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# SUP&R DST: SUstainable Pavement & Railways Decision Support Tool

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**ABSTRACT:** The importance of sustainability in transportation infrastructure has raised in response to the link between anthropogenic activity and global challenges, such as climate change, as well as in consequence of the ongoing development of models quantifying the social and economic impacts resulting from infrastructure development. Therefore, addressing the sustainability of transportation infrastructures requires exploring the environmental, social, and economic impacts of technological options while balancing the often conflicting priorities of different stakeholders, at an early design phase of the infrastructure delivery process. That is a typical multi-criteria decision-making (MCDM) problem, in which the decision-makers need to measure the sustainability through a set of meaningful, representative and quantifiable criteria, balance the relative importance of those criteria and determine the sustainability sequence of multiple alternative technologies for fostering transportation sustainability. In order to help the decisions makers to efficiently address this challenging task, a decision support toll (DST) was developed in the scope of the training-through-research programme Sustainable Pavements & Railways Initial Training Network ([www.superitn.eu](http://www.superitn.eu)). It consists of a computational platform that implements a conceptual framework developed to quantify sustainability. It comes with a set of sustainability indicators tailored to both road and railway systems as well as several objective and subjective weighting methods. Amongst those belonging to the last category, the DST includes a set of default weights derived from an Analytical Hierarchy Process (AHP)-based survey that engaged stakeholders from different sectors and from several European countries. At last, the Preference Ranking Organization Methodology of Enrichment Evaluation II (PROMETHEE-II) MCDM method is employed for prioritizing alternative road pavement and railway tracks solutions at the design stage. The SUP&R DST is a freely available upon request (<http://superitn.eu>) and can be used at professional level, by professionals interested in advancing sustainability in transportation, as well as for educational purposes, to provide knowledge and educate on the use sustainability concepts and on what are the important issues to consider during the sustainable transportation decision-making process..

**Keywords:** Sustainability; Life cycle analysis; Transportation infrastructures; Multi-criteria decision analysis; Decision-making support.

## 1 INTRODUCTION

Sustainability development is a multidimensional concept that aims to balance the social, economic and environmental consequences of our decisions. In the transportation sector, a sustainable infrastructure implies maintaining an acceptable condition throughout the infrastructure's life cycle while also considering the trade-off between economic, environmental and social impacts of infrastructure investments (Bryce et. al 2017).

Sustainability considerations are not new, and in fact have often been considered indirectly or informally, although most of those past endeavours have been focused on economic and environmental aspects

of sustainability. Therefore, further efforts are required to assess the sustainability of infrastructure projects in light of the triple bottom line framework and to incorporate the results of that assessment into the infrastructure management decision-making process in a more systematic, organized and comprehensive fashion (Bueno et al., 2015)

### 1.1 *Current methodologies for sustainability rating of roads and railways*

In the last decades increased efforts are being made to assess the sustainability of infrastructure projects and to incorporate the results of that assessment into the infrastructure management decision-making

process in a more systematic, organized and comprehensive fashion (Bueno et al., 2015). An example of the endeavours undertaken at the forefront of the sustainable movement is the development of sustainability rating systems to qualitatively assess the sustainability of construction practices.

In the building sector, two of the most known sustainable assessment tools to measure the environmental performance of buildings are the Building Research Establishment Environmental Assessment Method (BREEAM) and the Leadership in Energy and Environmental Design (LEED), respectively used in UK and US. Similarly, in the road sector several tools such as Envision™ (Institute for Sustainable Infrastructure, 2012), BE2ST-In-Highways™ (Lee J.C. et al., 2011), Greenroads (Muench et al., 2010), GREENPAVE (Lane et al., 2014) are available and often applied.

In case of railway infrastructures, a first approach to define a framework for sustainable rating system has been proposed recently (Bressi et al. 2017).

Notwithstanding the rating systems may be promising in pointing out areas where sustainability can be enhanced during the construction and maintenance phases, their success will depend on the availability of comprehensive data. Furthermore, researchers and decision-makers have highlighted several desirable features that are partially or totally lacking in these rating systems (Andreas et al., 2010). Self-assessment feature, customizability of criteria, and the choice of relevant criteria were identified as some of the desirable features generally absent in transportation infrastructure rating systems (Simpson et al., 2014). Additionally, aggregating all the indicators into a single score prevents decision-makers from seeing the underlying performance across project sustainability objectives (Haider et al., 2016). A pro-active consideration of sustainability goals for managing infrastructure assets therefore requires the setting of targets and the definitions of indicators that will allow decision makers, owners and operators to assess the current state of infrastructures, report on their technical, economic, environmental and social performances, and predict future conditions and performances from a cradle-to-grave perspective. This multi-dimensional and life cycle thinking-based approach goes well beyond the traditional single-discipline evaluation of performance prevailing in some rating systems and “Report Cards”.

## 1.2 Aim of this study: Multi-criteria sustainability assessment tool

The decision-making process in infrastructure management is, generally, a difficult, complex and multi-attribute exercise due to its multidimensional

nature and the participation of multiple stakeholders with different interests and views.

The challenge is, then, to develop a sound, comprehensive and user-friendly decision support tool (DST) that is flexible and capable of combining both quantitative and qualitative economic, environmental and social criteria into a single analytical framework, while capturing all of the priorities of multiple stakeholders in the decision-making problem, with the ultimate goal of guiding and supporting decision-makers in the early stages of the decision-making process to rationalize their decisions. Thereby, decision-makers are provided with a systematic framework that breaks the discrete decision problem into its basic components, making it easier to compare and ultimately ranking the various and competing transportation infrastructure construction and management practices intended to advance infrastructure sustainability.

In this paper, a performance-based sustainability assessment tool for road pavements and railway tracks (hereafter identified as SUP&R DST) developed under the framework of the SUP&R ITN research project is presented.

## 2 METHODOLOGY

The methodology of the proposed sustainability-based DSS follows the diagram presented in Figure 1 and is described in the sub-sections below. It comprises the following stages: (1) selection of the environmental, economic and social indicators to be adopted for sustainability assessment; (2) definition of the alternatives to be compared and evaluation matrix formulation; (3) definition of the decision-making matrix, which includes the specification of the weights to be assigned to each indicator and the assessment of the performance of each alternative with regard to each indicator; (4) performance of the Multi-Criteria Decision Analysis (MCDA) to rank the sustainability of the finite number of alternatives; and (5) sensitivity analyses of important input parameters and alternatives' scores to determine their impact on the ranking of the alternatives.

### 2.1 Sustainability Assessment framework

In the SUP&R ITN project several efforts have been employed for the determination of a systematic approach for defining a conceptual framework applicable to pavement construction and rehabilitation (Bryce et al., 2016). In particular, the DPSIR (Driving-Force-Pressure-State-Impact-Response) framework has been dipped in a performance management framework for establishing an evaluation process for

responsive actions that is based on sustainability objectives. The DPSIR, introduced by the European Environmental Agency (EEA) in 1999, represents the conceptual structure for understanding, modelling and therefore managing the cause-effect relationships between components of social, economic and environmental systems that mutually interact. As illustrated in Figure 1, the five nodes of the DPSIR structure combine human actions, environmental and economic aspects. In the case of infrastructure, it is possible to identify the Drivers as the economic and social needs for roads and railways. Pressures on the natural environment (emissions and waste) are the effects of driving forces, the construction and maintenance, which consequently cause changes to the State of the environment. The consequences on the State are analyzed and described in the Impacts. The decision makers are asked to develop Responses to mitigate the negative changes of the State. Responses might address any part of the system (Smeets and Weterings 1999; OECD 2003).

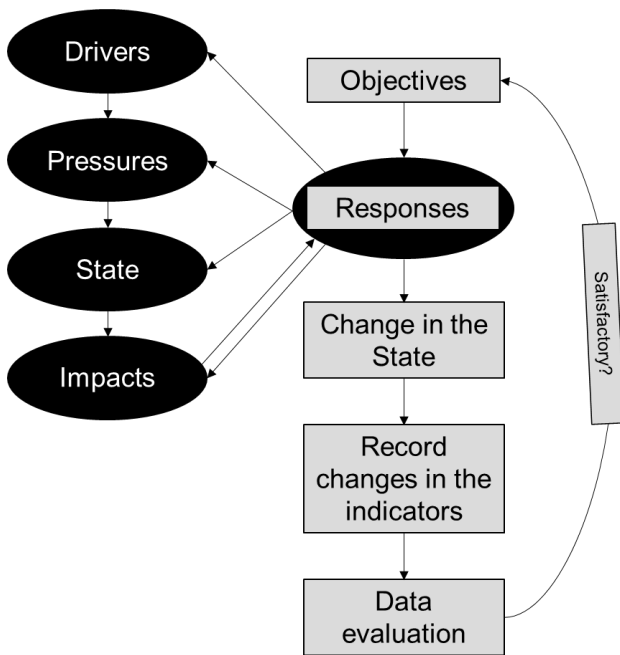


Figure 1. Integrated framework for the evaluation of responses to environmental stimuli.

The DPSIR framework was adopted to identify general categories that are progressively break down into sub-categories and indicators. This process led to the definition of an objective hierarchy (categories and sub-categories summarized in Table 2, indicators in the next section) that aims at maximizing the positive impacts towards each objective at the base of the hierarchy. The hierarchy represents a strategic approach that can guide the use of materials and technologies for road and rail projects to promote the fundamental objective of increased sustainability. Moreover, it allows a direct connection between the

more general Wellbeing dimensions and the realization of the infrastructure to be created that can be transformed into practical guidelines.

Table 2. Categories and sub-categories defined for road pavements and railway track-beds.

Wellbeing dimensions	Category	Subcategory
Environmental	Healthy Climate and Resources	Climate change
		GHG emissions and non-renewable resources
		Energy
		Life-long pavements
		Albedo
		Land resources
	Healthy Natural Environment	Local materials
		Recycling and materials conservation
		Waste
		Storm water, water use and water pollution
Healthy Ecosystems	Land pollution	
	Air quality	
Social	Healthy People	Marine life
		Terrestrial life
		Project/Occupational safety
		User safety and comfort
	Healthy Community	Occupational health
		Environmental health for humans
		Human health
		Personal development
		Visual pollution
		Light pollution
		Noise pollution
		Traffic
		Labor issues
		Equality
Education		
Cultural/historical preservation		
Good governance		
Improved urbanization		
Economic	Healthy Economy	Global economy
		Life cycle costs
		Employment

### 3 INDICATORS SELECTION

The methodology adopted to select the final sets of indicators comprises several interdependent steps (Figure 2). In the first step, the indicators collected and stored in the database were screened according to the following criteria:

1. **Measurability.** An indicator should be measurable and the unit indicated.
2. **Unique and globally accepted definition.** Every indicator should be clearly defined and its definition should be unequivocal and unambiguous.

3. Recurrence. The number of publications or tools in which an indicator is mentioned represents a measure of the importance that the scientific community assigns to a specific sustainable concern.

This first step of the selection process allowed a set of promising indicators to be identified. Nevertheless, in order to obtain a sustainability assessment tool that is really applicable a more compact set of indicators is required. Thus, other key aspects similar to those taken into account by Castillo and Pitfield (2010), Brodie et al. (2013) and Marsden et al. (1956) were considered to narrow down the list. Specifically, the following criteria were taken into account: (1) sensitivity; (2) updatable data; (3) available data, and; (4) non-corruptibility.

An indicator is sensitive if it is capable of capturing any variation in the system in order to measure comprehensive progress towards goals. An indicator should be based on data that are rapidly updatable to capture their evolution over time. Moreover, it should be possible to easily and at an affordable cost, collect reliable data on the indicator or predict its value. An indicator is non-corruptible when it does not show an improvement without corresponding to a positive improvement in the outcomes.

In the second step, a scoring procedure similar to that adopted by Castillo and Pitfield (2010) was considered, meaning that each indicator was given a score based on a three-point scale (i.e., 0, 1 and 2 points) for each criterion. Thereafter, the indicators that were given a score of zero in any of the individual criteria aforementioned were automatically excluded from the list of candidate indicators. In turn, the indicators still in contest for selection were ranked based on the sum of the scores gathered in all criteria. According to the scoring system adopted and the number of criteria considered, the maximum score that an indicator can obtain is 8 points.

The retained indicators were posteriorly reorganized to understand how they could be applied across the lifecycle of a road and rail project based on the different phases characterizing it. Once performed this sorting process, only the indicators describing an impact in this framework were kept. The phases considered were the following:

1. Design. Definition of the type of intervention and pavement or track-bed structure. Definition of the most appropriate materials and layers for the specific case.

2. Materials production. This phase includes plant process, type of raw material and energy for the production, transport.

3. Construction. Series of operations for building the infrastructure and for the complete execution of the project such as scraping, rolling, grinding etc.

4. Use, planned maintenance and rehabilitation. Series of operations scheduled to assure a satisfactory

level of transportation for the entire service life of the infrastructure.

5. Dismantling. This is the end-of life phase that involves all the operations of demolition, transportation, potential recycling, reuse, disposal of the waste.

In the next step, the third quartile (75th percentile) of the recurrence of the indicators still eligible was calculated. This value was used as a threshold, meaning that any indicator with a recurrence value inferior to that value did not qualify to be included in the final list of indicators. The application of this method to the indicators stored in database resulted in a threshold value of 4 for both road pavements and railways track-beds, respectively.

Finally, in the last step, the eligible indicators were subject to a critical judgment that would determine their fate with regard to the inclusion in the final short-list. Complementarily, the indicators excluded throughout the selection process were given the possibility of being taken up in face of well justified reasons. The rationality for the consideration of this stage is sustained by the following points:

1. To allow for the consideration of indicators belonging to misrepresented sustainability; dimensions (i.e., social sustainability);

2. To account for norms, reports and guidance documents published by leading authorities as well as for the outcomes of research projects with relevance in the topic;

3. To ensure a balanced distribution of the indicators among the several mean-objectives and subcategories considered.

4. To allow for the consideration of singularities related to specific indicators. An example that illustrates the applicability of this point pertains to the toxicity eco-toxicity indicators.

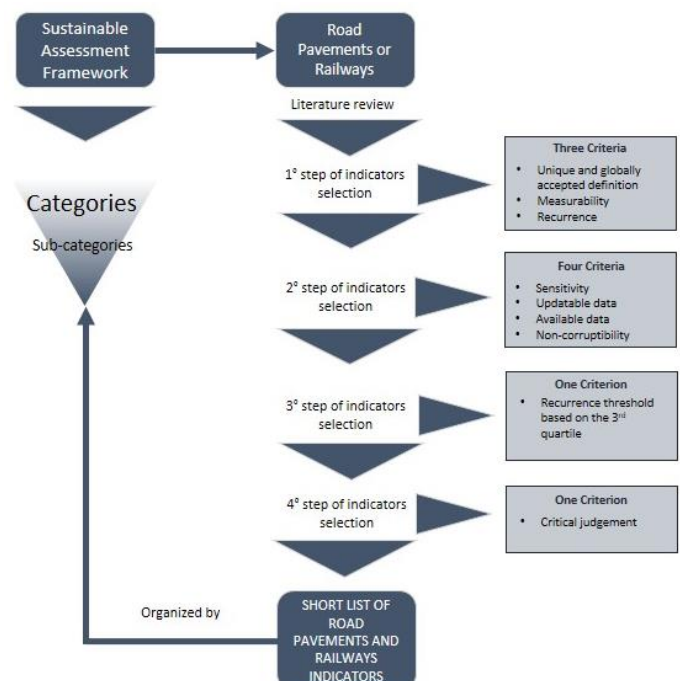


Figure 2. Schematic representation of the methodology adopted for selecting the two set of indicators.

Indeed, recent studies demonstrated that the features of the phenomena addressed by toxicity and eco-toxicity indicators make them, in general terms and apparently, interesting indicators to be included in methodologies that aim to assess the sustainability of infrastructure projects (e.g., eco-toxicity is very sensitive to construction phase; it can be used in the modelling of the end-of-life to assess the pollution after landfilling, etc.). However, a decision concerning its inclusion in methodologies intended to be used in a very short-term must take into account the following aspects: 1) these indicators require data that are not systematically collected across Europe (numerous pollutants may play a role in the variation of the toxicity and eco-toxicity scores); (2) the required data exhibit high errors associated with their collection practices; and; 3) these indicators exhibit strong variation, which for the moment are not explainable at light of a scientific basis. Those were the reasons why they were considered in the list of indicators produced in the scope of the European project LCE4ROADS (<http://www.lce4roads.eu/>) but were excluded from the list defined by the CEN/CENELEC Workshop Agreement (CWA) on SUSTINROADS - Sustainability assessment of roads which is supposed to be applied very shortly in standardization.

The final short-list of indicators for road pavements and railway track-beds resulting from the application of the methodology described previously is reported in Tables 4 and 5 and show the total score obtained by the indicators, the recurrence and the belonging subcategory of each indicator, for road pavements and railway track-bed respectively.

Table 1. Final shortlist of indicators selected to ascertain the sustainability of road pavements.

<i>Roadway indicator</i>	Recurrence	Subcategory	Score*
<i>Healthy Climate and Resources</i>			
Global warming indicator	71	Climate change	7
Energy demand	2**	Energy	7
Secondary materials consumption	2	Recycling and material conservation	8
<i>Healthy Natural Environment</i>			
Materials to be reused or recycled	2	Waste	8
Water consumption	9	Storm water, water use and water pollution	7
<i>Healthy Ecosystems</i>			
Eutrophication indicator	12	Marine and terrestrial life	8

Acidification indicator of soil and water	17	Marine and terrestrial life	8
Ozone depletion indicator	10	Marine and terrestrial life	8
<i>Healthy People</i>			
Particulate matter	24**	Human health	5
User comfort	2	User safety and comfort	6
Safety audit & safety inspection	2	Project/Occupational safety	6
<i>Healthy Community</i>			
Noise reduction	2	Noise pollution	6
Traffic congestion	31**	Noise pollution	8
<i>Healthy Economy</i>			
Life cycle cost Agency cost	67	Life cycle costs	8
Life cycle cost User cost	18	Life cycle costs	8

Notes: \*- The maximum score equals 8 points; \*\* - There are in the literature several indicators conveying (totally or partially) the meaning of energy consumption/demand. However, only in two cases it is reported with this name and corresponding definition; \*\*\* - This indicator is also termed in the literature as *Human Health Criteria Air Pollutants and Respiratory effects caused by inorganics*; \*\*\*\* - This number refers to the case in which the additional travel time experienced by the road users during the event of a pavement M&R activity is monetized.

Table 2. Final shortlist of indicators selected to ascertain the sustainability of railways track-bed.

<i>Roadway indicator</i>	Recurrence	Subcategory	Score*
<i>Healthy Climate and Resources</i>			
Global warming indicator	32	Climate change	7
Energy demand	14	Energy	8
Secondary materials consumption	2	Recycling and material conservation	8
<i>Healthy Natural Environment</i>			
Materials to be reused or recycled	2	Waste	8
Water consumption	7	Storm water, water use and water pollution	8
<i>Healthy Ecosystems</i>			
Eutrophication indicator	10	Marine and terrestrial life	7
Acidification indicator of soil and water	12	Marine and terrestrial life	7
Ozone depletion indicator	7	Marine and terrestrial life	7
<i>Healthy People</i>			
Safety impact	3	Project/Occupational safety	8
User comfort	2	User safety and comfort	8
Particulate matter	9	Human health	6
<i>Healthy Community</i>			
Noise reduction	4	Noise pollution	8
<i>Healthy Economy</i>			

Notes: \* - The maximum score equals 8 points.

### 3.1.1 Overview of indicators available in the literature

In this research work, an extensive literature review covering articles published in peer-reviewed international journals, reputed conferences, books, reports, guidance documents, rating tools (including manual, user guidelines and by exploring the tool itself) and relevant research projects on the sustainability assessment of road and railway infrastructures was initially conducted to identify the criteria and indicators that have been used to measure the sustainability of road pavement and railways projects. This literature review was meant to build a database of indicators that was posteriorly used to define a set of indicators distributed by categories and subcategories, which are intended to be the most relevant for a broader and complete sustainability assessment of road pavements and railways track-beds projects considering all the pillars of sustainability.

The content of every item was analyzed and the main aspects highlighted. An example of the key information of two selected papers is shown in Table 6. The frequency distribution by publication year is shown in Figure 3.

Table 6. Example of the data collected during the literature review.

Authors and year	Krezo et al. (2016)	Jones et al. (2017)
Title	Field investigation and parametric study of greenhouse gas emission from railway plain-line renewals	Life cycle assessment of high-speed rail: a case study in Portugal
Geographical context	Australia	Portugal
Scope of the study	Railway transportation mode	Railway transportation mode (high speed)
Level of analysis	Project	Project
Indicators	CO <sub>2</sub> , Greenhouse Gas Emission (GHG), Abiotic resource depletion	Climate change, terrestrial acidification, particulate matter

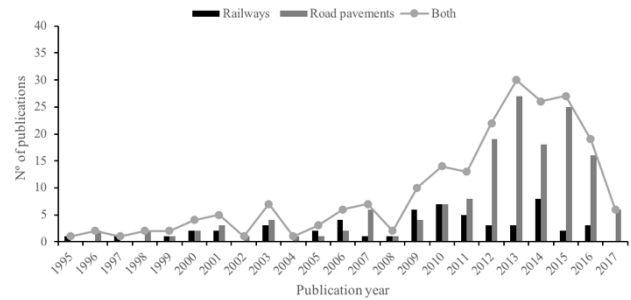


Figure 3. Number of publications per type of infrastructure.

The analysis of Figure 3 shows a slow and relatively steady increase in the combined number of publications from 1995 up to 2008. 2008 marks clearly a change in the tendency observed previously. From this year up to 2013 there is a sharp increase in the combined number of publications. This tendency is followed by a decrease, which may suggest that the research interest by the topic may have reached its maturation point. However, care must be taken when drawing this conclusion given the precocity of the inversion in the tendency. As far as the number of publications per type of infrastructure is concerned, Figure 3 displays an even number of publications up to 2011, after which the road pavement denotes a remarkably increase in the number of publications in comparison to that observed for the railways domain.

Regarding the type of indicators considered by the literature some considerations can be drawn. For instance, most of the literature elements rely on the consideration of environmental (mainly) and economic indicators to assess infrastructure sustainability, while the consideration of social indicators is rather limited. On one hand, this could be due to the tendency of addressing the social aspects in an indirect way, for instance encouraging the use of recycled materials and reducing waste. On the other hand, the social impacts may be considered, by who is not familiar with the social sciences, as mere perceptions or emotions, not belonging to reality. This phenomenon is known as social construction of reality (Rabel et al., 1994). Moreover, as highlighted by recent studies (Lucas, 2007) the indicators that contribute to the social sustainability and the interactions between social, economic and environmental outcomes are the least developed and understood.

The Interorganizational Committee on Guidelines and Principles for Social Assessment defines the social impact as the consequence to human populations of actions (design, construction, maintenance and dismantling) that alter the way people live, work, build relationships and generally cope as members of society. The social impact includes cultural aspects involving with beliefs, norms and values (Rabel et al., 1994). While for instance the consumption of energy and the CO<sub>2</sub> can be directly calculated as the consumptions and emissions of every stage of a process,

the study of the social indicators is based on the effects on a community where the infrastructure will be constructed. Therefore, it becomes fundamental to involve local communities that will be affected by the project under appraisal. “Interactions among all disciplines and stakeholder groups are essential to forge partnerships that will solve environmental problems, rather than deal with only one aspect in isolation” (Burger, 2008).

## 4 MULTI-CRITERIA DECISION ANALYSIS

SUPR&R DST is based on the MCDA approach with PROMETHEE II – Preference Ranking Organization Methodology of Enrichment Evaluation (Brans et al. 2005) This was implemented, enabling a quicker ranking and thereby identification of the most sustainable pavement and railways track construction and management solution.

### 4.1.1 *The PROMETHEE-II method*

In order to rank each alternative based upon its sustainability level, the proposed DSS implements an outranking MADA method, namely the PROMETHEE-II method (Brans and Mareschal, 2005).

An outranking approach was selected because of its non-compensatory nature, in the sense that a bad performance on an indicator cannot be compensated with a good performance on another indicator. According to Munda (2005), complete compensability is not desirable in a method for tackling sustainability decision problems. The rationale underlying to this statement lays on the concept of “strong sustainability”. According to this concept, natural capital is a set of complex systems, evolving interacting abiotic and biotic elements, whose consumption is irreversible and irreplaceable by manufactured capital and thus, no trade-offs are admissible. This concept contrasts with that of “weak sustainability”, according to which natural capital and manufactured capital are substitutable and no essential differences exist between the kinds of well-being they generate (Ekins et al., 2003). Therefore, in view of the implementation of the concept of “strong sustainability”, which constraint or abolish the compensation among sustainability dimensions, outranking approaches should be preferred to performance aggregation-based approaches.

Finally, as for the PROMETHEE-II method, its selection was driven by the following facts: (1) it is one of the best known outranking methods (Sultana and Kumar, 2012), with an applicability level extended to multiple domains (Behzadian et al., 2010); (2) it has a transparent computational procedure which can incorporate both quantitative and qualita-

tive data; (3) it requires fewer parameters from the decision maker when compared to other outranking methods, such as the ELECTRE (Betrie et al., 2013); and (4) the comparison of the alternatives can be performed without difficulty, producing results that consist of a ranking and the identification of the best alternative, and thereby are of easy understanding for any decision maker/stakeholder, regardless of its expertise level.

### 4.1.2 *Weighting Methodologies*

The weight of an indicator is a measure of how much it is important with respect to the other indicators. The SUP&R MCDA methodology comprises two weighting approaches: subjective and objective. Furthermore, each approach features two alternative weighting methods.

The subjective approach determine the weights of the indicators based exclusively on preference information of indicators provided by the decision maker. On. This regard, the tool provides a weighting set derived from an Analytical Hierarchical Process (AHP)-based survey conducted in the framework of the SUP&R ITN research project. This weighting set is named SUP&R ITN weighting set and implemented in the tool. Whereas in the objective approach weights are determined by employing mathematical models without any consideration of the decision maker’s preferences. The objective methods considered in the SUP&R DST methodology include the Entropy and the Mean weight methods.

## 5 OVERVIEW OF THE TOOL

SUPR&R ITN DST was developed using C#, on Visual Studio 2015. The database engine used is the SQL Server 2014 Management Studio, where all the user’s and default data are stored. The SUPR&R ITN DST framework is displayed in Figure 4.



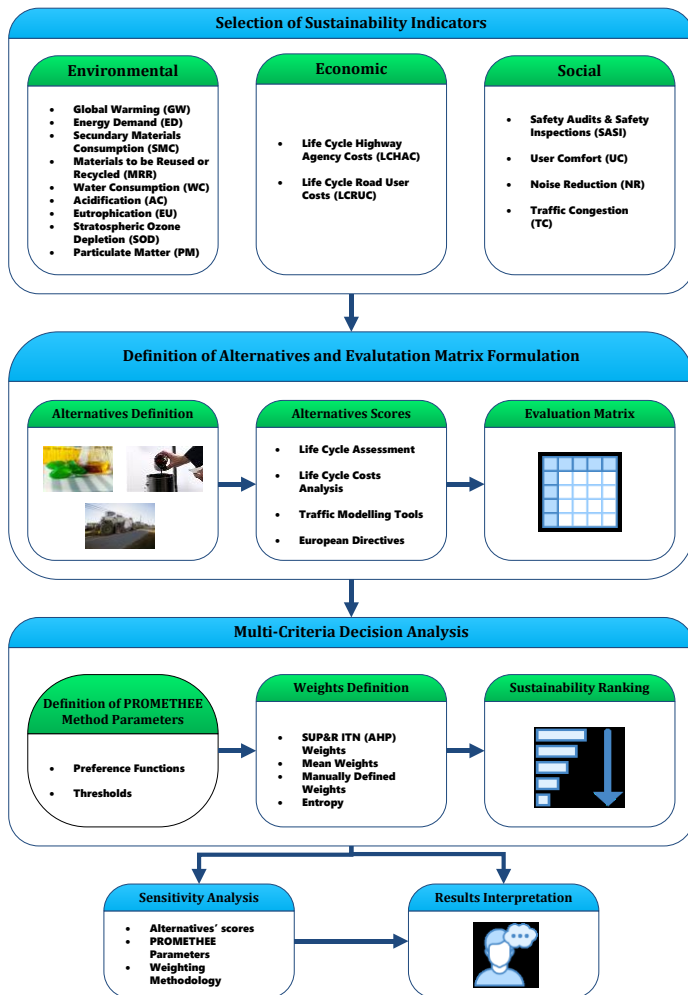


Figure 4. Schematic representation of the methodology adopted for selecting the two set of indicators.

- The first step consists of selecting the set of indicators that will rationally prioritize alternatives. The DST comes with a set of default indicators defined according to a methodology developed under the framework of the SUP&R ITN project (Bressi et al. 2017) with the final aim of maximizing their significance to the three Wellbeing dimensions. Nonetheless, the user is enabled to add and consider other indicators.

- In the second step the evaluation matrix is formulated. It corresponds to assess the performance of each alternative with regard to each indicator. This information is inserted by the user and might be both qualitative and quantitative, depending on the type of indicator.

- In the third step the matrix undergoes a filtering process. First, a dominance analysis is performed, meaning that the various alternatives are compared for each indicator individually. It allows to identify if a given alternative is better than the others for all the considered indicators. If so, that alternative might be excluded from the analysis depending on the user's intention. Next, a correlation analysis is undertaken by calculating the Pearson's correlation coefficients

to determine if there is a correlation between the selected indicators. The DST displays in matrixes the Pearson's correlation coefficients values as well as the results of their statistical significance. This procedure is done by calculating the t-statistic value of each correlation coefficient at the level of significance of  $\alpha=0.05$  and the respective p-value. Additionally, multivariate descriptive statistics (i.e., covariance matrix) and univariate descriptive statistics (i.e., mean, standard deviation, variance, maximum value, minimum value and range value) are also made available to the user in matrixes.

- In the step 4 the user has to decide about the relative importance (weights) of the different indicators. For that purpose, two different weighting approaches were considered, namely objective and subjective approaches, and for each one several methods were made available. The set of objective methods comprise the Entropy, the Criteria Importance through Inter-Criteria Correlation (CRITIC), the Mean Weights and the Standard Deviation methods, whereas the set of subjective methods include the AHP-based SUP&R ITN weights and the Manually Definition method. The AHP weights were obtained from a survey conducted within the scope of the SUP&R ITN research project. It engaged stakeholders of different sectors and from several European countries.

- In the step 5 the user is asked to define the PROMETHEE-II parameters, what means selecting preference functions (PF) and respective parameters (preference, indifference and eventually Gaussian thresholds). PROMETHEE-II methodology uses PF, which is a function of the difference between two alternatives for any indicator. Six types of PF based on the notions of indicators can be selected. Regarding the definition of the parameters, two alternative approaches were made available: an absolute value-based and a relative value-based approach. The relative value-based approach was considered with the objective of helping the users who do not have sufficient knowledge about the decision-making methodology. According to this approach, the parameters values are calculated as a user defined percentage of the difference between the highest and lowest evaluation for each indicator.

- In the step 6 the multi-criteria decision analysis results are displayed. They consist of the ranking of alternatives as well as several other PROMETHEE intermediate and final outputs (e.g., preference indexes, incoming, outgoing, and net flows).

- In the step 7 the user is given the possibility of conducting an uncertainty analysis to investigate the influence of modified input data and methodological choices on the calculated results and stability of the

solution found as the most sustainable. The set of input data and methodologies allowed to be changed comprise the evaluation matrix, the weighting method and the PROMETHEE PF and parameters.

## 6 CONCLUSIONS

The implementation of best practices for promoting more sustainable construction and maintenance activities and technologies for road pavements and railway track-beds projects should be a guided process, in which the sustainability performance is required to be properly assessed by using a systematic framework. The SUP&R DST is a freely available tool and can be used at professional level, by professionals interested in assessing sustainability of transport infrastructure technologies already at the design stage. The tool can be used for educational purposes, to provide knowledge and educate on the use sustainability concepts and on what are the important issues to consider during the sustainable transportation decision-making process. The methodology makes uses of multi-criteria decision analysis, it's now tailored for road pavements and railway trackbeds, however it's flexible enough to be adapted to any system.

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