Sustainability & Environment

What do National Road Authorities know and do about sustainability assessment of road pavements and asphalt mixtures?

Ana Jiménez Del Barco Carrion[1], Tony Parry[1], Luis Neves[1], Elisabeth Kejzer[2], Diana Godoi[2], Suzanne de Vos-Effting[2], Björn Kalman[3], Konstantinos Mantalovas[4], John Harvey[5], Davide Lo Presti[1,4]

[1]University of Nottingham, [2]The Netherlands Organisation for applied scientific research TNO, [3]Swedish National Road and Transport Research Institute VTI, [4] Universita' degli studi di Palermo, [5]University of California Davis

Abstract

Road pavements are complex and dynamic systems which need to be properly managed during their whole life cycle to ensure they deliver their function to society. The use of sustainability assessment methodologies (SA) is also prescribed by the European workshop agreement CEN CWA 17089:2016 "Indicators for the sustainability assessment of roads". This is probably the first effort globally aiming at standardising the definition of sustainable roads and identify indicators to develop sustainable practices for the design, construction and management of road pavements. Hence, stakeholders recognise the need of introducing sustainability at core of pavement engineering practices and Europe-wide a range of practices are being implemented. This paper describes the results of a series of interviews undertaken within the framework of the PavementLCM project to understand the level of knowledge in terms of sustainability of each NRA, as well as collecting best practices to facilitate the transfer amongst the countries. The interviews were carried out with eleven European national road authorities plus the California Department of Transportation, who is probably the most advanced worldwide in implementing sustainability and life cycle management in their practices. As a result, the key points of NRAs' practices on Sustainability Assessment were identified and are presented here, together with the most used indicators to measure the sustainability performance of pavements and the priorities for the development of more sustainable asphalts among NRAs. This work is being developed within the "PavementLCM" project funded by the Conference of European Road Director - CEDR call 2017: New Materials

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1. Introduction: Sustainability assessment of road pavement

Sustainability Assessment (SA) is the evaluation of the environmental, social and economic impacts of a product or system. SA is the first step in being able to establish benchmarks, measure progress, help decision-making and create policies toward Sustainable Development in pavement engineering. There are several tools, methodologies and techniques available for measuring sustainability with different advantages and disadvantages. The tools can be used individually or in combination, however their use for pavements still requires considerable work to define specific rules and common practices, and to establish how SA results should best be used to assess environmental and social impacts for pavement systems [1].

The most relevant and common techniques to quantify aspects of sustainability are:

- **Performance Assessment**. This involves the assessment of the asset in relation to its intended function. Performance of a new technique is most often evaluated in relation to that of the current standard practice. For instance, if the current standard asphalt pavement surfacing is expected to last 15 years, the value of an alternative surfacing is based on the projected service life of the considered alternative relative to the 15-year service life of the standard surface. The most common approach is that alternatives must perform equally to or better than the current standard practice [1].

- **Life Cycle Techniques**. The life cycle of a product or system is defined by its life cycle stages. A life cycle can begin with extracting raw materials from the ground and generating energy. Materials and energy are then part of manufacturing, transportation, use and eventually recycling, reuse, or disposal. A life cycle approach means recognizing how choices influence what happens at each of these points so we can balance trade-offs and positively impact the economy, the environment, and society. A life cycle approach is a way of thinking which helps recognizing how our selections are one part of a whole system of events [2]. The most common Life Cycle Techniques are Life Cycle Costing (LCC), Life Cycle Assessment (LCA), Social Life Cycle Assessment (S-LCA) and Life Cycle Sustainability Assessment (LCSA).

- **Sustainability Rating Systems.** A sustainability rating system is essentially a list of practices or features that impact sustainability, coupled with a common unit of measurement (usually a point system) that quantifies the relative impacts. In this way, the diverse impacts of various practices and features (e.g., pollutant loading in storm water runoff, changes in pavement design life, tons of recycled materials used, energy consumed and saved, pedestrian accessibility, ecosystem connectivity, and even the value of art) can all be compared using a common unit (rating points). In its simplest form, a rating system may count the implementation of every best practice equally (e.g., all worth one point), in which case the rating system amounts to a tally of the number of best practices used. In more complex forms, rating systems weight best practices (usually in relation to their impact on a selected definition of sustainability or a selected set of priorities), which can assist in choosing the most impactful best practices to use given a limited scope or budget. Many national and international pavement sustainability rating systems are currently available (e.g., INVEST, Greenroads, and Envision) [1].

Each of the methodologies described above offers certain unique benefits. For example, performance assessment is a longstanding method of evaluation measuring engineering performance and often comparing it to a commonly accepted standard. The use of LCC to assess cost impacts for pavements is well established and is a subset of a larger group of methods for assessing the macroeconomic impacts of spending on transportation in general. Rating systems are easily understood and are emerging worldwide and several have been implemented by various groups. LCAs are an emerging technology with a well-established baseline process (i.e., the ISO 14040 series of standards).

1.1. Sustainability assessment of road pavements in Europe

Sustainability is a current and multidisciplinary topic resulting in many (European) initiatives, standards, technical reports, policies and Directives that are relevant when formulating a common set of indicators. In this introduction, relevant initiatives that were taken into account are mentioned.

The "Europe 2020 Strategy" includes the Flagship Initiative: "Resource efficient Europe", where European Commission presents proposals aiming at cleaner, more efficient and more sustainable transport through the adoption of measures such as research and innovation, setting current standards and developing the necessary infrastructure support as well as regulatory measures such as pricing. The Circular Economy Package consists of an EU Action Plan for the Circular Economy that establishes a concrete and ambitious programme of action, with measures covering the whole cycle: from production and consumption to waste management and the market for secondary raw materials [3].

The White Paper on Transport [4], takes into account major policy initiatives for a competitive and resource efficient transport system under sustainable developments. Furthermore, ERTRAC (European Road Transport Research Advisory Group) sets out the following ambition: "Towards a 50 % more efficient road transport system by 2030" [5].

The construction and maintenance of roads in an energy and resource efficient way is an important policy objective for Europe. As a consequence, the European Commission has developed a process to set the Green Public Procurement Criteria mentioned above (GPP criteria) for design, construction and maintenance of roads and provide guidance on how to effectively integrate these GPP Criteria into the procurement process. GPP is a voluntary instrument and has the ultimate goal of providing precise and verifiable criteria that can be used to procure low environmental impact roads [6].

Considering the challenges mentioned and the general principles of sustainability in construction described in ISO15392:2008, all three dimensions of sustainability of civil engineering works (environmental, social and economic) are necessary elements in a systemic approach to a sustainable assessment. Statements on the sustainability performance of a civil engineering works shall address all three dimensions. This implies that when dealing with the sustainability assessment of a civil engineering works, all three dimensions of sustainability shall be included in an assessment of the civil engineering works' performance, and communication shall be made accordingly.

In 2015, 2017 and with the new version in 2019, Sustainability Assessment (SA) of civil engineering works was defined by the European Committee for Standardisation (CEN) as the "*combination of the assessments of environmental performance, social performance and economic performance taking into account the technical requirements and functional requirements of a civil engineering work or an assembled system (part of works), expressed at the civil engineering works level*". This definition is included in the "EN 15643-5 Sustainability of construction works - Sustainability assessment of buildings and civil engineering works - Part 5: framework on specific principles and requirement for civil engineering works" [7]. This standard provides a system for the sustainability assessment of civil engineering works using a life cycle approach and using quantifiable indicators measured without value judgements.

Furthermore, within the project "Life Cycle Engineering for roads, the new sustainability certification system for roads (LCE4ROADS)", funded by the European Commission via the 7th Framework Programme (FP7) in the call for "Innovative, cost-effective construction and maintenance for safer, greener and climate resilient roads", the CWA 17089:2016 [8] was produced to provide a recommended common set of indicators that can be used for sustainability assessment of roads and a suggested deployment procedure, with the aim of supporting National road authorities, private operators, contractors and engineering companies when considering sustainability for roads in their day to day business. These indicators are formulated to cover the three pillars in sustainability: environmental, economic and social. This list is drafted considering current relevant initiatives for the sustainability assessment of road structures such as: Envision TM, FHWA INVEST, and European research projects like COST354, EVITA, SUNRA, among others and the work performed by the Joint Research Centre (EC) to develop the Green Public Procurement Criteria. On the other hand, results from the EDGAR project: "Evaluation and decision process for greener asphalt roads" funded by the Conference of European Directors of Roads (CEDR) Transnational Road Research Programme Call 2013 have been also considered for this document.

1.2. Pavement LCM Sustainability Assessment Framework

The CEDR Transnational Research Programme was launched by the Conference of European Directors of Roads (CEDR). CEDR is the Road Directors' platform for cooperation and promotion of improvements to the road system and its infrastructure, as an integral part of a sustainable transport system in Europe. Its members represent their respective National Road Authorities (NRA) or equivalents and provide support and advice on decisions concerning the road transport system that are taken at national or international level.

The participating NRAs in the CEDR Call 2017: New Materials are Austria, Belgium-Flanders, Denmark, Germany, Netherlands, Norway, Slovenia, Sweden and the United Kingdom. As in previous collaborative research programmes, the participating members have established a Programme Executive Board (PEB) made up of experts in the topics to be covered. The research budget is jointly provided by the NRAs as listed above.

Within this CEDR Call 2017, PavementLCM is a 2-year international project aiming at supporting European National Road Authorities to introduce sustainability at the core of their practices by providing training on Life Cycle Management techniques and a user-friendly package to support their widespread implementation. The specific objectives are:

- To tailor guidelines towards the introduction of Life Cycle Management (LCM) in National Road Authorities with a focus on Sustainability Assessment
- To act as a platform for interactive transfer of knowledge on best practices on sustainability assessment and Life Cycle Management
- To produce the PAVEMENT LCM package of tools, guidelines, datasets, roadmaps and recommendations to introduce life cycle management practices into NRAs.

The work package 2 "Transfer of Knowledge" aims at providing NRAs with a state of the art and a framework for carrying out Sustainability Assessment (SA) of pavement materials and activities as part of their practices. The process followed for the development of the SA Framework is summarised in Figure 1. Firstly, the review of the State of the Art was conducted to get acquainted of the current advances in the topic. Next, interviews and the 1st CEDR workshop on SA with NRAs were carried out to understand the actual knowledge and practices related to SA in each them. Finally, the Pavement LCM framework for SA will be produced and delivered as depicted in Figure 1.

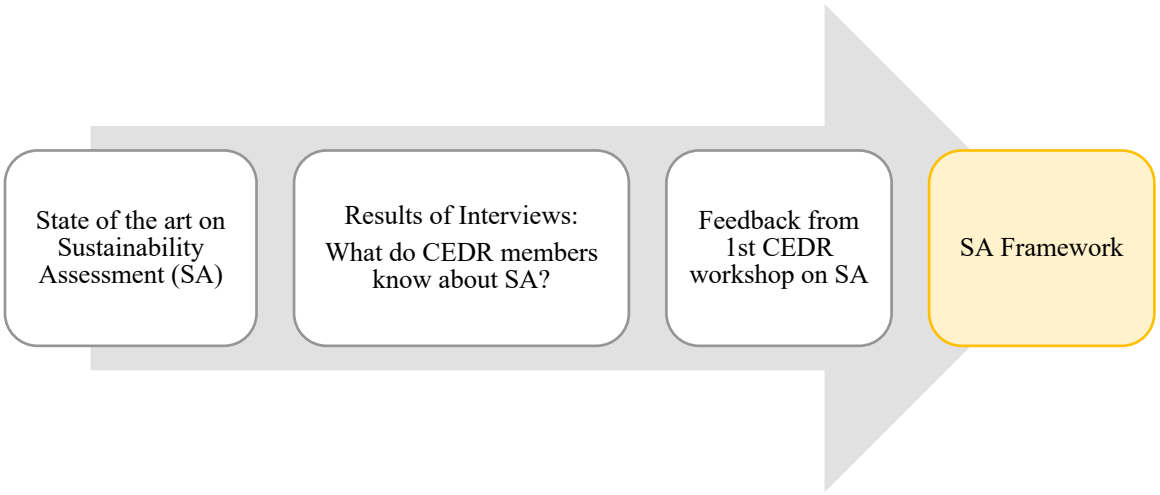


Figure 1. Structure and development of PavementLCM SA Framework

The aim of PavementLCM Sustainability Assessment Framework is to provide recommendations and guide NRAs to perform the SA of two systems: pavement materials and pavement activities.

Having stablished the background for this task, the recommendations of PavementLCM Sustainability Assessment Framework should meet the requirements of the standard EN 15643-3 and therefore as general features in this framework:

- Environmental, social and economic performance are assessed.
- Technical and functional requirements are taken into account.
- The assessment uses quantifiable indicators measured without value judgements. The indicators in EN 15804:2012 [9], EDGAR [10] and CWA 17089 [8] for the SA of pavement materials and activities are used as the basis for PavementLCM Framework.

- The assessment uses a life cycle approach. Based on the indicators in the CWA 17089 [8], the environmental and economic indicators will be measured using a life cycle approach through LCA and LCCA respectively, while the social indicators use a different approach.

1.3. Aim of the paper

As mentioned in the previous sections, standardisation bodies in the civil engineering sectors as well as CEDR are investigating methodologies to implement the directives of the European Commissions aimed at introducing sustainability in day-to-day business. However, what National Road Authorities know and currently do about sustainability assessment of road pavements materials and activities is still unclear and certainly not harmonised.

This paper wants to report the summary of the main results and conclusions of a series of interviews undertaken with European road authorities as well as with the California Department of Transportation, to understand the current and best practices related to introducing sustainability assessment into 11 National Road Authorities. A questionnaire with seven sections was used as a base to undertake interviews and guide the conversations. The main results of the "Sustainability assessment" and "Definition of more sustainable asphalt" are summarised in this paper and will be used to tailor the PavementLCM Sustainability Assessment Framework.

2. METHODOLOGY

With the background presented in mind, a questionnaire with seven sections was used as a base to undertake interviews and guide the conversations with the different National Road Authorities (NRA). In total, eleven interviews were conducted as follows: 1) Vejdirectoratet (Denmark); 2) Highways England (England); 3) Lithuanian Road Administration (Lithuania); 4) Trafikverket (Sweden); 5) Flemish Roads & Traffic Agency (Belgium); 6) Vegdirektoratet (Norway); 7) BMVIT (Austria); 8) BASt (Germany); 9) Rijkswaterstaat (Netherlands); 10) Direkcija RS za infrastrukturo (Slovenia); 11) Caltrans (California, USA).

Each NRA was contacted separately and at least one member, expert in "Sustainability", was interviewed for an average time of two hours. In most cases the NRA's representatives were more than one. In the case of California DOT, 5 experts from different departments agreed to provide us the requested information.

The full questionnaire can be requested to the authors. In this paper, only the results of two sections are discussed: "Sustainability assessment" and "Definition of more sustainable asphalt".

In order to tailor the questions of the "Sustainability assessment" section, the key points of SA defined in the standard EN 15643-5 were considered as following:

- Environmental, social and economic performance must be assessed. Therefore, the questionnaire should integrate questions about the three aspects of sustainability.

- The assessment should use a life cycle approach. In this regard, it is essential to understand what life cycle stages NRAs evaluate in their sustainability assessments.

- The assessment should use quantifiable indicators measured without value judgements. Thus, the questionnaire should ask which indicators NRAs are currently using: product, construction, use (including maintenance) and/or end-of-life.

- The SA of asphalt mixtures and pavement treatments can be performed for different purposes, these are:

    - To determine the sustainability aspects and impacts of the civil engineering works in its area of influence;
    - To enable the client, users and designers to make decisions and choices that will help to address the need for sustainability of civil engineering works;
    - To demonstrate or communicate the sustainability performance of the civil engineering works.

The purpose of the assessment should be clearly identified at the beginning of the study, since it will influence the whole process. Consequently, it is crucial to recognise the purpose of the assessment that NRA undertake.

In addition to the key points defined in EN 15643-5, two more aspects were included in the questionnaire. Firstly, it is important to highlight that SA can be performed at different levels within NRA' strategies, as following:

- Product level. SA can be used to report the sustainability performance of any material or technique and support their implementation, e.g. producing its Environmental Product Declaration.
- Project level. SA can be used to compare and select a pavement design alternative based on costs, environmental and social impacts, helping decision-making.
- Network level. SA can be used to prioritise network maintenance and preservation activities to minimise costs, environmental and social impacts.

Secondly, the SA can be conducted at different stages in a pavement engineering project life, as following:

- Planning. SA can be used to be developed strategies to improve construction in terms of environmental, social or economic performance.
- Procurement. SA of some products, in particular innovative products, might be required during the procurement of a project to be provided as an evidence of their environmental, social or economic performance.
- Design. SA can be used to select a design alternative over other (i.e. decision-making) in terms of environmental, social or economic performance.
- Execution. SA can be performed during the execution of a pavement engineering project (i.e. construction and use) to evaluate the environmental, social or economic performance and evaluate whether impacts can be reduced.
- Closure. SA can be used at the end of a project to assess how it performed and whether it could have been better done to develop future strategies.

For the purpose of the development of PavementLCM Sustainability Assessment Framework, it is therefore essential to understand NRA's practices regarding these two aspects (strategy level and project life stage of the assessment), so these issues were included in the questionnaire.

3. RESULTS

To begin the interviews, five questions were set in the questionnaire as an introduction to the topic of sustainability assessment asking about the awareness of the interviewee regarding this technique and how much value (1-10, being one the minimum score) he/she would give individually to 1) Sustainability assessment; 2) Environmental assessment; 3) Economic assessment; 4) Social assessment. The results of the scores of the eleven interviews are, in average:

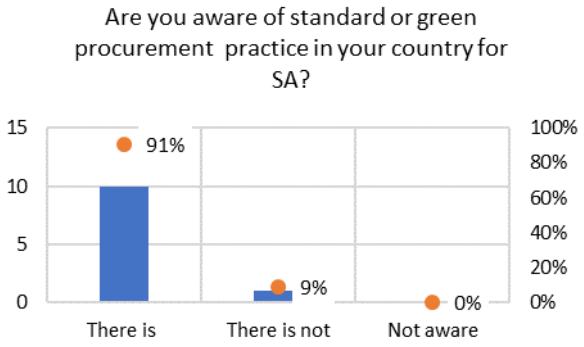
- Awareness of sustainability assessment: 8.7
- Value of sustainability assessment: 7.9
- Value of economical assessment: 8.5
- Value of environmental assessment: 7.8
- Value of social assessment: 5.9

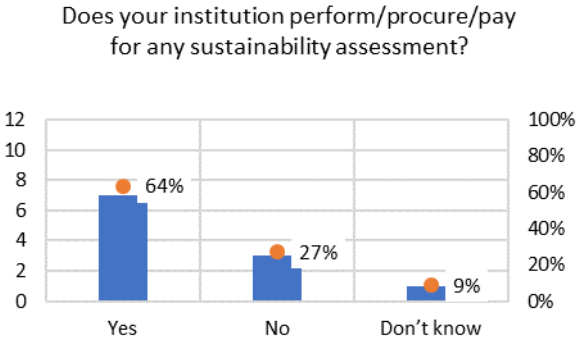
According to these results, it can be said that there is a high awareness about sustainability assessment in NRAs. Furthermore, the most valued pillar of sustainability is the economic, followed by the environmental and finally social. These results reflect the culture of sustainability in Europe, showing how economic aspects have always driven decision-making in pavement engineering. Nevertheless, it is also seen that the consideration of the environmental impacts this field is increasing, while social impacts remain as the last priority.

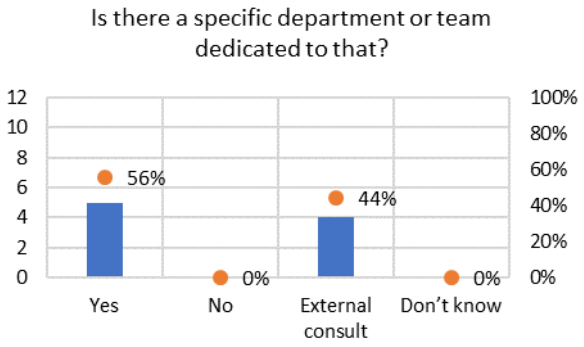
3.1. Sustainability assessment practices

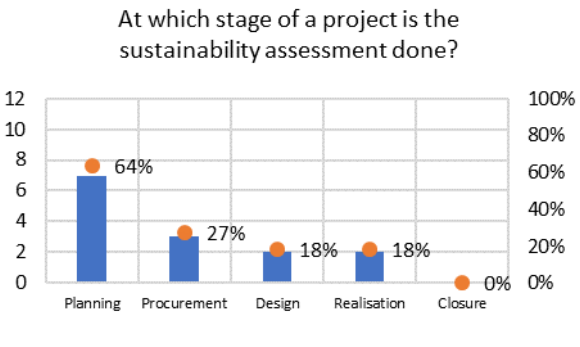
The next set of questions were set as multiple-choice question to understand the key points the sustainability assessment practices of each NRAs. The specific questions, choices given and results are shown in Figure 2. From Figure 2, the following points can be highlighted:

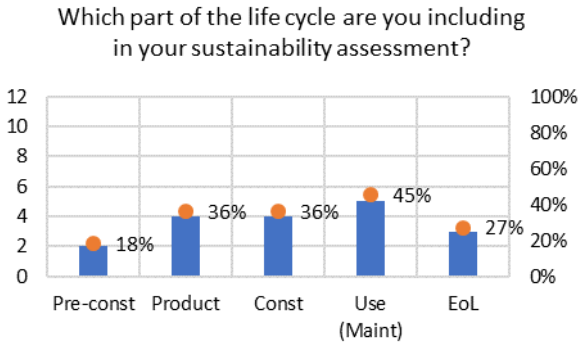
- 91% of interviewees are aware of the existence Sustainability Assessment Standards.
- 64% of the institutions perform some type of Sustainability Assessment, having a specific department to do it in most of the cases or through an external consultant.
- 64% of the NRAs interviewed perform the assessment at the planning phase of projects, including mainly the product, construction and maintenance stages of the life cycle of the pavement.
- 64% of the assessments are perform at project level, followed by network level and finally product level.
- The main purpose of the SA is to help decision making, followed by green procurement or as an external requirement, i.e. to report to the government.
- The most commonly assessed pillar of sustainability is economy, in accordance to the result of the previous section regarding the value given to each pillar.

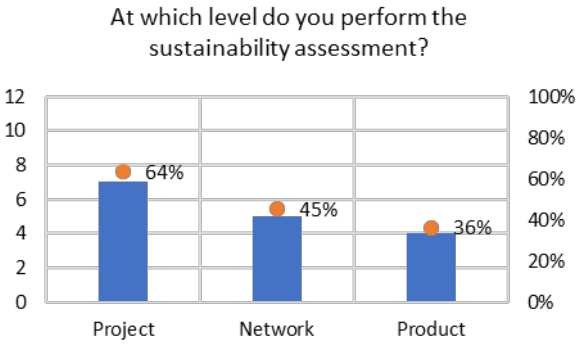












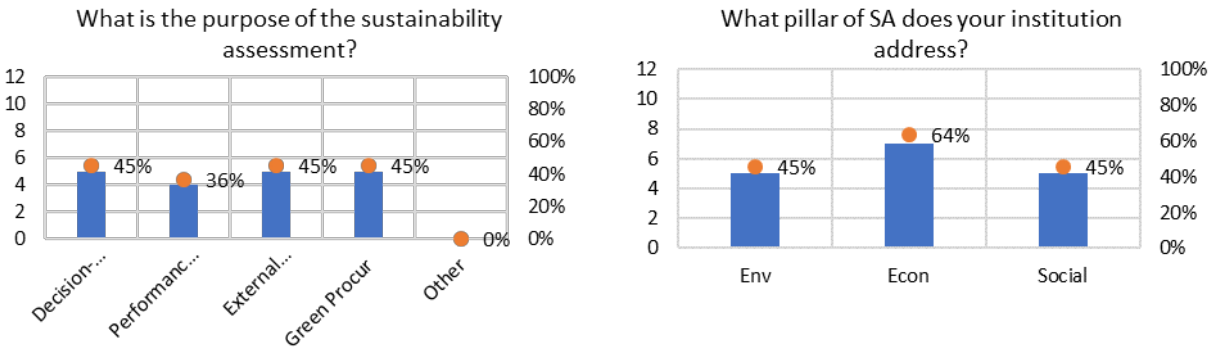


Figure 2. Results of the multiple-choice questions related to sustainability assessment practices of NRAs

3.2. Awareness and use of Sustainability Assessment indicators

EN 15643-5 highlights the need of using quantifiable indicators to measure the sustainability performance of civil engineering works. In this regard, in order to understand the use of indicators in NRA's practices, the set of 21 indicators proposed in the CWA 17089 [8] were presented in the questionnaire and four options were given to the interviewees for each indicator to select regarding their knowledge as follows:

- Not aware (1)
- Aware but not using (2)
- Aware and using (3)
- It is critical (4)

In order to analyse the results, the score in brackets in the list above was given to each answer. Next, a total score was assigned to each indicator as the sum of all the replies. The results of these scores are shown in Figure 3 for each indicator.

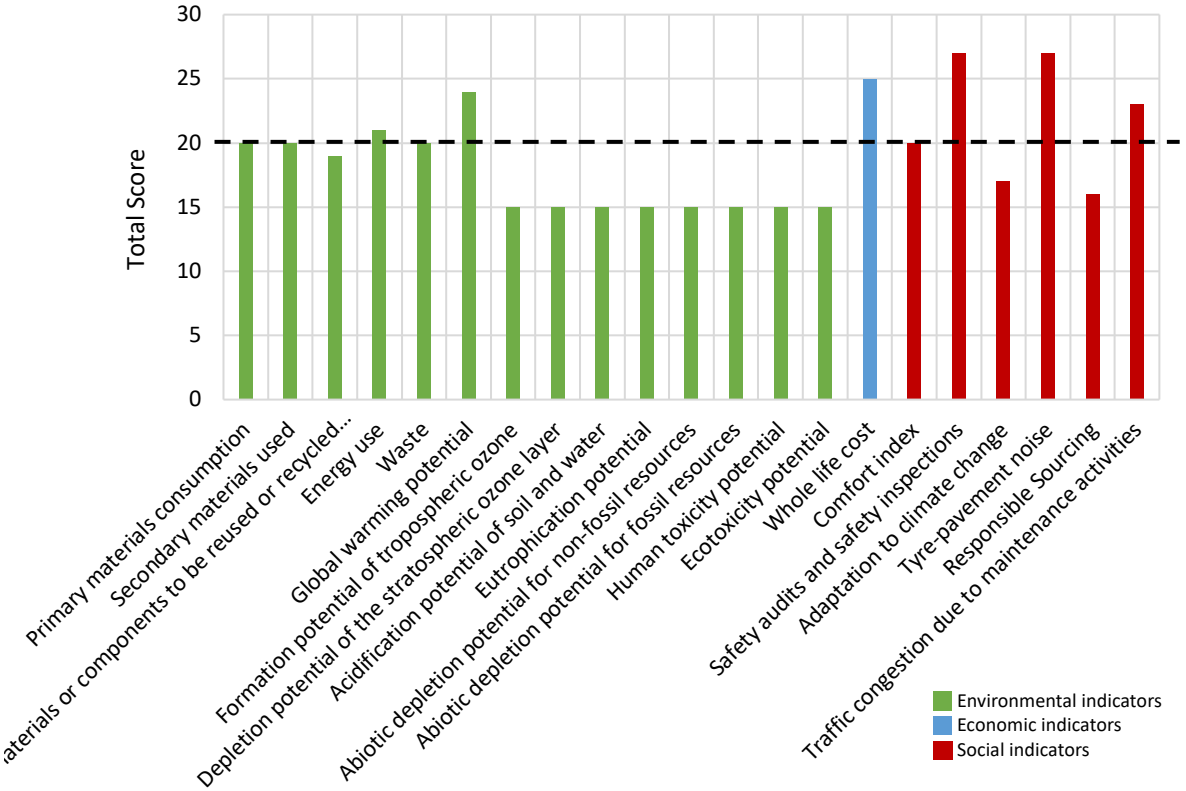


Figure 3. Total score of CWA 17089 indicators for sustainability assessment

To analyse Figure , a threshold of 20 points was taken to consider an indicator as relevant, taking into account that the maximum score could be 44 and the minimum 11. As a result, the relevant indicators in sustainability assessment practices for the NRAs interviewed are:

1. Primary materials consumption
2. Secondary materials used
3. Energy use
4. Waste
5. Global Warming Potential
6. Whole life cots
7. Comfort index
8. Safety audits and inspections
9. Tyre-pavement noise
10. Traffic congestion due to maintenance operations

From this list, five indicators are environmental, one indicator is economic (the only one proposed in CWA 17089) and four indicators are social. In this regard, comparing the number of relevant environmental and social indicators, and considering that "safety audits and inspections" and "tyre-pavement noise" are those with the highest score, these results may appear opposite to those in previous sections in which the social pillar was the least valued. However, this contradiction means that what the social indicators in CWA 17089 are in fact very relevant to NRAs.

This list of 10 indicators will then be used as an initial point to further screen and select indictors for PavementLCM SA Framework.

3.3. More sustainable asphalt mixtures

This section was used to identify the priorities of NRAs for the study of more sustainable asphalt in order to define the case studies for SA that will be perform in PavementLCM project to provide examples of assessments and significant

sustainability data for NRAs. For this purpose, 10 choices of techniques that are generally understood to be more sustainable asphalt were given, and the interviewees were asked to choose and rank 5 of them from the most to the least important for them. The choices given were:

1. Low rolling resistance
2. Reduced noise
3. Porous asphalt
4. Warm Mix Asphalt
5. Cold Mix Asphalt
6. Improved durability
7. Recycling
8. Secondary materials
9. By-products
10. Bio-materials

Analysing the results, the NRA priorities in terms of development of more sustainable asphalt we identified in order of preference as:

1. Improved durability
2. Reduced noise
3. Warm Mix Asphalt
4. Recycling

This ranking indicates that durability is the most important aspect of pavements related to sustainability for NRAs. Durability is in fact an essential factor since it will condition any operation to perform during the service life of the pavement, affecting the environment (e.g. emissions, energy consumption), economy and society (e.g. noise, traffic delays).

The four priorities for more sustainable asphalt in the ranking will be used to design the case studies for the SA exercise and durability exercises in WP3 and WP4 respectively of PavementLCM project.

3.4. Best practices of NRA's Sustainability Assessment

The questionnaire produced was used as a basis for discussions during the interviews. This basis stimulated further conversations which allow to identify best practices between NRAs regarding SA which are summarised here:

- ✓ England: Use of LCC to allocate budget at strategic level based on the type of treatment for maintenance. Sustainability Strategy in place.
- ✓ Netherlands: Use of Green Procurement and development of their own tool "Dubocalc" for environmental assessment.
- ✓ Sweden: Use of Green Procurement. EKA tool is used as declaration for giving bonus in evaluating tenders regarding asphalt materials. Climate tool is used to show climate impact and energy use for the construction, operation and maintenance of roads and railways, and for basic road contracts, from a life cycle perspective.
- ✓ Norway: Development of own EPD for asphalt mixtures (product stage) plus optional scenarios for construction, use and EoL stages.
- ✓ Denmark: Use of socio-economic model to quantify the benefit to the society of new pavement types
- ✓ California: eLCAP tool is used for LCA with a specific database for California. RealCost is used for LCCA. A pilot scheme is requiring EPDs to all contractors from 2019

These practices should be shared between NRAs to promote the creation of programmes towards sustainable development in pavement engineering and enrich their knowledge on how to do it learning from each other. For this purpose,

PavementLCM project organised the first CEDR workshop on Sustainability Assessment inviting NRAs. A second workshop will be organised in 2020.

4. CONCLUSIONS

Sustainability Assessment (SA) is the evaluation of the environmental, social and economic impacts of a product or system and represents a main step in being able to establish benchmarks, measure progress, help decision-making and create policies towards implementing sustainability practices in pavement engineering. PavementLCM is a 2-year international project aiming at supporting European National Road Authorities to introduce sustainability at the core of their practices by providing training on Life Cycle Management techniques and defining a framework to allow NRAs to perform SA of road pavements materials and activities. in compliance with the standard EN 15643-5. As a first step of this development, the authors carried out a series of interviews to understand the current culture and practices related to the use of SA and more general sustainability-related practices within NRAs in EU and USA. This paper presents a critical analysis of the results of such interviews which allowed drawing the following conclusions:

- There is a very wide range of practices and different level of knowledge and implementation of sustainability assessment between the different European NRAs
- Most of NRAs (91%) are aware of the existence of sustainability assessment and perform some type of assessment (64%), being this mostly economical
- Most of NRAs are willing to improve their use of sustainability assessment
- According to EN 15643-5, the SA of pavement materials and activities should include the three pillars of sustainability, use quantifiable indicators and use a life cycle approach.
- The most important SA indicators for NRAs are:
    - Primary materials consumption
    - Secondary materials used
    - Energy use
    - Waste
    - Global Warming Potential
    - Whole life cots
    - Comfort index
    - Safety audits and inspections
    - Tyre-pavement noise
    - Traffic congestion due to maintenance operations
- The NRAs' priorities for the study and development of more sustainable asphalt mixtures are:
    1. Improved durability
    2. Reduced noise
    3. Warm Mix Asphalt
    4. Recycling
- The definition of a set of SA indicators should consider these priorities, in the sense that these indicators should be able to measure the performance of different technologies in relation to such priorities.
- There are a series of best practices in EU towards the implementation of SA in NRAs which should be shared. PavementLCM is creating a platform to allow such transfer of knowledge between NRAs.

It is a strong belief of the authors that SA exercise should be requested by NRAs, however in order to be actually used SA should be a simple exercise that should be completed within 4-8 hours. At the same time SA exercise should comply with the recent standard for civil engineering works, it will need to be tailored for each stakeholder group (i.e. asphalt materials and road pavement maintainance) and each of these should be related so to allowing sharing datasets, results, etc. PavementLCM is currently developing a SA framework on the basis of these results and will provide it to CEDR

NRAs. The project will also produce the PAVEMENT LCM package of tools, guidelines, datasets, roadmaps and recommendations to facilitate the implementation of SA exercises into NRAs as well as the introduction of life cycle management practices. More information are available at http://pavementlcm.eu

5. ACKNOWLEDGEMENTS

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