Facilitating the adoption of sustainable technologies in the asphalt sector

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ABSTRACT

A need exists to bridge the gap between innovation in the bituminous materials sector and adoption of the new technologies by national road administrations (NRAs). The Evaluation and Decision process for Greener Asphalt Roads (EDGAR) enables NRAs to do this by providing an assessment methodology which makes sustainability information on new technologies readily accessible to the decision-making process, and therefore facilitates quick adoption of the technologies that offer the greatest sustainability benefits for the highways sector and society as a whole.

EDGAR commenced with a wide-ranging review of the range of 'green' technologies in the bituminous materials sector and the sustainability benefits that they offer. Two methodologies to assist NRAs were then devised. The first acknowledged that the ability to recycle asphalt is its foremost environmental attribute, and devised a quick, qualitative method for the assessment of recyclability. The second devised a methodology for a more detailed assessment of the sustainability of any bituminous technology, considering all three facets of sustainability: environmental, social and economic, with particular attention given to how the information might be used in the decision process by NRAs, and the common challenges they might encounter when assessing a 'novel' technology.

Keywords: Asphalt, Health Safety and Environment, Life cycle assessment, Reclaimed asphalt pavement (RAP) Recycling, Strategic Highway Research Program

1. INTRODUCTION

The EDGAR project aims to develop methodologies for the sustainability assessment of novel 'green bituminous mixtures'; a general term which has been used to apply to any type of bituminous mixtures produced using specific materials or technologies with the aim of reducing the environmental impact.
The project's outputs are mainly intended for European national road authorities (NRAs), who have to make decisions to allow or refuse the use of novel materials and technologies on the road network.
The reduction of energy consumption and CO_2 emissions are important motives for implementing the use of new materials and technologies, but the quantification of only these parameters is not sufficient to demonstrate their viability in terms of sustainability:

- There are other environmental impacts to be considered, as described in the European norm EN 15804 [1], which defines core rules for preparing Environmental Product Declarations (EPDs) for construction products.
- Road authorities have to balance environmental considerations against social and economic considerations; the safety and wellbeing of road workers, road users and residents is crucial and financial means are limited.
- A long term vision requires the consideration of environmental, social and economic impacts from a life cycle perspective, including all stages from cradle to grave and the benefits and loads beyond the end of life (EoL). Such a long term perspective is only possible when the performance of the bituminous mixture is known and the expected lifetime can be estimated with sufficient confidence.

Based on an initial review of relevant standards, it became clear that the methodology for evaluating green asphalt mixtures should be based on the principles of life cycle assessment (LCA), but extended in scope to consider environmental, social and economic impacts. The framework is designed to complement the Environmental Product Declaration (EPD) process. Figure 1 indicates how this might work.

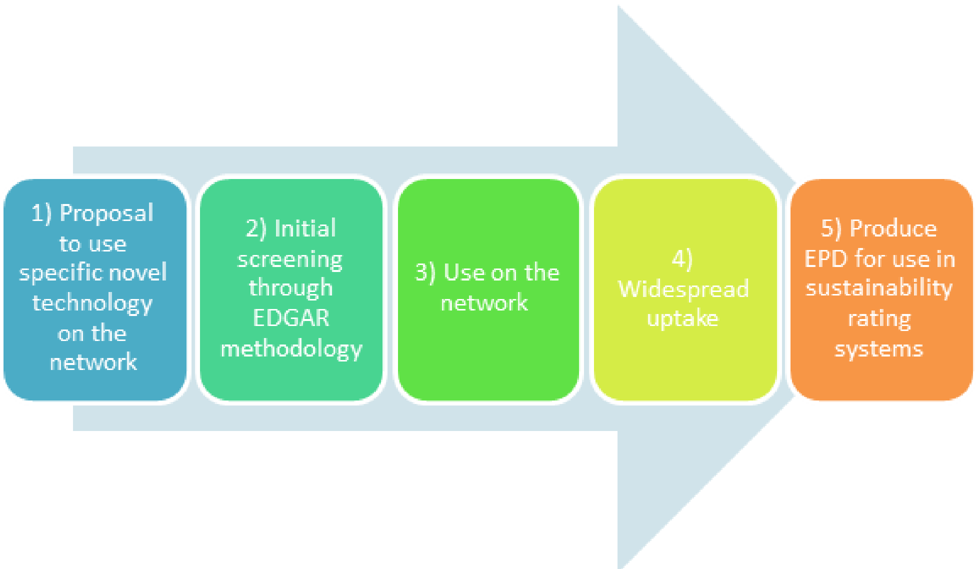

Figure 1: The EDGAR methodology in the context of EPDs

This paper details the approach taken to developing a sustainability assessment process for novel bituminous technologies, and the resultant methodology for NRAs to use. At the time this paper is being written, the EDGAR project is still ongoing. The methodology is in the process of being finalised and the next phase of the project will demonstrate the methodology using a number of test cases.

2. REVIEW OF MATERIALS AND TECHNOLOGIES

The first task within the EDGAR project was to conduct a wide-ranging review of existing literature, including completed or ongoing research projects related to "green" technologies and their impact on sustainability. This resulted in a report [2] that:

- Provides an overview of available information on 'green' technologies used in the bituminous materials sector, specifically the information related to key sustainability criteria.
- Makes a critical evaluation of the information available and identifies gaps in the existing knowledge.
- Identifies 'alerts' for a given material or technology. These are issues that have been identified that could possibly jeopardise overall sustainability performance and therefore should be concerns raised by NRAs.

Table 1 shows the categories of technologies considered. This list is not exhaustive, but includes the main technologies that are already available to road administrations and other clients.

Table 1: Technologies selected for review

Family of technologies	Sub categories
Warm and half-warm asphalt technologies	Foam based Using organic additives Using chemical additives
Cold and semi-cold asphalt technologies	Emulsion based Foam based
Asphalt recycling	Plant recycling In situ recycling
Secondary and open-loop recycled materials	Steel slag Fly ash Crumb rubber Shredded roofing Crushed glass
Alternative and Modified binders	Vegetal or bio-binders Sulphur modified/extended binders PMB (Polymer modified bitumen)
Additives	Anti-stripping agents Pigments for coloured asphalt Fibres Rejuvenators

For each of these technologies, the review considered the information and data identified that was related to the following sustainability indicators:

- global warming potential
- use of energy and material resources
- air pollution
- recyclability at the end of life
- health and safety
- financial/economical costs

Performance aspects were also considered, since durability is the key determinant for material replacement rates. Whilst it served its purpose for the literature review, this initial set of sustainability indicators was considered to be rather unrefined and not complete. An in-depth review of the relevance of various sustainability indicators in the field of bituminous materials has led to formulation of a more adequate "basket of indicators" later in the project (see Section 5).

The review has shown that there are still many knowledge gaps associated with the use of certain technologies, even though they may have already been in use for many years. Furthermore, sustainability information is often limited to one stage in the life cycle where the most notable gains can be demonstrated (usually the production stage). NRA's and other users should be aware that these gains can be partly or totally neutralised in another stage (e.g. in the production of raw materials or transport).

Regarding the main categories of sustainability criteria that were considered, the following general conclusions were drawn:

- Global warming potential is one of the most commonly evaluated impact categories. For bituminous mixtures, GWP is mainly attributed to the processes of extraction/production of the raw materials, drying/heating and transport. For the processes of drying/heating and transport, GWP can be estimated or measured fairly well. However, for the extraction/production of the constituent materials (including special additives), information is often missing.
- The use of resources for energy is also well covered, but the findings are similar to what is found for GWP. This is logical, since the emission of CO_2 is largely due to the combustion of fossil resources for drying, heating and transport. This suggests a strong correlation between GWP and the use of resources for energy for bituminous materials. Both indicators do not therefore need to be measured.
- Materials used over the life cycle of bituminous mixtures are mainly the constituents of the mixture itself. There is, of course, a significant positive impact from the use of reclaimed asphalt (RA) and secondary materials. The use of RA is particularly beneficial, since not only does it conserve aggregates from primary sources, but also bitumen. However, for various special additives, the use of material resources for the production of the additives is rarely documented or considered, which often leaves an incomplete picture with regard to the overall sustainability of the product.

- Air pollution is often assessed by measuring emissions at the plant or worksite. This is a good, objective way of investigating the air pollution associated with the production and construction stages. However, it is very difficult to find information on the air pollution associated with the production/extraction of the constituent materials or the processing of RA and secondary materials.
- Health and safety issues are rarely discussed, probably because it is very complicated and difficult to demonstrate if there are any impacts. Some researchers did measure the exposure of workers to air pollutants, dust and various chemical substances. Results were often below the detection limits of the measurement equipment.
- The impact on financial cost is reasonably well documented, but the impact is variable depending on many factors, such as the size of the plant, the amount of bituminous mixtures produced and the evolution of the prices of materials and energy over time. NRAs need to estimate the cost over the entire life cycle, which also depends on the maintenance needs, the estimated lifetime and a discount rate, used to determine the present value of future cash expenditure. This requires additional information which is not always available.
- It is usually claimed that recyclability will not be affected by the material or technology used. However, a precautionary approach should be taken to the use of some additives which may cause future health risks when recycling takes place at EoL. Even if there are no health risks, there are several levels of recyclability, achieved through hot or cold methods, or down cycling the RA to unbound applications. Recyclability is never discussed in such depth.
- Performance is well covered for many techniques, thanks to the performance based test methods that are now standard in Europe (wheel tracking, water sensitivity, fatigue, etc.). The fact that the use of RA is possible without a loss of performance is generally accepted, but this requires a correct mix design and handling/storage procedures for the RA, in order to control the risks and uncertainties associated with heterogeneity and variability of the RA characteristics.

This review was useful in terms of framing future work in the EDGAR project:

- It provided a good overview of current knowledge and knowledge gaps, but it also recognized that the information remained very general and the reliability was often variable.
- One of the biggest problems is that the boundaries of the system to which the data apply were not always well defined. In that case, it was very difficult to interpret or compare data. It became clear that, for the following work packages of EDGAR, the project team would have to dig deeper to find more detailed and reliable data, or methodologies that can be utilized to provide more evidence.
- The importance of recyclability confirmed the need for a quick assessment tool, which considers the consequences of using a specific technology on the recyclability of the asphalt at the end of life.
- The criteria on which the EDGAR methodology will be based should not be too detailed, since the literature showed that it would be very hard for NRAs to find all the required detailed information.

For some technologies there exists sufficient evidence that suggests that no impact with be observed in relation to many of the sustainability indicators. In that case, NRAs will only have to be concerned by those indicators for which alerts or knowledge gaps have been identified.

A further output of this review was the so-called ‘matrix of considerations’ [www.ntnu.edu/web/edgar/edgar] (see Step B in Section 4 below). This matrix indicates what type of additional evidence a NRA may wish to acquire or demand from producers or material suppliers to make an informed decision regarding the use of a particular technology.

3. RECYCLABILITY ASSESSMENT

As a prior step to assessing novel technologies or materials based on the full set of indicators, and, bearing in mind the importance of recyclability for construction materials, a flowchart was developed to provide a qualitative check. The flow chart results in a recyclability score.

In the case that an EoL product is not recyclable at all (e.g. tar containing asphalt which has to be taken out of the recycling chain by local legislation), it is considered that further assessment is not worthwhile since the inability to recycle a construction material severely negates any other positive sustainable attributes. Where recyclability is a possibility at EoL, a succession of qualitative and semi-quantitative questions are posed in order to assess the recyclability and obtain a score between the ideal 100% and 0%. Penalty factors during the assessment process decrease the score from the starting value of 100%.

The hierarchy of questions that are used to determine overall recyclability are as follows:

- *Is recycling permitted?*

If recycling is forbidden by legislation or the NRA decides to preclude a product from being recycled, the score for recyclability is immediately set to 0%.

- *Are there health and safety issues associated with excavation and treatment of the EoL product (e.g. milling, storage and sieving risks)?*

If there are unacceptable risks, the technology/material is rejected until the issues are resolved. If the risks are controllable, a penalty factor is applied, in order to take costs for supplementary measures into account.

- *Can the RA be reheated?*

If the material cannot be reheated for H&S reasons, cold in situ recycling is considered. If cold in situ recycling is not possible, the recyclability score is set to 0%. If it is possible, a penalty factor is added, because of the restriction on the possibilities of recycling in the next cycle. In the case where recycling through fixed plant, in situ hot recycling, or cold recycling is not restricted then no penalty factor applies.

- *Can in-situ recycling be applied?*

If yes, a penalty factor can apply if there is concern over the potential performance of the resultant product.

- *Are EoL products fully recyclable?*

If only a fraction (e.g. separated by sieving) can be recycled, a penalty factor applies.

- *Can the EoL products be recycled at the same level in a similar type of mix as they were originally used or will properties change/degrade, so that lower level applications must be considered (down cycling)?*

If reclaimed asphalt can be recycled while fully exploiting the materials potential (without down cycling), this outcome is considered preferable to being recycled, for example, in an unbound foundation layer.

By following the flowchart in Figure 2, the recyclability score is obtained. This approach to recyclability assessment is more qualitative than quantitative and the penalty factors may appear rather arbitrary. However, by following this methodology, NRAs will be obliged to consider the questions listed above, and could relatively rank several options for a given material, and therefore become more aware of the implications that their decisions may have on the future recyclability of the asphalt. In the extreme case where it is certain that the use of a technology will prohibit its future recycling, this technology should not be used and no further in depth assessment would be required.

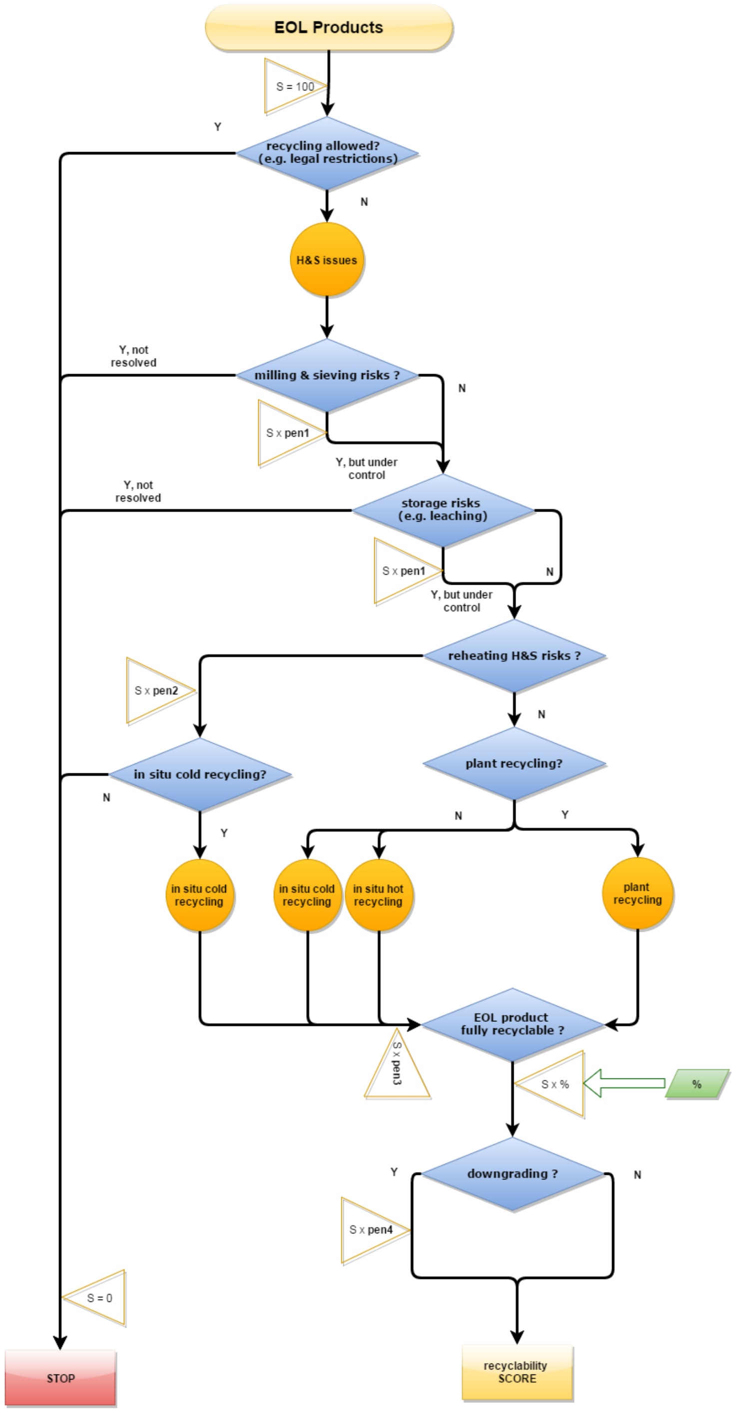

Figure 2: Flowchart to assess recyclability

4. EDGAR METHODOLOGY

4.1 Framework

The methodology is formulated in a six-step process, starting with NRAs raising concerns over a technology and ending with them enabled to make an informed decision over its use. The methodology provides assistance for NRAs at each key juncture, from identifying concerns, selecting the indicators to assess, performing the assessment, and evaluating the results with the assistance of weighting methodologies and conventional asphalt baselines. Figure 3 presents the structure of the framework.

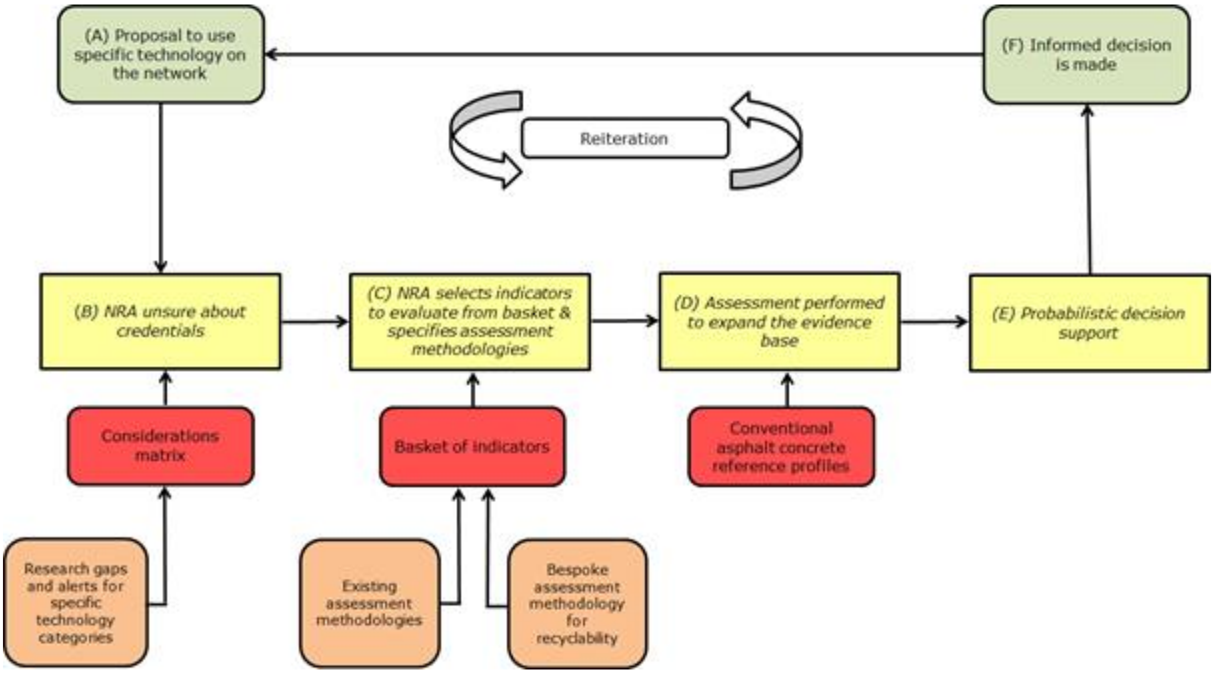

Figure 3: The EDGAR framework

The methodology is designed to facilitate quick adoption of new technologies on the network by enhancing the evidence base and allowing sustainable, informed decisions to be made.

4.2 Steps in the methodology

Step A – Proposal to use the novel technology on the network
An application is made by a contractor to use a new technology on the network. At this stage the product has already been CE marked by the manufacturer and a Declaration of Performance (DoP) drawn up to contain information about its performance in relation to the essential characteristics defined within the harmonised technical specifications.

Step B – NRAs unsure about the material or technologies' credentials
From a sustainability perspective, decision maker(s) in the NRAs are not fully confident about using a new technology on the network, or would like the evidence base supporting the material to be expanded in order to inform the decision-making process. The current evidence base might be lacking since it does not address perceived risks associated with use of the technology on the road network (whether environmental, social or economic), or does not make the advantages clear enough.

A 'matrix of considerations', produced from a synthesis of research supporting the adoption of different types of technology on highways, will assist NRAs to identify areas where the evidence base might be lacking for specific families of technology. More information on how this matrix was formulated is presented in Section 2 above and in EDGAR Deliverable 2.2 [3].

Step C – NRA selects indicators to evaluate from the basket of indicators and specifies the assessment methodologies
A basket of eleven indicators has been arrived at through evaluation of a wide range of environmental and socio-economic indicators in the context of bituminous mixtures and through the process of normalisation (see Section 5 and EDGAR Deliverable 2.2; [3]). The basket has been compiled to address the main sustainability concerns associated with the application of bituminous technologies on the network, across their full life cycle. Based on the list of concerns identified in Step B, the NRA will select the indicators that they would like to be measured. For each indicator, a methodology has been recommended. This would need to be specified by the NRA as the specified assessment methodology. The assessment process can be streamlined according to the level of confidence that already exists in use of the family of materials: the number of indicators selected might

be just one or two for established families of asphalt technologies, or a greater number if the technology is more emerging.

Step D – Assessment performed to expand the evidence base
The NRA might require the contractor to augment the evidence base, it may wish to do this in-house, or commission an independent third party to conduct the assessment, such as a test house or independent research organisation.

It is recommended that a 'control' is assessed in all cases; this would typically be conventional hot mix asphalt in widespread use such as asphalt concrete, if the proposed technology is a material, or conventional plant if the technology is targeted at a process improvement. This will give a point of reference on which to base relative comparisons of performance.

Step E – Probabilistic decision support
Having been provided with the results, the NRA can insert the results into the decision support framework that is described in more detail in Section 6 (and Deliverable 2.2 [3], to make the results obtained more manageable and comparable.

Step F – Informed decision is made
The decision support framework will assist the NRA in making a final decision over use of the technology on the network.

5. BASKET OF INDICATORS AND ASSESSMENT METHODOLOGIES

5.1. Selection

As described previously in Section 2, a fairly arbitrary selection of sustainability indicators was used to carry out the initial review of literature and projects. A further review of relevant standards, including EN 15804 [1], LCA normalisation of standard asphalt EPDs and a degree of expert judgment arrived at a more adequate basket of eleven indicators to use for sustainability assessment of asphalt products. These are outlined in Table 2.

Table 2: EDGAR basket of indicators

Indicator	Description
Global warming potential	Evaluating the contribution to climate change of the technology in material terms (cradle-to-gate) or its 'in use' effect
Depletion of resources & waste management	Assessing the overall 'material balance' of a tonne of asphalt, considering primary and secondary materials, and waste
Air pollution	Assessing pollution potential on the basis of air pollution (non-CO_2 emissions) during production and installation
Leaching potential	Assessing pollution potential on the basis of leaching potential to groundwater for the material in situ
Noise	Health & safety perspectives relating to surface characteristics of the materials used
Skid resistance	
Financial cost	In life cycle cost (LCC) terms, measured as net present value
Recyclability	Assessing the potential for the valuable properties of asphalt's constituents to be retained into the next lifetime
Performance (durability)	Using a selection of test methods to assess different characteristics of bituminous materials that relate directly to how long it will last in the pavement structure
Responsible sourcing	Evaluating social aspects related to the supply of constituent materials
Traffic congestion	Social aspects related to installation of the material at the road site and the consequences for road users

5.2. Assessment methodologies

Methodologies were reviewed in relation to each indicator and a recommendation of which to use was made. The EDGAR framework does not specify methods to use, realising that different RAs will have their own preferences where methods are concerned. However, some methodologies were recommended based on an extensive review and criteria deemed particularly pertinent (degree of material-focus, quantitative, speed of assessment and cost of assessment). The recommended methodologies are presented in Table 3.

Table 3: EDGAR recommended methodologies for assessment

Indicator	Selected methodology	Output format	Reference
Global warming potential	asPECT v4.0 (cradle-to -gate)	kgCO_2e per tonne of asphalt	[4]
	MIRAVEC (in use phase impacts)	CO_2 in tonnes	[5]
Depletion of resources & waste management	Indicator MD-2 from Greenroads v2.0	1 point. 8% recycled 2 points 18% recycled 3 points. 28% recycled 4 points. 38% recycled 5 points. 48% recycled	[6]
Air pollution	ECORCE v2.0 or PaLATE	Emissions per tonne of asphalt	[7], [8]
Leaching potential	CEN/TS 16637 leaching tests	mg pollutant / m^2 surface area	[9], [10]
Noise	Laboratory drum methods	Close-proximity (CPX) dB Statistical pass-by (SPB) dB	[11], [12]
Skid resistance	Pendulum test	pendulum test value (PTV)	[13]
Financial cost	LCCAExpress 2.0	$/mile	[14]
Recyclability	EDGAR bespoke methodology	A score 0-100	See Section 3
Performance (durability)	Resistance to fatigue	ε_6 microstrain	[15]
	Resistance to rutting	mm at rate µm/cycle	[16]
	Water sensitivity	ITSR %	[17]
	Stiffness	MPa	[18]
Responsible sourcing	BES 6001	Points system or Excellent / Very Good / Good / Pass	[19]
Traffic congestion	QUADRO	User costs (£) per traffic management scenario	[20]

All indicators have a quantitative output with the exception of 'responsible sourcing', that uses a points system to arrive at an excellent/very good/good/pass rating, Greenroads indicator MD-2 for depletion of resources, and 'recyclability' that arrives at a score (as detailed in Section 3).

6. DECISION SUPPORT

A decision support methodology, based on the work carried out by [21] has been developed. The proposed model aims to compare different types of "green" asphalt mixtures and assist the NRA in the decision making process. The multi-criteria model is divided into two main parts:

- In the first part, the data to be used for the decision analysis are generated through the assessment methodologies described in Section 5.2 and the evaluation of the various asphalt mixtures (i.e. alternatives) is entered. The criteria considered are basically the basket of eleven indicators described in Section 5.1.
- The second part of the model consists of the decision making process.

The decision making process is implemented in four steps. In the first level, a Pareto representation is used to identify the dominant processes over the lifespan of each asphalt mixture. This first level does not compare the various alternatives directly, but focuses on the contribution of each LCI phases to the total (pollutants) of a given indicator. A first comparison of the alternatives is conducted at the second evaluation level. To achieve this, various graphical analyses are used, permitting the user to highlight the potential outranking alternatives. In these first two levels, raw data are used, without any treatment or weighing.

Multi-Attribute Decision Making (MADM) methodologies are introduced in the third and fourth levels, with the introduction of user preferences and qualitative criteria. Existing methods applied in MADM domains were selected for implementation in the specific context of asphalt mixture evaluation. The application of MADM also permits the user to perform a sensitivity analysis of the ranking and include some probabilistic aspects characterizing the confidence in the alternative ranking. In the third evaluation level, a partial aggregation method using pseudo-criteria is proposed. The favoured option in this respect was the ELECTRE III method that presents the particular property of considering various outranking degrees by comparison of two alternatives. The fourth evaluation level uses an algorithm derived from the Evidential Reasoning approach, modified for application in the framework of MADM. The fourth evaluation level is also the most complex, but it allows the model to take into account the occurrence probability of a given performance, and data unknowns. Finally, the relative value of each alternative is calculated.

7. CONCLUSIONS AND PERSPECTIVES

Enhancing the evidence base in a targeted manner is a necessary step to improve confidence amongst road authorities to use novel bituminous technologies on the road network. Innovation in the bituminous materials sector has always been healthy, with a wide-range of technologies coming to market that address all elements of the asphalt lifecycle. However, uptake of these technologies has rarely reached potential, partly because NRAs have been unable to fully appraise the risks associated with full-scale deployment on the network. Furthermore the shift towards more sustainable practice now often features within the strategic approaches of NRAs, but the claims surrounding the use of novel technologies are often unfounded, or indeed unexplored, hence informed decision making with sustainability related issues cannot take place.

The EDGAR project set out to address some of the deficiencies in the evidence base surrounding the use of novel technologies and provide a framework for informed decision making with regards to sustainability aspects. The framework that resulted included a six-step process for NRAs to follow when considering a novel technology, commencing with raising concerns, selecting appropriate indicators from a basket of eleven, and utilising the results with the assistance of user-preference modelling to make a final decision concerning use of the technology. Use of the methodology will be demonstrated in the next stage of the project with a number of case studies that consider some of the main families of asphalt innovations: recycling, lower temperature mixing and the use of additives. The project will conclude in June 2016; all deliverables will be freely accessible on the project website: https://www.ntnu.edu/edgar

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