10

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ASSESSMENT OF SOCIAL EFFECTS IN ASSET MANAGEMENT

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SUMMARY: The transnational European CEDR project ISABELA (Integration of social aspects and benefits into lifecycle asset management) was launched to define a common basis for social impact assessment in asset management. The aim was to define a holistic asset management framework for social key performance indicators (S-KPIs) and to model social benefits in terms of social effects (monetary and non-monetary), social backlog and social risk. These project results are becoming increasingly important in the context of evaluating different maintenance strategies for road infrastructure networks. While decision makers need to present the consequences of their maintenance strategies and policies on both technical and social levels, ISABELA showed how social aspects can be an integrated part in asset management frameworks, how to present social impacts and how to discuss maintenance needs using social aspects. The project aimed to identify clear and justifiable social key performance indicators in combination with existing technical parameters, taking into account different stakeholders and their needs and expectations. To this end, ISABELA considers maintenance aspects such as traffic availability, disturbance and efficiency (travel time, vehicle operating costs, etc.), road safety (fatal and serious accidents related to asset condition), environment (noise, air pollution, natural resources, etc.) and socio economy (asset value, wider social effects, etc.). In addition to the S-KPIs, ISABELA proposed a decision-making process for the selection of appropriate parameters and models, and demonstrated the assessment of social effects with practical examples.

KEY WORDS: Road infrastructure asset management, Social effects, Social risk, Social backlog, Maintenance strategies.

1 INTRODUCTION

Managing our ageing road infrastructure is a major challenge for our society in the 21st century, especially for the Road authorities (RA) who are responsible for these networks. The increasing importance of road infrastructure leads to a growing responsibility in maintaining road infrastructure assets and terms such as availability, safety, sustainability, environmental friendliness, etc. express the expectations of different stakeholders that need to be taken into account. Thus, asset management has become a complex task in which the objective is to find the optimal solution in the form of a balance between the expectations of the different stakeholders and the technical requirements, between the highest possible societal benefits and the always limited financial resources.

Over the last twenty years, many research and development projects have been devoted, in whole or in part, to the analysis of the social impact of the management of road infrastructures, including their operation and maintenance. For example, the development of the HDM system began in the 1970s under the auspices of the World Bank. More recently, a considerable number of European projects have addressed this issue. One of the first, PAV -ECO [1], extended by FORMAT [2], focused specifically on the conceptual development of a framework for cost-benefit analysis and technical models adapted to different contexts or European countries. It quickly became apparent that a key factor in the implementation of this type of analysis by RAs was the development of indicators to characterise the impact of the condition of a road network (in its construction, operation and maintenance phases) on the economic and social activity of the region it affects and, more recently, on the environment.

The COST 354 project [3] sought to identify and propose, at the European level, indicators and indexes to quantify the condition of a network, the first step towards a characterization of the relationship between this condition; the operation -

especially dysfunctions – of road infrastructure; the measures to overcome these dysfunctions; and the effects of both (dysfunctions and remedial measures) on the economy, society and the environment.

While COST 354 focused on technical indicators and indexes, the cornerstone of the overall analysis, a report of the PIARC Technical Committee D1 [4] was mainly interested in identifying indexes (existing or created), called high-level indexes, to measure the social and environmental impacts of road activities. An approach by stakeholders was conducted, which allowed identifying the expectations of these stakeholders regarding the road network, both positive (the need to improve their living conditions) and negative (the fear of deterioration, even temporary, of those). This done, it was possible to propose, when it does not already exist, a scale for assessing the degree of satisfaction or dissatisfaction of each stakeholder, based on combinations of measurable quantities. In continuation of this work, EVITA project [5] went deeply into the construction of indexes to characterize the impact of the roads on the environment, favouring an approach at the road sections level, in particular targeting the impacts on the Society, mainly noise, air pollution and water, removal of non-renewable natural resources (both aggregates and fossil energies). And for its part, the project SBAKPI [6] treated the economic impacts of the operation and maintenance of a network, considered as a whole.

2 ISABELA PROJECT

ISABELA (Integration of social aspects and benefits into life-cycle asset management) aims at defining a holistic asset management framework for social key performance indicators (S-KPIs) and modelling social benefits in terms of social effects (monetary and non-monetary), social backlog and social risk. ISABELA represents a significant extension for life cycle assessment of maintenance strategies. The project closes this gap and makes it possible to include social aspects and benefits in classical asset management.

2.1 Review of stakeholders, and their needs and expectations

The review began with an assessment of stakeholder requirements and expectations and included a literature review of S-KPIs in use and interviews with experts from RAs regarding their current practise and use of S-KPIs. The aim was to review and complete the stakeholder expectations and requirements together with the inventory of available indicators, data, models and methods already available from existing groups/projects.

Five groups of stakeholders were identified: Users, Neighbours, Road Authorities (with subcategories of Road Owners and Road Operators), Financial Institutions and Society.

Users are defined as direct and immediate users, i.e., people (or businesses) who use road infrastructure for transportation and/or commuting, making them the infrastructure's primary service delivery capability. In general, most users expect safe and timely communication between two locations.

Second, the neighbourhood is defined as all households and properties in close proximity to the road infrastructure whose day-to-day functioning is closely related to the performance of an infrastructure. Neighbours may have numerous benefits from their proximity to the road, but they may also be annoyed by traffic noise, maintenance and closures, traffic accidents, and the like.

On the other hand, road authorities and especially road operators certainly tend to provide safe and reliable infrastructure, but in line with budgetary constraints and strategies for the development of a particular area. Therefore, in many cases, the financial aspect can be the crucial one in the asset management of the road network.

Finally, it is a duty of society (defined as both individuals and numerous organisations and associations) to ensure that infrastructure does not have a negative impact on quality of life, ecosystems, cultural heritage, etc.

Obviously, stakeholders agree on many of their expectations - on the importance they attach to the provision of adequate services; however, in order to view the road network asset holistically as a functioning system with many interactions, it is important to consider all requirements in line with all five groups of stakeholders mentioned above when defining future maintenance strategies.

The project group found 30 single stakeholder requirements and expectations from the literature review. However, some of these expectations relate to more than one area, so 63 expectations were eventually identified, of which 15 relate to Users, 11 to Neighbours, 8 to Financial Institutions, 8 to Road Authorities and 21 to Society.

Stakeholder requirements and expectations were grouped into four areas related to the following maintenance aspects: Availability and Disturbance; Road Safety; Environment; and Socio-economics.

2.2 Literature review of socio-economic indicators

In order to respond adequately to stakeholder requirements, road asset managers use a range of indicators that provide a means of measuring, quantifying, comparing and monitoring all aspects of a complex system.

The literature review identified a large number of indicators that relate to four key maintenance aspects. For the "Availability and disturbance" aspect, 16 indicators were identified in five subcategories: Accessibility, Condition, Congestion, Restrictions and Travel Time. For the "Road Safety" aspect, a total of 23 indicators were identified in five subcategories: Accidents, Condition, Overall Safety, Safety Costs, and User Perceptions; most of these indicators were placed in the "Accidents" subcategory. The "Environment" aspect includes 18 indicators divided into five subcategories: Air Quality, CO_2 Emissions, Natural Resources, Noise, and Soil and Water Quality. Finally, for the aspect "Wider socio-economic costs", 45 indicators were identified in the literature, divided into eight sub-categories: Asset Value, Condition, Cost Effectiveness, Environmental Costs, Safety Costs, Wider Socio-economic Costs, Stakeholder Satisfaction and User Costs.

The indicators are derived from the TPs, which provide a certain measure of road asset performance. In this research, an attempt was made not only to define the scope of possible parameters (and derived indicators) capable of covering the widest range of stakeholder expectations, but also to adequately assess the parameters (and indicators) in terms of several objectives. For example, it is important to define indicators with detailed knowledge of mutual interactions and overlaps that adequately address established stakeholder needs, and to assess their degree of objectivity (whether the indicator is based on measurement or estimation), applicability and reliability, assuming timely, non-costly and reliable data sources.

It was found that Availability and Disruption is very important from the perspective of a number of stakeholders and almost directly represents the ability of the infrastructure to provide services to its users. However, infrastructure availability also represents a measure of an operator's efficiency, while disruption can be as important to neighbours as it is to users. It is therefore not surprising that one aspect of availability and disturbance is represented by a number of indicators and parameters. Availability and disturbance- related indicators include five subcategories: Accessibility, Condition, Congestion, Restrictions, and Travel Time.

Road safety is also one of the most important aspects of the overall performance of the road network, affecting users, neighbours, road authorities, but also the whole society. The Road safety category is divided into five subcategories: Accidents, Condition, Overall Safety, Safety Costs and User Perception.

Environmental impacts are still insufficiently considered in asset management, although they are crucial for the quality of life and general well-being of society. There are a large number of indicators in the literature. Environmental impact indicators are divided into the following subcategories: Air Quality, CO_2 Emission, Natural Resources, Noise, and Soil and Water Quality.

Socio-economic indicators include the following sub-categories: Asset Value, Cost Effectiveness, Environmental Costs, Safety Costs, Wider socioeconomic costs, Stakeholder Satisfaction, and User Costs.

2.3 Use of Socio-economic indicators in Road Authorities

The indicators identified in the literature served as the basis for interviews with experts from interested Road Authorities to identify indicators that are either currently in use or that there is interest in using in the development of authorities' asset management programs. Based on these interviews, additional S-KPIs used by authorities were added to the list of indicators.

Most of the identified S-KPIs are not systematically used in the development of asset maintenance programs, and very few of the identified indicators are used by a significant number of road authorities. However, there is considerable interest in implementing and using some of these indicators in the future, particularly those for which data are available in some form within road authorities.

The importance of considering expectations in the area of Road availability and Disturbance in maintenance planning is recognized in all countries, but to varying degrees. The indicators used mostly include some form of condition rating for carriageways and bridges, while other indicators related to accessibility, congestion, availability and travel time are used to a lesser extent.

All countries use some of the S-KPIs related to road safety. The indicators used are mostly related to the number of fatalities, injuries or simply the number of accidents. Based on these data, more complex indicators can be calculated, related to safety costs or frequency of occurrence of accidents. In addition, many authorities use some of the condition parameters to identify appropriate maintenance treatments to achieve certain safety-related levels of these parameters. The S-KPIs for overall safety, safety cost, and user perception are not currently considered significant for maintenance planning by most.

Noise stands out as the most important environmental parameter used by most RDs as a result of implementing the European Noise Directive. Other parameters, such as air quality, CO2 emissions, environmental costs, natural resources, soil and water quality, do not currently influence planning, but are to some extent part of national legislation. However, as environmental impact is becoming a major issue for all European societies, there is a great interest in the application of the relevant parameters in the future.

Among the parameters related to economics, cost-effectiveness and especially the benefit/cost ratio of maintenance programs seem to be used by most authorities to assess the socio-economic impact of maintenance activities. All other parameters are used to a lesser extent.

3 PROPOSAL OF ISABELA S-KPIS

The focus of the ISABELA project is on indicators that can be applied at the network level (although most of the indicators collected are defined at the project level and then aggregated for use across the network) and that can be related to road maintenance activities. In addition, consideration was given to whether indicators could be monetised and whether there are existing models or whether it was possible to develop models for social benefit, social risk and social backlog.

Therefore, the following main criteria were used as a basis for indicator selection: can the indicator be related to maintenance activities? Is the primary purpose of the indicator to be used for asset management at the network level? Can it be used in existing social benefit models or is it possible to use it for modelling? Is it possible to monetize it?

The following chapters present a brief summary of selected indicators in four main areas: Availability and disturbance, Road Safety, Environment and Socio-economic Impacts, which can be used for socio-economic analysis related to the management of road assets.

3.1 Availability and disturbance

Most Availability and disturbance indicators can be related to travel time to some extent. A functional relationship can be established between the *density of the road network* and the *loss of travel time*. On the other hand, *road availability* is important from the point of view of maintenance and *possibility for detour*. There is also a potential relationship between these two parameters and the importance of the road.

Vehicle operating costs are highly correlated with *road condition*. Travel time at the project level and aggregated at the network level depends on *congestion* caused by maintenance. Therefore, congestion-related indicators can also be related to travel time. *Availability constraints* due to weather are relevant for winter or routine maintenance, but not for construction maintenance.

Three other indicators related to constraints were also considered: due to *load restriction* and *clearance*, and due to the *length of the construction site*. Finally, the aspect of user satisfaction is covered by other indicators (*condition*, *travel time*) in a more objective way.

3.2 Road safety

Road safety indicators include indicators related to accidents, road condition, overall safety and user perception.

Within the Accidents subcategory, indicators are divided into *accidents by impact*, *accidents by user*, and *site-specific accidents*. Within the Condition subcategory, most indicators, such as *longitudinal roughness*, *skid resistance*, *rutting*, and *ravelling*, are routinely collected at the network level for asset management systems. The sub-category Overall safety includes, in addition to the *EuroRAP* score, the *number of tunnels complying with EU safety regulations*.

3.3 Environment

The Environment category includes indicators on air quality, greenhouse gas (GHG) emissions, natural resource use, noise, and soil and water quality.

The air pollution indicator includes emissions of various air pollutants, including *aldehydes*, *sulphur dioxide*, *polycyclic aromatic hydrocarbons*, *CO*, *NOx*, *PM10* and *PM2.5*, and *CO2*. GHG emissions are split into two indicators covering emissions related to *traffic*, and emissions related to *road construction and maintenance activities*.

Similarly, indicators related to natural resource use are divided into those related to *energy consumption* and *materials use*. Noise indicators include *Noise maps*, *Exposure to traffic noise* and *Noise annoyance to humans*. The *Water pollution* index is important from the perspective of salt consumption for winter maintenance. Soil and water pollution indirectly feeds into the evaluation of the *adequacy of the drainage system* and the consequences of road improvement: *Release of hazardous substances due to accidents* and *Emissions of substances that cause acidification*.

3.4 Socio-economic impact

Indicators related to asset value and cost-effectiveness are included in the group of socio-economic effects indicators. This group also includes indicators for *accident costs*, *user costs*, *environmental impact costs*, and costs associated with maintenance activities that reflect *preservation of road investments* and/or *protection of the environment*. All of these indicators are compatible with the expected approach taken in the modelling phase by assuming monetisation of social benefits for various social effects.

One of the remaining indicators for wider socio-economic effects relates to the *contribution of road operations to socio-economic development and employment*.

4 SOCIAL BENEFIT MODELLING

4.1 Decision making process

The selection of appropriate parameters for the specification of Social Key Performance Indicators (S-KPIs) is the first step in the modelling process. For this purpose, the basic requirements from the modelling, the expectations of the stakeholders and which social aspects should be considered have to be matched with the list of indicators and their parameters. The criteria for the selection and assessment process can be summarized by the following questions:

What parameters are needed for the application of the model? Is data available for these parameters at the network level? Is there a correlation between the parameters and the specific social aspect to be addressed? Can the parameters be used to support the expected outcomes and outputs of the modelling?

In principle, the selection of appropriate models and the corresponding S-KPIs should be done by the road authority itself. The ISABELA project does not prescribe the models to be used, nor the indicators to be considered, nor the outputs to be provided to decision makers. Nevertheless, the project provides a practical approach and shows how the modelling part and the calculation of social effects can be carried out using different indicators.

Regardless of how the specific maintenance program is handled by the road authority, the best level for calculating the social effects is when the individual maintenance projects (usually an accumulation of different maintenance activities on different assets) are defined. In particular, social effects need to be assessed taking into account the different stakeholders and the specific impacts of the maintenance activities as well as the improved asset condition. Each individual maintenance project of a comprehensive maintenance program should be assessed in the same way. Finally, the results can be cumulated over the entire network to reflect the impact at the network level.

As a summary of the study on the processes, the different planning levels, the availability of data and indicators and the models, the recommended approach should be applied at the levels where the maintenance program is defined (by individual maintenance projects) and the results can be cumulated over the whole network.

Thus, ISABELA is a network-level approach for assessment of committed or recommended maintenance programs that takes into account the specifications of maintenance projects and the potential effects of maintenance treatments on societal benefits and drawbacks. However, the recommended approach can also be integrated at other levels to assess asset-specific maintenance treatment strategies (pavement management, bridge management, etc.) and scenarios.

4.2 Modelling social effects

The starting point of the ISABELA approach to social effects modelling is a defined, planned or recommended maintenance program of heavy maintenance (overlay, reinforcement, rehabilitation, etc.) that should be assessed from a social perspective and compared with other options (e.g. do-minimum strategy, routine maintenance strategy). The program can be related to a single asset (e.g., roadway) or to a combination of asset-specific maintenance treatments (cross-asset project). The input parameters can be divided into the following categories: Input parameters describing the maintenance section; Input parameters describing the maintenance project; Input parameters describing the road infrastructure network; Cost rates; and General additional input parameters.

The calculation of the different social effects of a maintenance project is described in detail in the deliverables of ISABELA. The effects, expressed in terms of social savings and social costs, are the basis for the social assessment of each maintenance project. To apply this social valuation to a maintenance project, it is necessary to compare the savings with the costs and obtain a monetary parameter that reflects the total social effects of the maintenance project m. This monetary parameter can be positive or negative. In the case of a positive value, the social savings are higher than the costs; in the case of a negative value, the social costs outweigh the savings. Regardless of the sign, a trade-off between social savings and social costs must be made, as shown in Table 1 below.

Table 1: Balance sheet for the calculation of total social effects of a maintenance project

Category	**Social savings** (savings in social costs)	**Social costs** (additional social costs)
Social category X	$savXCST_{s,m}$	$addXCST_{s,m}$
Total social effects	$MSocEff_{s,m}$	

To calculate the total social effects of a maintenance project *m*, the following equations can be applied:

$$SocSAV_{s,m} = \sum_X savXCST_{s,m} \quad \text{(Eq. 1)}$$

$$SocCST_{s,m} = \sum_X addXCST_{s,m} \quad \text{(Eq. 2)}$$

where:

$SocSAV_{s,m}$.................social savings of maintenance project *m* on section *s* [€]

$SocCST_{s,m}$.................social (additional) costs of maintenance project *m* on section *s* [€]

$savXCST_{s,m}$...............savings in social costs of category (aspect) *X* due to maintenance project *m* on section *s* [€]

$addXCST_{s,m}$...............additional social costs of category (aspect) *X* due maintenance project *m* on section *s* [€]

The difference between the savings in social costs and the additional social costs returns the total social effect of the maintenance project *m* on section *s* (see Equation 3).

$$MSocEff_{s,m} = SocSAV_{s,m} - SocCST_{s,m} \quad \text{(Eq. 3)}$$

Two other concepts are proposed by ISABELA to be included in decision making regarding road infrastructure maintenance.

The social maintenance backlog can be defined as the social effects, caused by the failure to meet strategic requirements. It is the difference between the total monetary social effects of the 'target' maintenance strategy, which includes all maintenance activities to meet the strategic requirements and represents the maintenance policy, and the planned maintenance construction programme, e.g. the strategy Do-Minimum. If the total social effects of the planned maintenance construction programme is equal to or higher than the total social effects of the "target" maintenance strategy, a social backlog is zero or non-existent. Note that the "do-minimum" strategy here only meets the minimum requirements, while the "target" strategy is to represent maintenance activities to achieve the strategic requirements of the maintenance policy.

Each maintenance strategy carries some social risk that needs to be assessed and compared with other strategies. This can be done in a qualitative or quantitative way. Basically, social risk can be defined as the expected social consequences in relation to stakeholder expectations in the social domain. Compared to social effects, benefit and backlog, social risk involves an assessment of whether a planned or committed maintenance programme (or strategy) can be implemented under the given social conditions. Mathematically, social risk is evaluated as the product of the likelihood that a predefined maintenance strategy will fail to meet stakeholder expectations and the resulting social consequences, taking into account various uncertainties within the asset management process.

Social risk seeks to imply a better understanding of social effects and responsibilities. Therefore, it is strongly recommended to discuss the definition from a social point of view with relevant experts (risk managers, sociologists, economists, etc.) and adapt it if necessary. As an outcome of ISABELA, this definition of social risk can be used as a starting point for this discussion.

4.3 Practical application

Two different test sites were selected for practical application of the ISABELA models to test the model implementation in existing asset management tools [7]. Here, a summary of the results of the calculations for a section of the A4 motorway (E58 / E60) in Austria is presented.

As an example of the results, Figure 1 compares the social costs and savings for the planned IIP strategy (Infrastructure Investment Program) and the strategy Do-Minimum. It can be seen that both strategies have social costs due to the maintenance projects, but also social savings in safety as a result of the long-term effect of a better pavement condition.

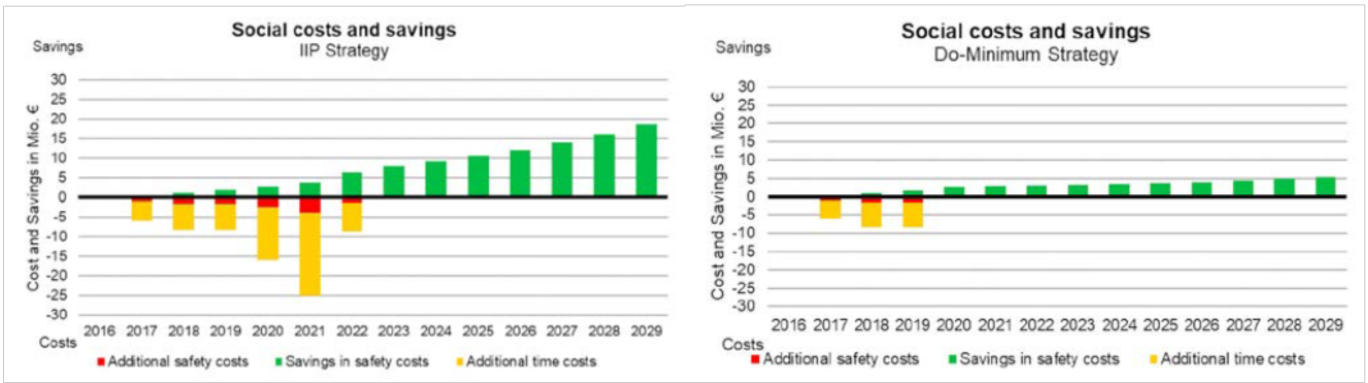

Figure 1: Comparison of social costs and savings for the planned (left) and the Do-Minimum (right) strategy in ISABELA [7]

5 CONCLUSIONS

The study of social performance indicators and models has shown that most social aspects can be covered by simplified approaches, taking into account existing models and available input data and their correlation with expected outputs and outcomes. Most of the models presented in ISABELA are based on simplified relationships between traffic, asset condition and physical or economic effects, which makes them suitable for application in an asset management software solution.

Based on the results of the research and the assessment of the different types of indicators, a procedure for calculating social benefit, social risk and social backlog was developed. A crucial step in the process is the transformation of technical parameters into monetary and non-monetary performance parameters using different models that take into account the different social aspects and stakeholder requirements.

A socio-economic impact analysis can certainly be carried out using the ISABELA models and methodology in most existing asset management systems, provided they meet some requirements derived from the study. However, to perform a reliable and satisfactory socio-economic assessment of their maintenance policy, Road Authorities probably need to collect more socio-economic information (parameters, coefficients...) adapted to their context and take great care in collecting and storing their road data. The results of the socio-economic analysis can be used at different levels depending on the level of application (for individual assets or for maintenance projects) and should be integrated in the decision-making process.

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