffic disruption
Fewer env. impacts, floods, fires, ?					Low cost

A.3.2 How do the different stakeholders express their expectations and how to know?

Users	Owners	Operators	Neighbors	Financing body	Society
Automobile clubs or associations	Policy	Project manageme nt	Citizen's initiative	Political contracts	Passive in general
Public debates	Project planning and management	Business plan	Media	Internal competitio n for budget	Political decisions by regional or national governments
Blame the owners in front of users	Business plan	Information to users	Politics	Well based arguments for budget needs	Politics
Complaints (written or vocal) about poor condition of road	Via policy	ITS and similar connections	Complaints through mailing, mass media to owners	Interventio n near the top manager of the road authority	Media
Media reports about poor condition of traffic jams	Via business plans	Information to residents (neighbors)	Road closures	No profile, no money	Loudest voice = no consistent medium and may not be majority view
Via news media	Via performance pay	Press release and media	Demands from financing bodies	Instruction s along with funds	Via protest

Via operator lead communication web / marketing polls	Via reporting	Media	Media	Annual reporting	Via politicians
Automobile club	Via KPI's	Complaints to owners, financing bodies	Word of mouth	Budget restrictions	Via media (traditional)
Media	Instruction to the operators	Contracts: standards <-> prices	Voted at elections	Budget and goals	Via social media
Dialogue with operators	Information to the users (newspaper, radio, TV,…)	Link with the Public Transport Authority	-> road owner	Amount of investment	Use of mass media
Complaints through mailing to road owners / operators	Information to users	Tenders	-> road operator	Via audit	Ad-hoc interventions like road closures
User associations (touring clubs…)	Well argumented requests to politics and financing bodies	Media reports about high maintenance prices or poor quality of road condition	Politics	Via business plan	Demands for better quality of roads
Letters, calls, mails to road authorities	Public information system	Cost of operation and maintenance	Media	Via annual reporting	Demands for lower pollution through media
Letters, calls, mails to politicians	Internal quality assurance system	Via management processes	Public protest	Via KPI's	Low cost maintenance through media
Satisfaction surveys	Information to the neighbors (mails)	Via policy	Complaints about noise, vibrations, air and water pollution to road authorities		Levels of administrations and parliaments from local to European
Intervention	Dialogue with	Via audit	Through		Word of

at owner, etc.	funding bodies	and reporting	public representative		mouth
Public media	Press report	Information to the user	Letters, calls, mails to local authorities and politician		Political expression (votes, general and specific)
User's associations (ÖAMTC, etc.)	Budget and standards	Information to the neighbors	Protestations, traffic disturbances		Investigation of effects of transportation systems and economy
Use of the road	Politics		Public debate		Votes and elections
Votes at parliament, elections	Media		Local associations		Media
Through users' associations	Advice to the operator		Similar as users but different background		Transport strategy
Public pressure through media	Through mass media		Interventions		Strategy of sustainable environment
Directly by phone call or mail	Leaflets, reports		Protests		
Word of mouth	Announcements		Political pressure		
Politics	Demands to financing bodies		Via protest		
Media			Via local council / national parliament		
Road owner			Operator lead communication, web page, visits to neighbors (meeting)		
Road operator			Public demonstrations (when expectations		

			are not met)		
			Use of the road		
			Through local communities		
			Public pressure through media		