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PAVEMENT LCM

Sustainability Assessment for road pavements: State of the Art

Deliverable D2.1a

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Life Cycle Management of Green Asphalt Mixtures and Road Pavements

Deliverable D2.1a – Pavement LCM State-of-the-Art

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Executive summary

This report (D2.1) has been already delivered in Sep2019, however due to updates of standards on SA over 2020 and 2021 and with the willingness of including the feedback from all the advisory workshops, the consortium has decided <u>to significantly update the Framework and the entire deliverable.</u>

Furthermore it has been divided into two parts: D2.1a and D2.1b, which respectively contain the State-of-the-Art and the PavementLCM Framework.

Background

The PavementLCM project has the aim of introducing Sustainability Assessment (SA) as a common practice within European National Road Authorities (NRAs) practices. This consortium intends to do so with a bi-lateral learning process structured in three levels and leading to the PavementLCM "Package" which includes the life cycle management Guidelines for road authorities together with Tools and Resources that the consortium is creating to facilitate the implementation of the products, recommendations and practices suggested within the project.

PLCM Level 1	PLCM Level2	PLCM Level 3
What is SA?	**How do I perform SA?**	**Pavement LCM Package**
• State of the Art • Interviews • Advisory workshops	• PavementLCM Framework *according to standardised procedure (EN CEN TC 350)*	• PavementLCM Guidelines • PavementLCM Tools • PavementLCM Resources

Figure 1- PavementLCM project structure and deliverables

Goal and Scope

The goals of this report are to cover the content of Level 1 and Level 2 as follow:

- To help the road authorities in their sustainability knowledge
- To perform a series of interviews with NRAs in order to better understand the variety of current practices around Europe, identify and share existing best practices as well as creating a state-of-the-art of international practices and standards.
- To create and implement a platform for knowledge transfer through a series of tailored advisory workshops/webinars aimed at involving NRAs in the project development as well as providing an opportunity to learn and share about the complex issue of engineering sustainability within the road industry
- To propose the PavementLCM Framework for SA road pavements (D2.1b) which considersthe findings of the intense literature review and as well as complying with the most recent EN standards on "Sustainability of Construction Works".

Results: State of the Art in SA (SoA)

Chapter 1 focuses on firstly providing the necessary background on Sustainability, Sustainable Development, Sustainability Assessment, Life Cycle Thinking and Techniques to help NRAs to understand their importance and usefulness to start introducing these practices in their organisations. From this background, the following conclusions and recommendations are drawn:

- There is a current need and pressure to move toward the achievement of the Sustainable Development Goals in every field. Pavement engineering has a strong influence in the three pillars of sustainability (environmental, economic and social) and the commitment of NRAs to decrease negative impacts on them is required.
- To do this, NRAs should create their own Sustainability Strategy to identify their specific role and possible contributions to sustainability, taking into account impacts, context and influence. This would include the identification of impacts of main concern and the planning of a review of the key contributions the NRA can make to influence sustainability further, through mandates, resources, existing priorities and activities.
- Sustainability Assessment (SA) is the evaluation of the environmental, social and economic impact of a product or system. SA is the first step in being able to establish benchmarks, measure progress, support decision-making and create policies toward Sustainable Development in pavement engineering. The most commonly used methodologies are: performance assessment, life cycle techniques and sustainability rating systems.
- The standard EN 15643-5 Sustainability Assessment Framework for civil engineering works is the umbrella under which PavementLCM SA Framework has to be built according to several key points of the standard:
    - Environmental, social and economic performance must be assessed.
    - Technical and functional requirements must be taken into account.
    - The assessment should use a life cycle approach.
    - The assessment should use quantifiable indicators measured without value judgements.
- Given the importance of analysing the three pillars of sustainability, PavementLCM suggests to move from the use of the term “green asphalt or pavement” to “more sustainable asphalt or pavement” including in this way the three dimensions of sustainability and the fact there is no “absolute” sustainability, but more sustainable options.
- Life Cycle Approaches and Techniques are tools to apply (i.e. materialise) Life Cycle Thinking (LCT) which “*is about going beyond the traditional focus on production site and manufacturing processes to include environmental, social and economic impacts of a product over its entire life cycle”.* LCT helps to make choices by allowing the identification of the critical activities or points in the whole life cycle of a product or system causing the highest environmental, social and economic impacts. This enables developing strategies and policies for their mitigation and minimisation, involving the appropriate stakeholder to take actions towards Sustainable Development.
- Life Cycle Assessment, Life Cycle Cost and Social Life Cycle Assessment are the specific methodologies proposed to evaluate each of the pillars of sustainability when performing the SA of civil engineering works, and consequently to be used in pavement engineering.

Secondly, the SoA focused on reviewing the available standards and guidelines to perform SA, and present the main EU projects related to SA in pavement engineering. From this review, the following conclusions can be drawn:

- There is a lack of standards defining calculation methods for the SA of civil engineering works. In this regard, PavementLCM SA Framework has to focus on developing such methods defining (See section 7):
  - Objects of assessment
  - Functional/declared units
  - System boundaries/Life Cycle stages to include in the assessment
  - Analysis period
  - Cut-off rules
  - Allocation procedures
  - Data quality requirements
  - Sustainability Assessment indicators
  - Recommendations for the presentation of results
- EN 15643-5 provides the general framework to define those elements and presents the rest of standards to comply with to perform the environmental, economic and social assessment of civil engineering works, which are:
  - ISO 14040:2006, ISO 14044:2006, EN 15804:2012+A2:2019 for environmental assessment
  - ISO 15686-5:2017 for economical assessment
  - ISO 15392:2019 for social assessment
- There is a series of PCRs available to perform the LCA of asphalt mixtures and pavements. For each element of interest:
  - Object of assessment. It is important to distinguish between asphalt mixtures (pavement materials in general) and pavement activities. These concepts must be defined in PavementLCM Framework
  - Functional or declared unit. The most common declared unit used for asphalt mixtures is 1 tonne of manufactured asphalt mixture. The most common functional unit for pavement activities is 1 m^2 of paved surface which fulfil the specified quality criteria during the analysis period
  - System boundaries/Life Cycle stages to include in the assessment. The system boundaries and life cycle stages to study depends on the goal of the SA and are different for asphalt mixtures and pavement activities. These concepts must be defined in PavementLCM Framework
  - Cut-off rules. The most common rule is to have a Life cycle inventory (LCI) with data for a minimum of 99 % of total inflows. In fact, ISOs allow to cut-off 1% of renewable and non-renewable primary energy usage in case of insufficient data.
  - Allocation procedures. As in EN15804 for most of the PCRs, it is recommended to avoid allocation. If this is not possible, in the case of co-production mass allocation should be used. In the case of recycling, recycled materials should carry the burdens from the recycling process, including the transportation from where the material is obtained to the recycling process site.
  - Data quality requirements. There is a series of quality criteria to check for the

use of data, these are:

- Temporal Representativeness (Age)
- Technological Representativeness
- Geographical Representativeness (Geography)
- Precision
- Uncertainty
- Completeness
- Reliability
- Process Review

Recommendations for scoring data against these criteria must be provided in PavementLCM SA Framework.

- LCIA. There are differences in the use of impact categories and indicators for LCA. The indicators to use must be defined in PavementLCM SA Framework.

- There are a series of EU efforts dedicated to the development of SA indicators, being: EDGAR, LCE4ROADS with the definition of CWA17089 and SUP&R ITN. PavementLCM SA Framework will use these efforts to define to use in the SA of pavement materials and activities.

Results: Interviews with National Road Authorities

After carrying out and analysing the results of the interviews, the following conclusions can be drawn:

- There is a very wide range of practices and different level of knowledge and implementation of sustainability assessment between the different 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
- The most important indicators for NRAs are:
    - Primary materials consumption
    - Secondary materials used
    - Energy use
    - Waste
    - Global Warming Potential
    - Whole life costs
    - Comfort index
    - Safety audits and inspections
    - Tyre-pavement noise
    - Traffic congestion due to maintenance operations

This represents the first screening of for the definition of a set of indicators for PavementLCM SA Framework.

- 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 aims at creating a platform to allow such transfer of knowledge between NRAs.

As additional outcome of the interviews, during the discussion, the following best practices regarding SA were identified:

- ✓ England: Use of LCC to allocate budget at strategic level based on the type of treatment for maintenance. Sustainability Strategy Developed (available online).
- ✓ 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 (available online).
- ✓ 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 benefits 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
- ✓ USA (FHWA): LCA Pave tool that has data libraries built for USA (under-review at FHWAs)

Results: Feedback from Advisory Workshop

Within the project lifetime the coordination organised three workshop. Here are the main results from each workshop:

<u>1 – 25/06/2019, Nottingham, UK</u>

The main aim of the workshop regarding the development of PavementLCM SA Framework was to obtain feedback about the current state of development and agree about the set of indicators to include in it and that is the information reported here. The complete results of the workshop were delivered in a stand-alone document together with the presentations and a questionnaire about the quality of the workshop.

It was established that a "More Sustainable pavement material" can be identified only through a comparative analysis with currently used materials. The audience agreed that at least the 5 indicators must be used for this comparison are:

1. Global Warming Potential
2. Energy use

3. Secondary materials consumption
4. Cost
5. Laboratory Performance

Similarly, a “More Sustainable pavement activity” can be identified only through a comparative analysis with current practices. The audience agreed that at least 6+1 indicators must be used for this comparison:

1. Global Warming Potential
2. Energy use
3. Secondary materials consumption
4. Cost
5. Tyre-pavement noise
6. Service Life of pavement components (Durability)
7. OPTIONAL: Air pollution

2 – 16-17/12/2020, Online, (Webinar in collaboration with EAPA)

This event was held in form of a open webinar organised on December 2020 (16 – 17/12/2020) in collaboration with EAPA to discuss and develop important key concepts together with other stakeholders such as NRAs, academics and with the aim of discuss and develop the following key areas:

- Theory, framework, standards and regulations of Sustainability Assessment
- PAVEMENTLCM framework for sustainability assessment of asphalt mixes and road pavements
- Implementation of sustainability assessment practice for both the asphalt mixtues and road pavement industries
- Hands-on practice on the elaboration of EPD for asphalt pavements and LCA of road pavements Next steps on Sustainability Assessment of asphalt pavements.

The Webinar was moderated by EAPA Technical Director Breixo Gómez and Davide LoPresti, Coordinator of the Project PavementLCM. Content and feedback form participants are detailed within the report

3 – 28/05/2021, Online

The 3rd CEDR PavementLCM Advisory Workshop was held on the 28th May 2021 through an online platform. The workshop was tailored for the CEDR Project Executive Board (PEB) and National Road Authorities (NRAs). The objectives of the workshop were:

- To share knowledge, practices and opinions for the implementation of durability withinSustainability Assessment (SA) in NRAs in Europe
- To gather an expert opinion on the reference estimated service life of wearingcourses in Europe
- To share experience on the factors affecting the estimated service life of wearingcourses in Europe

NRAs members accepted very well the proposal of a SA framework addressed to three main actors: asphalt manufacturer, asphalt contractors and road owners.

The survey on durability assessment have been distributed to NRAs few days before the workshop (limited to conventional wearing courses) and within the workshop (also more sustainable wearing courses). Results have been analysed together within the workshop as well as with a subsequent desk study. The exercise highlighted the level uncertainty in estimating service life of a component by means of expert opinion only.

Furthermore, it was established that it would be beneficial gathering expert opinion on the reference service life of pavement layers with a wider audience. The Coordiantion then plan to propose another joint open workshop with EAPA and other stakeholders that focuses on estimation of durability of pavement components targeted to support the implementation of life cycle management practcies within NRAs.

Conclusions and Recommendations:

The following conclusions and recommendations divided in topics can be drawn:

<u>Background and State of the Art in Sustainability Assessment for NRAs</u>

- There is a current need and pressure to move toward the achievement of the Sustainable Development Goals in every field. Pavement engineering has a strong influence in the three pillars of sustainability (energy consumption, GHG emissions, noise, costs, etc.) and the commitment of NRAs to decrease negative impacts on them is required.
- Sustainability Assessment (SA) is the evaluation of the environmental, social and economic impact 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. The main tools to perform are: performance assessment, life cycle techniques and sustainability rating systems.
- NRAs should implement SA practices complying with the international and European standards on Sustainability of Construction Works (EN 15643-5) This standard proposes a general Sustainability Assessment Framework for civil engineering works which is the umbrella under which PavementLCM SA Framework has to be built according to several key points of the standard:
  - Environmental, social and economic performance must be assessed.
  - Technical and functional requirements must be taken into account.
  - The assessment should use a life cycle approach.
  - The assessment should use quantifiable indicators measured without value judgements.

- Given the importance of analysing the three pillars of Sustainability, PavementLCM suggests to move from the use of the term “green asphalt or pavement” to “more sustainable asphalt or pavement” including in this way the three dimensions of sustainability and the fact there is no “absolute” sustainability, but more sustainable options.
- Life Cycle Approaches and Techniques are tools to apply (i.e. materialise) Life Cycle Thinking (LCT) which “*is about going beyond the traditional focus on production site and manufacturing processes to include environmental, social and economic impacts of a product over its entire life cycle”.* LCT helps to make choices by identifying the critical activities or points in the whole life cycle of a product or system causing the highest environmental, social and economic impacts and therefore enable to develop strategies and policies for their mitigation and minimisation, involving the appropriate stakeholder to take actions towards Sustainable Development.

- Life Cycle Assessment, Life Cycle Cost are the specific methodologies proposed to evaluate each of the pillars of sustainability when performing the SA of civil engineering works, and consequently to be used in pavement engineering.

Knowledge transfer activities

- As a result of the knowledge transfer activities (interviews, questionnaires and advisory workshops), it is clear how European NRAs are activing very differently in terms of sustainability assessment practices.
- Amongst those interviewed, the Netherlands and Scandinavia are leading the way, while UK and Germany are implementing some practices.

- Continuous knowledge transfer of SA practices amongst NRAs could be beneficial.

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1. Introduction

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, BelgiumE 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, datasets, roadmaps and recommendations to introduce life cycle management practices into National Road Authorities.

This deliverable is part of Work Package 2 – Transfer of Knowledge and aims at providing the State of the Art (SoA) and Framework for Sustainability Assessment (SA) of pavement materials and activities for National Road Authorities (NRAs) to introduce or improve it in their practices, as part of Life Cycle Management.

The process followed for the development of the SA Framework is summarised in Figure 1. Firstly, the SoA was established to get acquainted of the current advances in the topic. Next, interviews with NRAs were carried out to understand the current state of knowledge and practices related to SA. The draft of the framework has been prepared and shared with PEB and CEDR members in several occasions such as the first draft of the D2.1 and at least a couple of advisory workshops in 2019 (Nottingham, UK) and 2020 (Online with EAPA). The feedback from the workshops and advisory board, shared also with PEB, allowed to define this last last draft of the framework which is here presented.

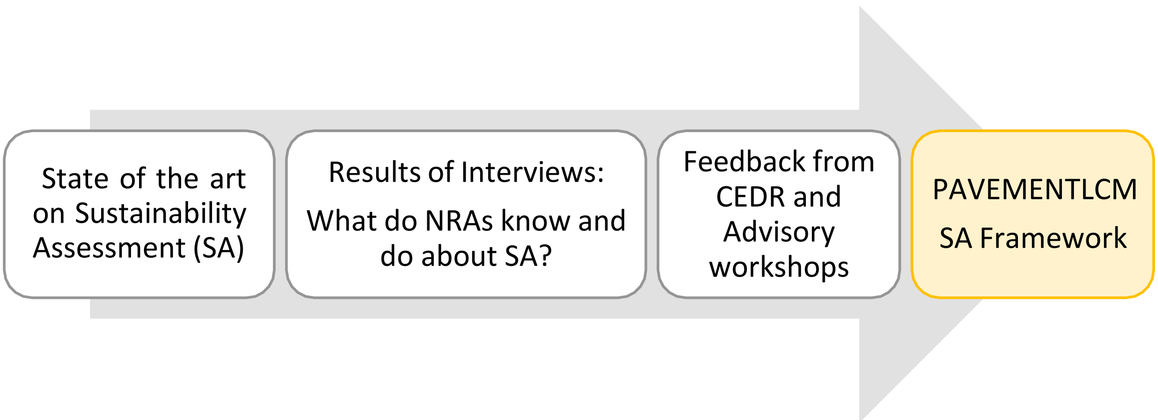


Figure 3. Development of PavementLCM SA Framework

2. State of the art of Sustainability Assessment

This chapter offers an introduction to Sustainability Assessment (SA) in pavement engineering. SA is an approach for exploring the combined environmental, social and economic impacts of products and systems. Such assessment can also assist decision-making and strategic planning for National Road Authorities (NRAs).

The section aims at helping NRAs to increase their understanding of SA by providing:

1. A background on Sustainability and Sustainable Development, how to introduce them in their institutions, basic concepts of Sustainability Assessment, Life Cycle Thinking, Life Cycle Approaches and Techniques.
2. State-of-the-Art of Sustainability Assessment of pavement materials and activities presented covering available standards, guidelines and previous projects.

2.1 Background on Sustainability and Life cycle thinking

2.1.1 Sustainability and Sustainable Development

In 2015, countries adopted the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals defined by the United Nations (UNs) (UN, 2015). The most widely accepted definition of Sustainable Development is the one provided in 1987 by the UN appointed World Commission on Environment and Development (WCED) in the Brundtland report, named after its Chairman, former Prime Minister of Norway Ms. Gro Harlem Brundtland. The core definition is:

> "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*." (WCED 1987, p. 43).

This definition is focused on the concept of "needs" and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs. In a shorter version of this, sustainability is often described as being made up of the three components of environmental, social, and economic needs. Following this definition, the 17 Sustainable Development Goals are the blueprint to achieve a better and more sustainable future for all. They address the global challenges that the world faces, including those related to poverty, inequality, climate, environmental degradation, prosperity, and peace and justice. The 17 goals are:

- Goal 1. End poverty in all its forms everywhere
- Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture
- Goal 3. Ensure healthy lives and promote well-being for all at all ages
- Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
- Goal 5. Achieve gender equality and empower all women and girls
- Goal 6. Ensure availability and sustainable management of water and sanitation for all
- Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

- Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- Goal 10. Reduce inequality within and among countries
- Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable
- Goal 12. Ensure sustainable consumption and production patterns
- Goal 13. Take urgent action to combat climate change and its impacts
- Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development
- Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
- Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
- Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

In the 2030 Agenda for Sustainable Development the UN set targets for each of these goals. In order to achieve them, every sector and industry needs to contribute by adopting its own policies and practices towards Sustainable Development covering the three pillars or dimensions: environment, economy and society, also known by the triple bottom line (3BL) and the three "Ps": planet, profit and people (Figure 4). A focus in sustainability should always include the three pillars, although the relative importance of each of them is case sensitive, driven by the objectives, characteristics and requirements of each project.

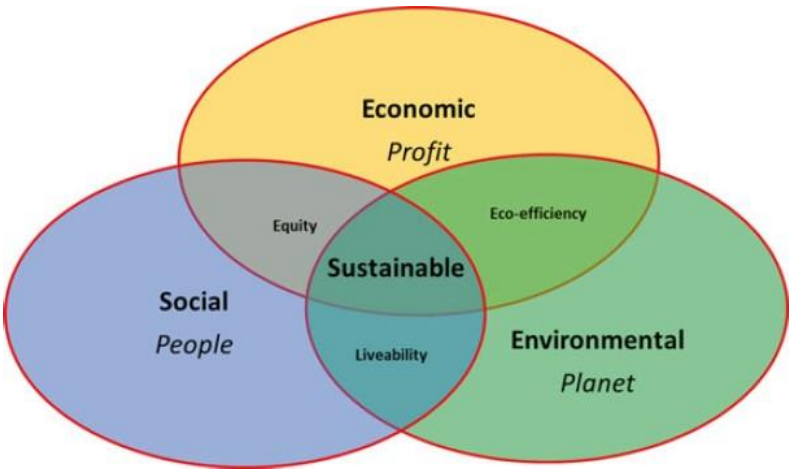


Figure 4. The three dimensions of Sustainability (Sonnemann, Gemechu, Remmen, & Jensen, 2017)

2.1.2 Importance of Sustainability in Pavement Engineering

Transport is one of the main pillars of societies to guarantee their proper development and, within transport infrastructures, roads are the most impactful mean. According to the European Asphalt Pavement Association (EAPA), in EU, more than 80% of motorised inland passenger transport and 70% of all inland freight transport use roads (http://www.eapa.org/asphalt.php). Ensuring the correct performance of roads at the same time than dealing with their associated problems in a sustainable way is the most important target nowadays in pavement engineering, as an integral part of the road network.

Pavements should provide a smooth and durable surface that benefits a range of vehicles (cars, trucks, buses, bicycles) and users (commuters, commercial motor carriers, delivery and service providers, local users, leisure travellers), as well as a resilient structure able to resist traffic loads and climate conditions. Given their key role and widespread use, there is a unique opportunity to improve the sustainability of pavement structures with the potential to deliver tremendous environmental, social, and economic benefits. With regard to those components, listed below are just a few examples of how pavements can impact sustainability:

- Environmental component: energy consumption0 GreenHouse Gases (GHG) emissions0 noise0 air quality0 stormwater treatment.
- Social component: safety0 smoothness0 vehicle operating costs0 GHG emissions0 access, mobility0 noise0 aesthetics.
- Economic: construction, maintenance, and rehabilitation costso vehicle operating costso accident costs.

An ever-growing number of agencies, companies, organizations, institutes, and governing bodies, including transportation and highways authorities, are embracing principles of sustainability in managing their activities and conducting business. This approach focuses on the overarching goal of emphasizing key environmental, social, and economic factors in the decision-making process.

"Sustainability," in the context of pavements, refers to system characteristics that encompass a pavement's ability to (Van Dam et al., 2015):

- Achieve the engineering goals for which it were constructed.
- Preserve and (ideally) restore surrounding ecosystem.
- Use financial, human, and environmental resources economically.
- Meet basic human needs such as health, safety, equity, employment, comfort, and happiness.

2.1.3 Sustainability Action Plan or Strategy for NRAs

The first step to introduce Sustainability in NRAs is to produce a Sustainability Action Plan or Strategy. The CEDR project SUNRA (SUstainability – National Road Authorities) 2013 tailored a specific framework to help NRAs in this task. A Sustainability Action Plan or Strategy is a document which communicates the commitment, approach and priorities of an institution towards sustainable development. In SUNRA, the framework provides four steps that NRAs are recommended to take when defining sustainability, it suggests key elements to consider within each step, and proposes specific outputs to be delivered from each step. This framework is described in details in two deliverables of SUNRA:

- D3 SUNRA Framework Part 1 REPORT v2.0: The purpose of this report is to describe the full process of the development of SUNRA Framework Part 1 "Sustainability Definitions for NRAs".
- D3 SUNRA Framework Part 1 v2.0: This document provides a practical four-step framework (20 pages) to help NRAs create and apply an appropriate definition of sustainability which can frame its subsequent activities in relation to sustainability.

Therefore, in this deliverable of PavementLCM the steps to produce the Sustainability Action Plan or Strategy are briefly described.. The four steps are as follows:

Step 1: Interpretation of sustainability in the context of transport and road systems.

In this step the NRA is to consider key existing definitions and principles of sustainable development, and key ideas on how these relate to the context of the transport system and road sector. This will help the NRA to appreciate fundamental aspects of sustainability and how sustainability applies to NRAs and will help them adopt a scope and level of ambition of their sustainability efforts. The interpretation of sustainability in the context of sustainability should be summarised in a note, and the scope should refer to a level of aspiration

Step 2: Review of impact and influence.

In this step the NRA should consider its more specific role in and possible contributions to sustainability, taking into account impacts, context and influence. This will include the identification of impacts of main concern and the planning of a review of the key contributions the NRA can make to influence sustainability further, through mandates, resources, existing priorities and activities.

Step 3: Crafting a strategic commitment.

In this step the NRA will formulate a commitment, based on the work undertaken in Steps 2 and 3.

Step 4: Implementing the commitment.

In this step the NRA will adopt an action plan for how the commitment will be communicated, plus the strategy and next steps in the application and integration of the commitment in relevant NRA documents, procedures and activity areas.

SUNRA Framework does not advise on a full implementation process of the Sustainability Strategy or Action Plan but provides some recommendations. Within PavementLCM Sustainability Assessment Framework, it is important to highlight that if a NRA is willing to introduce Sustainability in their practices, performing Sustainability Assessment should be included in the strategy or action plan. An example of Sustainability Development Strategy and Action Plan, including Sustainability Assessment in their practices, developed by a NRA is the one of Highways England. This document was first released in April 2017 and updated in December 2018. As examples, they include Sustainability Assessment in the following two statements:

*“**Incorporate consideration of sustainable development and environmental performance into relevant Design Manual for Roads and Bridges (DMRB) documents**. Sustainable development and environmental issues are addressed in many areas of DMRB. In the review and revision of DMRB we will ensure that improved performance is embedded into all requirements relating to assessment, design, construction, management and disposal of our network. This includes updating all DMRB assessment and design documents that specifically relate to sustainable development and the environment, and also ensuring sustainable development and environmental considerations are appropriately handled in all other relevant documents.”*

“***Ensure we have an approach to environmental management of the Strategic Road Network that suits our new ways of doing business**. Our company is changing the way it manages the Strategic Road Network, with management contracts being progressively brought in5house enabling a more hands5on approach. This gives us the challenge of ensuring that network management decision making is supported by an appropriate*

Environmental Management System. We will undertake an assessment of possible options for achieving better embedded environmental performance within the organisation, including the potential use of a formal Environmental Management System."

2.1.4 Sustainability Assessment

Sustainability Assessment (SA) is the evaluation of the environmental, social and economic impact 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 and which can be used individually or in combination (Harvey et al., 2016). 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 is most often addressed 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 (e.g., open-graded friction course, stone matrix asphalt, or rubberized asphalt concrete) 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 sentiment is that alternatives must perform equally to or better than the current standard practice (although this may be a narrow view because it does not consider other possible added benefits). Performance may also be addressed in terms of specific physical attributes (e.g., pavement structural capacity, material attributes, and condition or distress measures) and the behaviour mechanisms that link these attributes to expected performance (Harvey et al., 2016).

- **Life Cycle Techniques**. Life Cycle Techniques evaluate the impact of a product or system during its life cycle, i.e. using a Life Cycle Approach and Life Cycle Thinking. 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 (Life Cycle Initiative/SETAC, 2004). 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) (Harvey et al., 2016).

Each of the tools described above offers certain unique benefits. For example, performance assessment is a longstanding method of evaluation, essentially 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), but their use for pavements still requires considerable work to define specific rules and common practices, and to establish how LCA results should best be used to measure and assess environmental and social impacts for pavement systems (Harvey et al., 2016).

In 2017, 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" (EN 15643-5, 2017), which forms part of a series of European Standards (EN 15643), produced by CEN/TC 350. 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. Further information about EN 15643-5 can be found in Section 2.2.1.1 of this report.

As civil engineering works and part of works, the SA of pavement treatments and asphalt mixtures must comply with this EU standard. There are several key points to highlight from this definition and features:

- Environmental, social and economic performance must be assessed. The three pillars of sustainability must be considered in the assessment. However, in the framework, no more details are provided about how to combine them or whether one pillar can have more importance than others. These features are opened to the practitioner on how to further use the results of the sustainability assessment.

- Technical and functional requirements must be taken into account. Technical requirements are defined as "*type and level of technical characteristics of a civil engineering works or an assembled system (part of works), which are required or are a consequence of the requirements made by the client, users and/or by regulations*", and functional requirements are defined as "*type and level of functionality of a building, civil engineering works or assembled system which is required by the client, users and/or by regulations*". These concepts are important in the sense that the technical and functional characteristics of the civil pavement treatments and asphalt mixtures are fixed by the client's brief or project specification. These requirements influence the results of the assessment and therefore need to be taken into account. In other words, the definition of the pavement treatments and asphalt mixtures for the purpose of the assessment should always include the technical and functional requirements they should meet.

- The assessment should use a life cycle approach. The assessment should therefore consider the life cycle of pavement treatments and asphalt mixtures and use Life Cycle Techniques to perform the SA.

- The assessment should use quantifiable indicators measured without value judgements. The environmental, social and economic performance of the pavement treatments and asphalt mixtures should be expressed in terms of quantifiable indicators. This requires the definition of indicators for the three pillars.

The PavementLCM Sustainability Assessment Framework for pavement materials and activities works under EN 15643-5 and is focused on giving recommendations on how to perform the SA using a life cycle approach and specific indicators.

The SA of asphalt mixtures and pavement treatments can be performed for different purposes. According to EN 15643-5, these are:

- To determine the sustainability aspects and impacts of the civil engineering works inits area of influence
- To enable the client, users and designers to make decisions and choices that willhelp to address the need for sustainability of civil engineering work
- To demonstrate or communicate the sustainability performance of the civilengineering works.

The purpose of the assessment should be clearly identified at the beginning of the study, since it will influence the rest of the whole process. In this regard, the SA can be performed at different levels, here some examples of use:

- 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.

Finally, the SA can be conducted at different stages in a pavement engineering project life, here some examples of use:

- 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.

2.1.5 Life Cycle Thinking, Life Cycle Approach and Life Cycle Techniques

EN 15643-5 introduces the concept of Life Cycle Approach to be used in the SA of civil engineering works. Life Cycle Approaches and Techniques are tools to apply (i.e. materialise) Life Cycle Thinking (LCT) which "*is about going beyond the traditional focus on production site and manufacturing processes to include environmental, social and economic impacts of a product over its entire life cycle* (Figure 5)" (https://www.lifecycleinitiative.org/). The main goals of LCT are to reduce a product's resource use and emissions to the environment as well as improve its socio-economic performance through its life cycle. This may facilitate links between the economic, social and environmental dimensions within an organization and through its entire value chain. A product life cycle can begin with the extraction of raw materials from natural resources in the ground and the energy generation. Materials and energy are then part of production, packaging, distribution, use, maintenance, and eventually recycling, reuse, recovery or final disposal. In each life cycle stage there is the potential to reduce resource consumption and improve the performance of products.

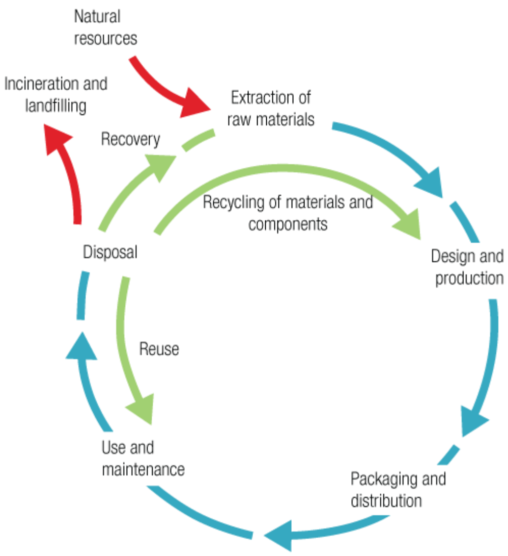


Figure 5. A typical product life cycle diagram (Life cycle initiative)

LCT involves three key steps:

1. Identifying the goal of the study. The goal of the study will determine and guide the rest of the analysis (next two steps). Examples of goals are the comparison of the sustainability performance of several materials or the evaluation of scenarios for network-level decisions and strategies for preservation, maintenance and rehabilitation.

2. Defining the life cycle stages of the product or system being considered. In pavement engineering, the products or systems to analyse can be asphalt mixtures, concrete, tack coats, pavement treatments, pavement structure, etc. Figure 6 shows an example of a pavement structure life cycle and activities associated to each stage. Depending on the goal of the study, the product or system and its life cycle stages to analyse will be different. PavementLCM is dedicated to pavement materials and activities, and more information about their life cycle stages can be found in Chapter 7 and in D5.1.

3. Conducting an analysis within the three pillars of sustainability using the appropriate techniques. There are several methods of measurement that are used to quantify the three pillars of sustainability, known as Life Cycle Techniques, these include: Life Cycle Management (LCM), Life Cycle Costing (LCC), Life Cycle Assessment (LCA) and Social Life Cycle Assessment (S-LCA). Additional information about these techniques is provided in the next subsections.

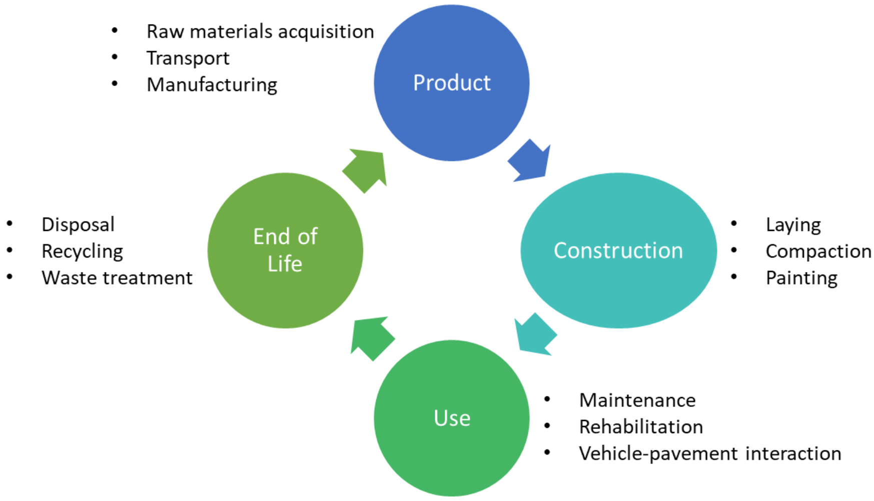


Figure 6. Example pavement structure life5cycle stages and activities associated

Benefits of Life Cycle Thinking and Approach

According to the Life Cycle Initiative, a life cycle approach helps to make choices. It implies that everyone in the whole chain of a product's life cycle has a responsibility and a role to play, taking into account all the relevant impacts on the economy, the environment and the society.

The impacts of all life cycle stages need to be considered comprehensively by all the stakeholders, when they make decisions on consumption and production patterns, policies and management strategies. A life cycle approach enables product designers, service providers, government agents and individuals to make choices for the longer term and with consideration of the three pillars of sustainability. It provides a transparent methodology that can be used to support the decision-making process for sustainability related issues at the product, project and network level.

Life Cycle Thinking and Approach help to identify the critical activities or points in the whole life cycle of a product or system causing the highest environmental, social and economic impacts and therefore enable to develop strategies and policies for their mitigation and minimisation, involving the appropriate stakeholder to take actions towards Sustainable Development.

The Sustainability Framework in Figure 7 describes a scheme where sustainability is achieved through the use of life cycle approaches, programmes and activities, and is supported by relevant and reliable datasets, as well as an appropriate policy framework. Figure 7 highlights that the base to carry out any Sustainability Assessment is the availability of data. Next, Life Cycle Approaches should be used to perform an assessment using Life Cycle Techniques. Once the assessment is conducted, it can be used for different purposes such as decision-making, sustainable design, sustainable procurement, etc. Based on this, Life Cycle Management systems and new policies can be developed and implemented to finally achieve Sustainability. In Figure 7, Phase III refers to the activities performed by the Life Cycle Initiative in 2012-2017.

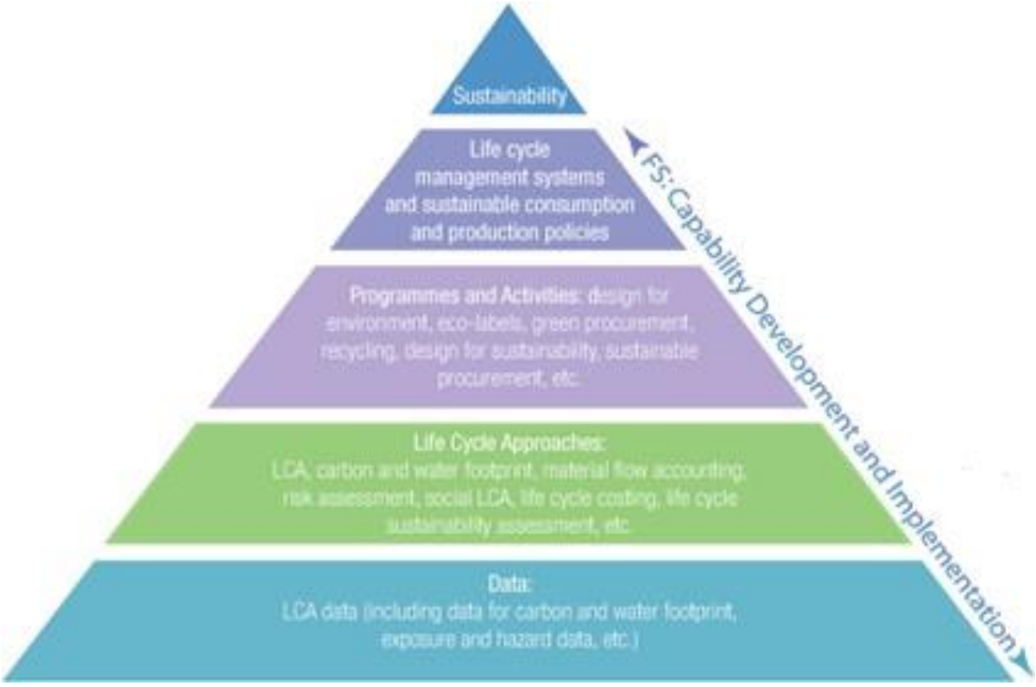


Figure 7. Sustainability Framework supported by Life Cycle Thinking and Approaches (Fava, 2017).

2.1.5.1 Life Cycle Techniques

Life Cycle Thinking is made operational through Life Cycle Management (LCM). LCM is a business management approach that can be used by all types of organizations in order to improve their sustainability performance, ensuring a more sustainable value chain management. LCM can be used to target, organize, analyse and manage product-related information and activities (Remmen & Jensen, 2007) towards continuous improvement along the product life cycle. LCM is used beyond short-term success and aims at long-term achievements minimising environmental and socioeconomic burden while maximising economic and social value (Sonnemann & Margni, 2015). Figure 8 represents all the elements in LCM, including tools and Life Cycle Techniques.

PavementLCM will address LCM in more details in WP5. Life Cycle Techniques are briefly described in the following sub-sections in terms of:

- Description
- Methodology
- Inputs and data needed
- Output
- Typical applications in pavement engineering
- Example practices
- NRA's resources needed to perform them
- Available information and tools

These techniques are further presented in details in the SA framework (Chapter 7 of this deliverable).

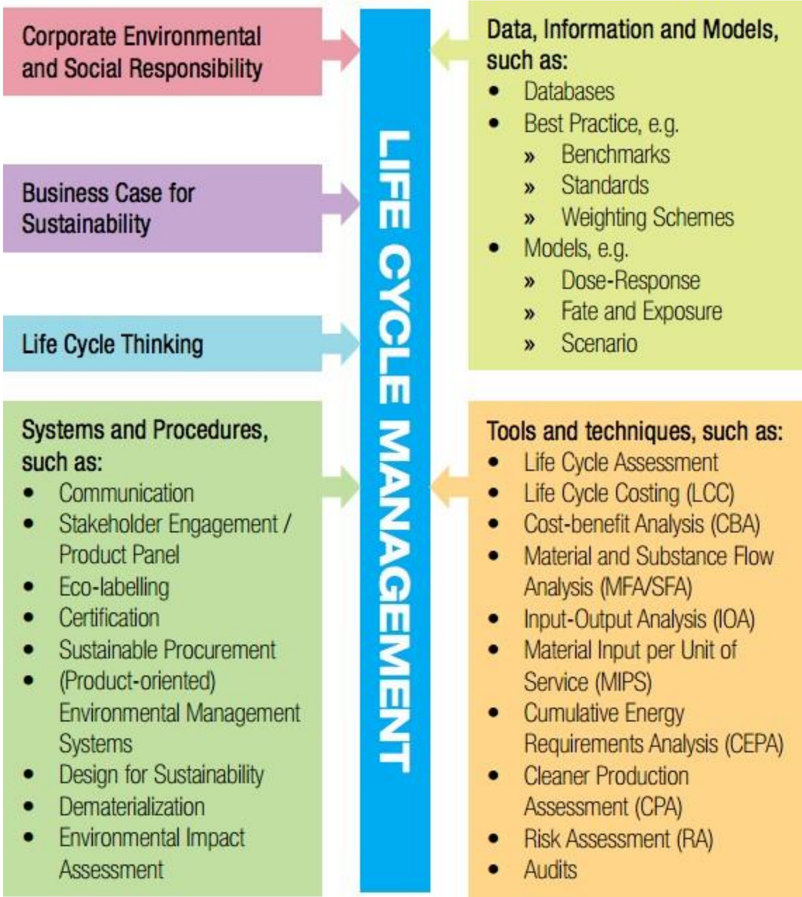


Figure 8. Life Cycle Management: A Business Guide to Sustainability (Remmen & Jensen, 2007)

2.1.5.2 Life Cycle Costing (LCC)

Description

LCC is a methodology for the systematic evaluation of the costs of an asset or its parts throughout its life cycle, while fulfilling the performance requirements and over a period of analysis (15686-5, 2017). This technique uses economic analysis to evaluate the total cost of an investment option in constant currency over the analysis period. It is therefore a measurement of the economic component of sustainability (Harvey et al. 2016). LCC will be further used to denominate this technique in this framework.

According with the costs taken into consideration, SETAC-Europe Working Group on LCC defines three different approaches: conventional, environmental, societal. The Conventional LCC evaluates all internal costs associated to the Life Cycle (or part of it) from a specific point of view (manufacturer or consumer), while the environmental LCC looks at the complete Life Cycle from several points of view, taking into consideration all the costs, internal and external. It means that there is a translation of environmental effects (externalities) in terms of money. The Societal LCC evaluates all the costs associated to the LC faced by all the actors, public administration included

For pavements, LCC provides a way of measuring the economic consequences of changes in design, materials, construction techniques, maintenance schemes, and end-of-life treatments over a defined analysis period. If only the internal costs for Agencies are taken into consideration, we can talk about conventional LCC. Otherwise, if the environmental costs (i.e. the consequences of CO2 emission) have to be considered in terms of money, it's necessary to translate LCA results with a specific methodology (i.e. ExternE) and to perform an environmental LCC.

Methodology

LCC methodology for a conventional study has five steps (Life-Cycle Cost Analysis Primer, 2002):

1. Establish LCC Framework. Select analysis period for the LCC. Determine how inflation will be addressed and establish discount rate to be used. Establish economic analysis indicators to be used for presenting results (e.g. net present value (NPV), equivalent uniform annual costs (EUAC)).

2. Establish Design Alternatives. Identify a range of possible design alternatives. Consider a minimum of two options that offer the same level of performance for a selected analysis period.

3. Determine Activity Timing. Define the schedule of initial and future activities (e.g. construction, maintenance, end of life) and their performance period for each selected pavement design or treatment alternative.

4. Estimate Costs. Estimate agency and user costs associated with the activities of each pavement design or treatment alternative being investigated over the selected analysis period.

5. Compute Life Cycle Costs. Calculate the total life-cycle cost agency and user cost for each alternative considered. All cost are converted to present currency (e.g. Euros, Sterling Pounds) using an established engineering economics technique known as “discounting” to account for the time value of money. Next, all the initial and future costs are summed to provide a NPV for the entire analysis period. If different analysis periods are used, the costs may be expressed in terms of a EUAC.

Inputs and data needed

- → Analysis period
- → Alternatives to be considered
- → Timing, performance and cost of each activity to be performed during the analysis period for each alternative
- → Discount rate
- → Current and projected traffic volumes
- → If user costs are to be considered:
  - ○ Construction work zone inputs (such as number of work zone lanes, work zone duration, etc.)
  - ○ User cost inputs (value of time categories of vehicles using the pavement)

Output

- ← LCC provides one indicator for the decision-making process. Agency costs and user costs can be included and may be expressed in terms of net present value (NPV) or equivalent uniform annual costs (EUAC).

Typical applications in pavement engineering

- Determine the pavement type or treatment strategy that results in the lowest overall life-cycle cost at the required level of performance
- Demonstrate the benefits of various maintenance strategies or construction processes on the users (e.g. vehicle operating cost, user delay costs, etc.)
- Estimate the initial costs and support future agency budget decisions for designing, constructing and maintaining a pavement at a specific performance level over a defined analysis period

Examples of applications within NRAs

- Trafikverket (Swedish Transport Administration) uses LCC at the core of their planning, procurement and design for any type of project. They have also used Green Procurement for years, providing discounts in the tender when a reduction in CO_2 is given.
- The California Department of Transportation has developed a detailed LCC procedure manual and requires LCC to be performed on all project that include a pavement cost component (with some exceptions such as preservation projects).

NRAs resources needed to perform LCC

- Internal staff or hired experts in LCC
- Calculations can be performed using pencil and paper, calculator or simple spreadsheet-based tools
- Some NRAs have developed their own customised LCC policy and software tools

Tools

- Real Cost LCCA (US, CA) - a tool to perform LCCA for pavement selection in accordance with FHWA best practice methods.
- SMART SPP - innovation through sustainable procurement" - Has been developed to help performing (LCC) and assessing emissions (CO2, CO2eq, NOx, SO2, NMHC and PM) of different products, work and services to assist in procurement decision-making.

References and available Information

- ISO 15686-5:2017 Building and constructed assets – Service life planning – Part 5: Life Cycle Costing (15686-5, 2017)
- EN 15643-4 Assessment of Buildings Part 4: Framework for the assessment of economic performance (EN 15643-4, 2012)
- Federal Highways Administration's LCC Primer (U.S. Department of Transportation, 2002)

2.1.5.3 Life Cycle Assessment (LCA)

Description

LCA is the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO 14040, 2006). LCA provides a comprehensive approach to evaluating the total environmental burden of a product or process by examining all of the inputs and outputs over the life cycle, from raw material production to end of life. This systematic approach identifies where the most relevant impacts occur and where the most significant improvements can be made while identifying potential trade-offs.

The processes and rules for conducting an LCA are generally defined by the International Organization for Standardization (ISO) in its 14040 family of standards (ISO 2006). These standards are quite broad; thus, more precise guidance is needed for their application to a specific material or process. Such guidance is usually developed by the relevant industries and other stakeholders. It is therefore a measurement of the environmental component of sustainability (Harvey et al. 2016).

Methodology

LCA methodology has four phases:

1. Goal and Scope definition. Goals for an LCA must first be set by the organization performing the LCA in order to determine the type of study, the scope and the approach for assessing impacts and making decisions. The scope of an LCA defines the system boundary (i.e., what is and is not to be included in the LCA). The scope should address the life cycle stages and processes to be included, identify the system boundaries of the analysis, define the functional unit of analysis, and define the required data quality, cut off rules and allocation procedures. These last elements are defined as:

    a. System boundaries: set of criteria specifying which unit processes are part of a product system

    b. Functional unit: quantified performance of a product system for use as a reference unit. When the LCA only includes the product stage as life cycle stage, the term used in declared unit.

    c. Data quality: characteristics of data that relate to their ability to satisfy stated requirements

    d. Cut off rule: specification of the amount of material or energy flow or the level of environmental significance associated with unit processes or product system to be excluded from a study

    e. Allocation: partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems

2. Life Cycle Inventory. The environmental flows (inputs of materials and energy, and outputs of waste, emissions and co-products) are estimated and quantified for each activity in the system being studied to produce the life cycle inventory (LCI).

3. Life Cycle Impact Assessment. The inputs and outputs flows from LCI are translated into selected impact category indicators, which varies depending on the Life Cycle Impact assessment methodology used. The most common impact category indicator in Global Warming Potential (GWP), and the most commonly used methodology in Europe is CML (Centre for Environmental Studies at the University of Leiden, the Netherlands).

4. Interpretation of Results. The overall results are summarised and discussed as a basis for conclusions, recommendations and decision-making in accordance to the defined goal and scope. Proper LCA practice, as defined by ISO 14044, includes an interpretation phase where the results are presented for the functional unit, the major environmental contributions are identified and explained in terms of where the environmental impacts are most pronounced (hotspots), the data uncertainty and variance are noted, and sensitivity analyses are conducted for the most important methodological assumptions.

Inputs and data needed

- → Analysis period
- → Timing, performance and material quantities for each activity to be performed during the analysis period
- → Datasets for all materials used (LCI of aggregates, bitumen, reclaimed asphalt, cement, etc.) or Environmental Product Declarations (EPDs)
- → Transportation modes and distances involved in all processes
- → Plants operation data (energy consumption)
- → Construction work zone inputs

→ Construction site equipment (energy use, use duration, emissions)

Output

← A full-LCA generates a range of environmental indicators, such as global warming potential, ozone depletion, particulate formation, acidification and eutrophication. The importance of each indicator for decision-making depends on each case study

Product Category Rules (PCRs), LCA and Environmental Product Declarations (EPDs)

One of the purposes of performing the LCA of a product might be to develop and Environmental Product Declaration (EPD). An EPD is a transparent, verified report used to communicate the environmental impacts of a specific product, providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information (ISO 14025, 2010).

EPDs express the results of an LCA of a product performed according to the Product Category Rules (PCRs). EPDs are developed with industry stakeholders and LCA experts and subjected to a critical review process following the industry standards described in the PCR document. Figure 9 shows the connection between PCRs, LCA and EPDs.

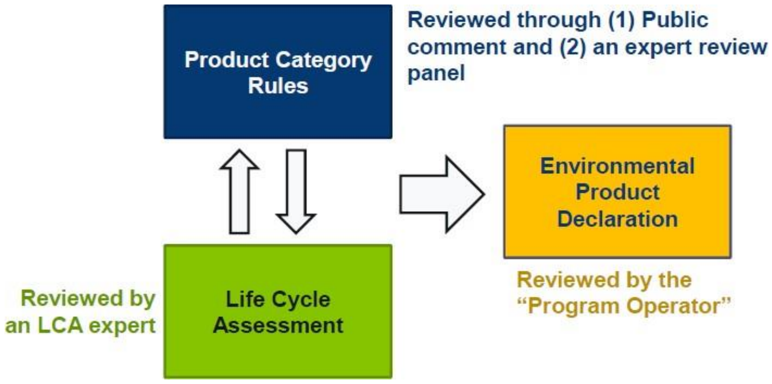


Figure 9. Relationship between PCRs, LCA and EPDs (Santero, 2014)

EPDs can then be used by industry for green procurement, communication and environmental performance progress evaluation.

Typical applications of LCA in pavement engineering

- Identyfing opportunities to improve the environmental performance of products at various points in their life cycle -> pavement material or structural design selection (FHWA)
- Determine the pavement type or treatment strategy that results in the lowest overall life-cycle cost at the required level of performance, in conjunction with LCCA
- Demonstrate the benefits of various maintenance strategies or construction processes on the users (e.g. vehicle operating cost, user delay costs, etc.)
- Quantifying information on the environmental performance of a product or system (The development of an EPD)), (FHWA)

- Estimate the initial environmental impact and support future agency budget decisions for designing, constructing and maintaining a pavement at a specific performance level over a defined analysis period
- Evaluation of scenarios for network-level decisions and strategies for preservation, maintenance and rehabilitation. (FHWA)
- Informing and guiding decision makers in industry, government, and nongovernmental organizations for a number of purposes, including strategic planning, priority setting, product or process design selection, and redesign, (FHWA).

Examples of current best practices within NRAs

- Rijkswaterstaat (Netherlands' Road Authority) uses LCCA and LCA for decision- making, performance measurement and green procurement as a requirement from the government. They applied these techniques at project level during the planning and realisation of projects. They have developed their own tool for LCA, Dubocalc.
- The California Department of Transportation and the Oregon Department of Environmental Quality are taking steps toward requiring Environmental Product Declarations (EPDs) for pavement and other transportation infrastructure materials for use in reporting, benchmarking, and LCA for design and asset management. California requires that EPDs for steel used by state agencies to be considered in procurement.

NRAs resources needed to perform LCA

- ➢ Dedicated internal staff or hired experts in LCA
- ➢ There are numerous LCA software tools that already include databases (LCIs) which can be used to develop LCA models
- ➢ Some NRAs have developed their own customised LCA policy and software tools, such as the Netherlands and Dubocalc

Tools

Common sustainability assessment tools:

- ◊ Simapro, GaBi and openLCA: generic LCA tools which are very flexible for modelling but not user friendly. The users usually have to be LCA experts to be able to handle them.

Common tools used by NRAs to compare products and verify sustainability claims in tendering processes are the following:

- ◊ asPECT (UK) - estimates CO2e emissions from asphalt paving processes in a cradle -to -gate scenario, meeting the specifications of the UK standard PAS 2050
- ◊ DuboCalc (NL) - calculates the environmental impacts over the entire life cycle. The environmental effects are converted into a single number via the "shadow price method".
- ◊ Ecorce M and SEVE (FR) - evaluate potential impacts on the environment in terms of several indicators using own database
- ◊ Klimatkalkyl (SE) - Calculates energy use and greenhouse gas emissions of transport infrastructure
- ◊ GreenDOT (USA) - Greenhouse Gas Calculator for State Departments of Transportation (GreenDOT), estimates CO2 emissions from construction, maintenance, and operations activities.

- ◊ EFFEKT (NO)

References and available information

- ◊ ISO 14044:2006+A1:2018 Environmental management. Life cycle assessment. Requirements and guidelines
- ◊ ISO 14040:2006 Environmental management. Life cycle assessment. Principles and framework (ISO 14040, 2006)
- ◊ EN 15804 Environmental Product Declarations – Core rules for product category of construction products (EN 15804, 2012)
- ◊ EN 15643-2 Assessment of Buildings Part 2: Framework for the assessment of environmental performance (EN 15643-2, 2011)
- ◊ Federal Highways Administration Pavement LCA Framework (Harvey et al. 2016)

2.1.5.4 Social Life Cycle Assessment (S-LCA)

Description

S-LCA is a systematic process using best available science to collect best available data on and report about social impacts (positive and negative) in product life cycles from extraction to final disposal. The scope (the life cycle) and the methodology (a systematic process of collecting and reporting about social impacts and benefits) are both key aspects which draw interest in the technique. S-LCA is best used for increasing knowledge, informing choices, and promoting improvement of social conditions in product life cycles (Benoît et al., 2010).

In S-LCA the potential or actual impacts are associated to a specific category of stakeholders, defined at the beginning of the study, who are expected to have similar interests due to their similar relationship to the investigated product system".

In 2004, the United Nations Environment Programme (UNEP)/SETAC life cycle initiative recognized a need for a task force on the integration of social criteria into LCA. S-LCA is therefore a recently developed technique and is not commonly used in pavement engineering. S-LCA is not used within PavementLCM SA Framework, although it is recognised as the next frontier for the sustainability assessment in the road industry

Methodology

Methodologically, a specific ISO doesn't still exist, therefore S-LCA is based on the same ISOs used for an environmental LCA, with some adaptations. A useful instrument are the Guidelines, (UNEP/SETAC, 2021) and the Methodological Sheets for Sub-categories in Social Life Cycle Assessment (2013), which identify the stakeholders categories who the specific impact subcategories correspond to.

S-LCA methodology has four phases:

1. Goal and Scope definition. Goals for an S-LCA must first be set by the organization performing the S-LCA to determine the type of study, the scope and the approach for assessing impacts and making decisions. The scope of an S-LCA defines the system analysis boundary (i.e., what is and is not included in the LCA). The scope should address the life cycle stages and processes included, identify the geographic and

temporal boundaries for the analysis, define the functional unit of analysis, and define the required data quality. Furthermore it is important to define the stakeholders involved on the basis of the categories identified in the Guidelines and the impact method (Reference Scale vs Impact Pathways).

2. Life Cycle Inventory. S-LCA gathers information on the organizational aspects at the enterprise/management level along the product life cycle concerning the social and socio-economic impacts.

3. Life Cycle Impact Assessment. The inputs and outputs flows from LCI are translated into selected indicators, such as number of jobs created. Indicators in S-LCA are divided into stakeholder categories (worker, consumer, local community children, value chain actors and society) and sub-categories (such as health and safety, feedback mechanism, consumer privacy, transparency and end of life responsibility). The assessment is carried out according to the methodological choice made in the first phase.4. Interpretation of Results. The overall results are summarised and discussed as a basis for conclusions, recommendations and decision-making in accordance to the defined goal and scope. Proper S-LCA practice, as defined by ISO 14044, includes an interpretation phase where the results are presented for the functional unit, the major environmental contributions are identified and explained in terms of where the impacts are most pronounced (hotspots), the data uncertainty and variance are noted, and sensitivity analyses are conducted for the most important methodological assumptions.

Further information

◊ UNEP/SETAC Guidelines for Social Life Cycle Assessment of Products (2009) (UNEP-SETAC & Initiative, 2020)
◊ UNEP/SETAC The Methodological Sheets for Sub-categories in Social Life Cycle Assessment (2013) (UNEP-SETAC & Life Cycle Initiative, 2013)
◊ ISO 14040:2006 Environmental management. Life cycle assessment. Principles and framework (ISO 14040, 2006)
◊ ISO 14044:2006+A1:2018 Environmental management. Life cycle assessment. Requirements and guidelines

2.1.5.5 Life Cycle Sustainability Assessment and Life Cycle Management

Description

Life Cycle Sustainability Assessment (LCSA) is the combination of LCCA, LCA and S-LCA (UNEP-SETAC, 2011) putting together the three dimensions of sustainability using Life Cycle Thinking towards more sustainable products. The implementation of LCSA into real world decision-making processes both at product, process or individual organizational level is to be ensured through the application of a broader Life cycle management (LCM) concept that aims at maximizing the triple bottom line. Finkbeiner (2011) referred to it as life cycle sustainability management (LCSM) for the first time.

Life cycle management (LCM) is a business management concept applied in industrial and service sectors to improve products and services, while enhancing the overall sustainability performance of the business and its value chains (UNEP-SETAC & Initiative, 2009). It makes life cycle thinking and product sustainability operational for businesses that are ambitious and are committed to reduce their environmental and socio-economic burden, while maximizing economic and social values. In this regard, LCM is used beyond the short-term business success rather it aims at taking businesses forward towards long-term achievements and sustainable value creation. So LCM requires a holistic view and a full understanding of interdependency of businesses in order to support relevant decisions and actions so as to improve sustainability performance that takes into account both the environmental and social benefits and at the same time offer a number of value creation opportunities to the business.

Further information

- UNEP/SETAC Life Cycle Sustainability Assessment of Products (2009) (UNEP-SETAC & Initiative, 2009)
- Finkbeiner M (ed) (2011) Towards life cycle sustainability management. Springer, Dordrecht/Heidelberg/London/New York

2.2 State of the art on Sustainability assessment in pavement engineering

After having introduced a background on Sustainabiliy Assessment (SA), the State-of-the-Art (SoA) is presented in this Section to summarise the main standardisation and research efforts and advances on SA for pavement engineering. The SoA is divided in sub-sections including:

- Standards
- Guidelines
- Main EU projects related to SA of pavements

This SoA represents the ground on which PavementLCM SA Framework is built and therefore the review of the documents is focused on presenting the elements that will be useful for the development of the framework.

2.2.1 Standards

The European Committee for Standardisation (CEN) Technical Committee 350 (CEN/TC350) is responsible for the development of horizontal standardized methods for the assessment of the sustainability aspects of new and existing construction works (buildings and civil engineering works), including horizontal core rules for the development of environmental product declaration of construction products (EPD). CEN/TC350 is also entrusted with an advisory function to CEN TCs to ensure the effective implementation of horizontal core rules regarding the development a specific product category rules based on “EN 15804 Sustainability of construction works — Environmental product declarations — Core rules for the product category of construction products (EN 15804, 2012)“.

The Technical Committee is divided into eight Working Groups (WG):

- CEN/TC350/WG1: Environmental performance of buildings
- CEN/TC350/WG3: Product Level (EPDs, communication formats, etc.)
- CEN/TC350/WG4: Economic Performance Assessment of Buildings
- CEN/ TC350/WG5: Social Performance Assessment of Buildings
- CEN/TC350/WG6: Civil Engineering works
- CEN/TC350/WG7: Framework and coordination
- CEN/ TC350/WG8: Sustainable refurbishment

Within PavementLCM, WG6 is the one of particular interest since it is dedicated to civil engineering works. In 2017, “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” was released as the first standardised framework for the sustainability assessment of civil engineering works. In this regard, any framework built for the sustainability assessment of pavements, or any sustainability assessment itself, must comply with this standard.

“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” forms part of a series of European Standards (EN 15643), written by CEN/TC 350, that provide a system for the sustainability assessment of civil engineering works using a life cycle approach. The sustainability assessment quantifies aspects and impacts to assess the environmental, social and economic performance of civil engineering works using quantifiable indicators measured without value judgements.

CEN/TC350 work programme is divided in three levels to create standards for different purposes as following (Table 1):

- Framework level: the purpose is to provide a framework with principles, requirements and guidelines for the sustainability assessment of a system. It focuses on the general principles and requirements for the assessment of the environmental, social and economic performance of a system.
- Work level: the purpose is to provide calculation methods for the assessment of the performance of new and existing systems.
- Product level: the purpose is to provide core product category rules for all construction products and services. It provides a structure to ensure that all Environmental Product Declarations (EPD) of construction products, construction services and construction processes are derived, verified and presented in a harmonised way.

Table 1. Levels for standardisation of construction works

	Buildings	**Civil Engineering Works**
Framework level	EN 15643-1 Sustainability of Construction Works – Sustainability Assessment of Buildings Part 1: General Framework	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
	EN 15643-2 Assessment of Buildings Part 2: Framework for the assessment of environmental performance	
	EN 15643-3 Assessment of Buildings Part 3: Framework for the assessment of social performance	
	EN 15643-4 Assessment of Buildings Part 4: Framework for the assessment of economic performance	
Works level – Calculation methods	EN 15978 Assessment of environmental performance of buildings – Calculation method	
	EN 16309 Assessment of social performance of buildings – Calculation method	
	EN 16627 Assessment of economic performance of buildings – Calculation method	
Product level	EN 15804:2021 + A2:2019- Environmental Product Declarations – Core rules for product category of construction products	
	EN 15942 Environmental Product Declarations – Communication format - Business	
	CEN/TR 15941 Environmental Product Declarations – Methodology for selection and use of data	

Table 1 summarises the current status of development of standards for the three different levels and each pillar of sustainability for buildings, civil engineering works and construction works. EN 15643-5 is part of the framework level series, whose purpose is to enable comparability of the results of assessments. It is clear from Table 1 that the standardisation process of the sustainability assessment of buildings is a step forward compared to civil engineering works, especially at work level and which shows the following status:

- Framework level: 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.
- Work level: WI 00350028: Assessment of environmental, economic and social performance of civil engineering works. Calculation method – WG6's work in progress with several drafts based on the existing standards for buildings.
- Product level: EN 15804:2012+ A2:2019 Environmental Product Declarations – Core rules for product category of construction products. EN 15942 Environmental Product Declarations – Communication format – Business. CEN/TR 15941 Environmental Product Declarations – Methodology for selection and use of generic data.

EN 15643-5 does not set benchmarks or levels of performance but it is developed to allow the sustainability assessment to be made on the basis of the technical characteristics and functionality of the object of assessment. The standard applies to all types of civil engineering works and includes environmental, social and economic impacts.

2.2.1.1 Sustainability Assessment of civil engineering works – EN15643‑5

Considering the context in which EN 15643-5 has been developed, the main features of this document are summarised here to understand the umbrella under which PavementLCM SA Framework has to be built. Therefore, the objectives, object of assessment, principles and requirements, information modules, requirements for data quality, reporting and communication and the overview of the methodology for the SA are presented. After that, the standards to which EN15643-5 refers to for the performance of the environmental, economic and social assessment are reported.

2.2.1.1.1 Objectives of sustainability performance assessment of civil engineering works

EN 15643-5 sets the objectives of the assessment as:

- To determine the sustainability aspects and impacts of the civil engineering works inits area of influence0
- To enable the client, users and designers to make decisions and choices that willhelp to address the need for sustainability of civil engineering workso
- To demonstrate or communicate the sustainability performance of the civilengineering works.

2.2.1.1.2 Object of the assessment

The definition of the object of assessment shall include:

- Civil Engineering Work (CEW)
- Its area of influence
- External works and temporary works associated

The system boundary for the assessment of environmental, social and economic performance of a civil engineering works shall start from the beginning of the planning of the development, acquisition or refurbishment of a civil engineering works or from the start of assessment of any existing civil engineering works and include the life cycle of the civil engineering works. The system boundary shall include:

- Spatial boundary (area of influence)
- Study period (life cycle considered)

Given that the area of influence is not always limited to the civil engineering works itself or some set distance from this area, the area of influence shall be defined for each of the dimensions of sustainability: environmental, social and economic. On the other hand, the study period must be the same for the three pillars of sustainability. The study period may or may not be the same as the required service life of the CEW. If the study period is not the same as the required service life, the remaining service life, if any, shall also be considered.

Assessments can be undertaken either for the whole civil engineering works, for a part of the civil engineering work or for a combination of several civil engineering works. If the assessment is restricted to a part of the object of assessment or to a part of the life cycle, or if any relevant impacts are not addressed, this shall be documented, reported and justified.

2.2.1.1.3 Principles and requirements

All the dimensions of sustainability shall be included in the assessment of civil engineering works' performance. In carrying out assessments, scenarios and a functional equivalence are determined at the civil engineering works level. Assessment at the civil engineering works level means that the descriptive model of the works with the major technical and functional requirements has been defined in the client's brief or in the regulations, as illustrated in Figure 10. Technical and functional characteristics influence the assessment therefore need to be taken into account by referencing to the functional equivalent, which also forms a basis for comparison of the results of other assessments.

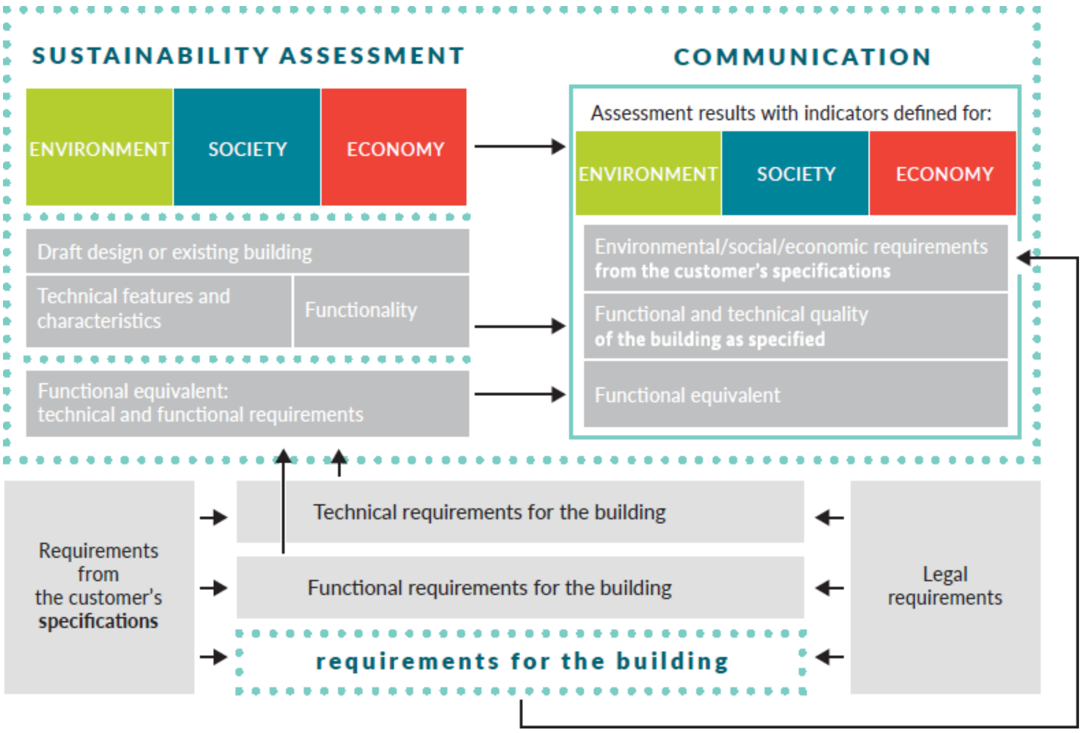


Figure 10. Concept of sustainability assessment of Civil Engineering works (EN 1564355:2017). Source: A. Passer TU Graz 2017

2.2.1.1.4 Information Modules

The assessment of the sustainable performance of a civil engineering works requires information on the environmental, social and economic aspects and impacts based on a life cycle approach for all information modules (A to D) shown in Figure 11. The definition of these modules and the code used with letters and numbers assigned to each module is widely used in any sustainability assessment to refer to the different life cycle stages of the system (e.g. A1 Raw Material Supply).

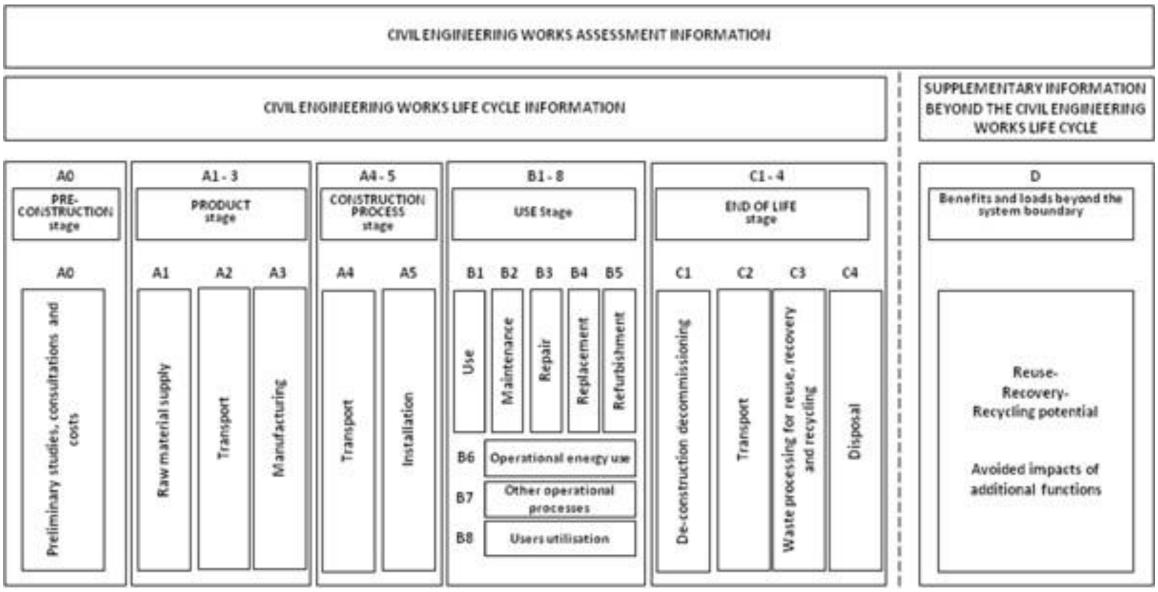


Figure 11. Information modules applied in the assessment of environmental, social and economic performance of civil engineering works (EN 1564355)

Assessments shall be established on the basis of specified **scenarios** that represent the civil engineering works life cycle. The applied scenarios shall be described or referenced in the assessment report and made available for communication. The scenarios shall be realistic and representative and in accordance with the technical and functional requirements as given in the functional equivalence.

2.2.1.1.5 Type of data and requirements for data quality

The data quality in terms of accuracy, precision, completeness and representativeness for the assessment of environmental, social and economic performance of civil engineering works shall be in accordance with the requirements of the future standard on calculation methods of sustainability for civil engineering works. Environmental information at the product level shall be in accordance with EN 15804 (see Table 2).

The development of an assessment standard for environmental, economic and social performance of civil engineering works will be the subject of future standardization work of CEN/TC 350/WG 6. The assessment standard will describe the detailed calculation methods and appropriate sources of data for the environmental, economic and social indicators.

2.2.1.1.6 Reporting and communication

The sustainability assessment of civil engineering works uses different types of information. The results of a sustainability assessment of a civil engineering works provide information on the different types of indicators, the related civil engineering works scenarios, and the life cycle stages included in the assessment.

The results of the assessments shall be organized as shown in Figure 12:

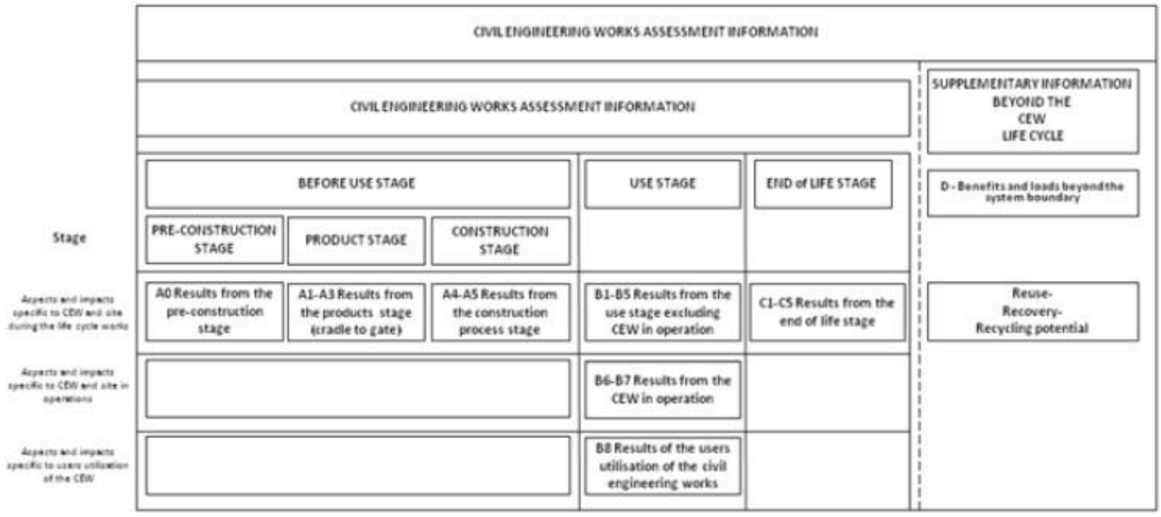


Figure 12. Organization of the results of the assessment to be communicated in accordance with the life cycle stages and the normative groups of information (EN 1564355)

2.2.1.1.7 Overview of the methodology

For the assessment of the environmental, social and economic performance of a civil engineering works, the following shall apply:

- The assessment of the environmental performance shall be based on the Life Cycle Assessment in accordance with the guidelines and requirements of EN ISO 14044 and additional quantifiable environmental information0
- The assessment of the economic performance shall be based on cost and financial value, and should take into consideration ISO 15686-5.
- The assessment of the social performance shall be based on the general principles contained within ISO 15392: 2019 0

In order to support the assessment of sustainable performance of civil engineering works, the future series of standards within this framework shall provide:

- the description of the object of assessment (the civil engineering works)0
- the functional equivalence
- the system boundary that applies at the civil engineering works level0
- the indicators and calculation procedures to be used0
- the requirements for the data necessary for the assessment0 and
- the requirements for presentation of the results in reporting and communication.

The following requirements are further specified in EN15643-5 for the development of indicators:

- They should be quantitative or if not quantitative, shall be quantifiable
- The indicators used at the product level also shall be applicable for the civil engineering works level assessment

- It shall be possible to aggregate the results of individual indicators from the product level to the civil engineering works level (while still keeping the modularity principle). It should be noted that aggregation is only possible for modules identified within the "product system"
- They shall avoid double counting

In this way, EN15643-5 sets the framework in which the SA of civil engineering works, and therefore pavement materials and activities, has to be performed. The standards mentioned above and further relevant standards are next presented.

2.2.1.2 Environmental assessment standards – EN ISO 14040, EN ISO 14044 and EN15804

The environmental assessment of pavement materials and activities has to be carried out using Life Cycle Assessment (LCA) according to EN15643-5. The principles and framework to perform a LCA of any system are established in EN ISO 14040 and the requirements and guidelines in EN ISO 14044.

LCA methodology consist of four phases that were described in Section 2.1.5 of this deliverable. These phases are related between each other as shown in Figure 13, together with its direct applications.

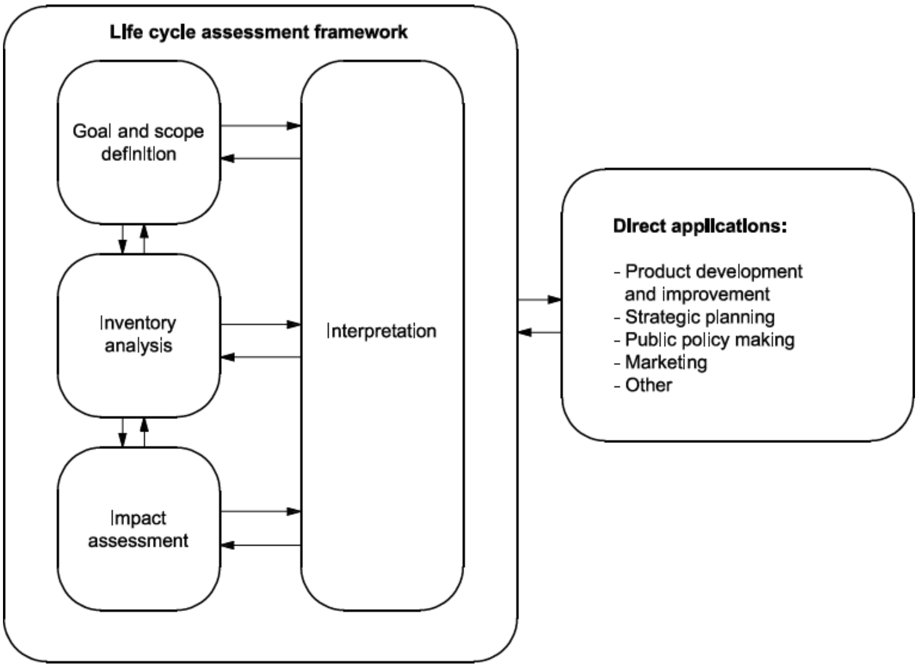


Figure 13. LCA Phases (ISO 14040)

ISO standards provide the general principles, methodological framework, guidelines and requirements to perform the LCA of any system and should be always complied with. However, these standards leave details and choices (e.g. system boundaries, impact assessment methodology, etc.) open to practitioners of each field. In this regard, in order to facilitate and harmonise the LCA of the same products and systems and allow comparisons, Product Category Rules (PCRs) are developed to set a common ground to carry out the assessment, allow the comparison of results and produce Environmental Product

Declarations (EPD).

In this context, “EN 15804:2012 Sustainability of construction works – Environmental product declrations – Core rules for the product category of construction products“ was developed to have common European PCRs for construction products.

Considering the life cycle stages of a system (Figure 6), different types of LCA can be performed depending on the life cycle stages included in the study as following:

- Cradle-to-gate: only the product stage is included.
- Cradle-to-gate with options: the product stage and selected further life cycle stages are included.
- Cradle-to-grave: all the life cycle stages are included.

If EPDs are to be produced, EN15804:2012 + A2:2019 establishes mandatory and optional life cycle stages to include for each case as in Figure 14.

	CONSTRUCTION WORKS ASSESMENT INFORMATION																
	CONSTRUCTION WORKS LIFE CYCLE INFORMATION																SUPPLEMENTARY INFORMATION BEYOND CONSTRUCTION WORKS LIFE CYCLE
	A1 - A3			A4 - A5		B1 - B7							C1 - C4				D
	PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARY
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
	Raw material supply	Transport	Manufacturing	Transport	Construction - Installation process	Use	Maintenance	Repair	Replacement[1]	Refurbishment	Operational energy use	Operational water use	Deconstruction demolition	Transport	Waste processing	Disposal	Reuse, recovery, recycling potential
				scenario	scenario	scenario	scenario	scenario	scenario	scenario	scenario	scenario	scenario	scenario	scenario	scenario	scenario
Cradle to gate with modules C1-C4 and module D	Mand.	Mand.	Mand.										Mand.	Mand.	Mand.	Mand.	Mandatory
Cradle to gate with options,modules C1-C4 and module D	Mand.	Mand.	Mand.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.	Mand.	Mand.	Mand.	Mand.	Mandatory
Cradle to grave and module D	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mand.	Mandatory
Cradle to gate[2]	Mand.	Mand.	Mand.														
Cradle to gate with options[2]	Mand.	Mand.	Mand.	Opt.	Opt.												

The main features of EN 15804:2012 + A2:2019 and any PCR are related to the definition of functional or declared unit, cut-off criteria, allocation procedures, data quality requirements and LCIA, and are therefore summarised in Table 2.

Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

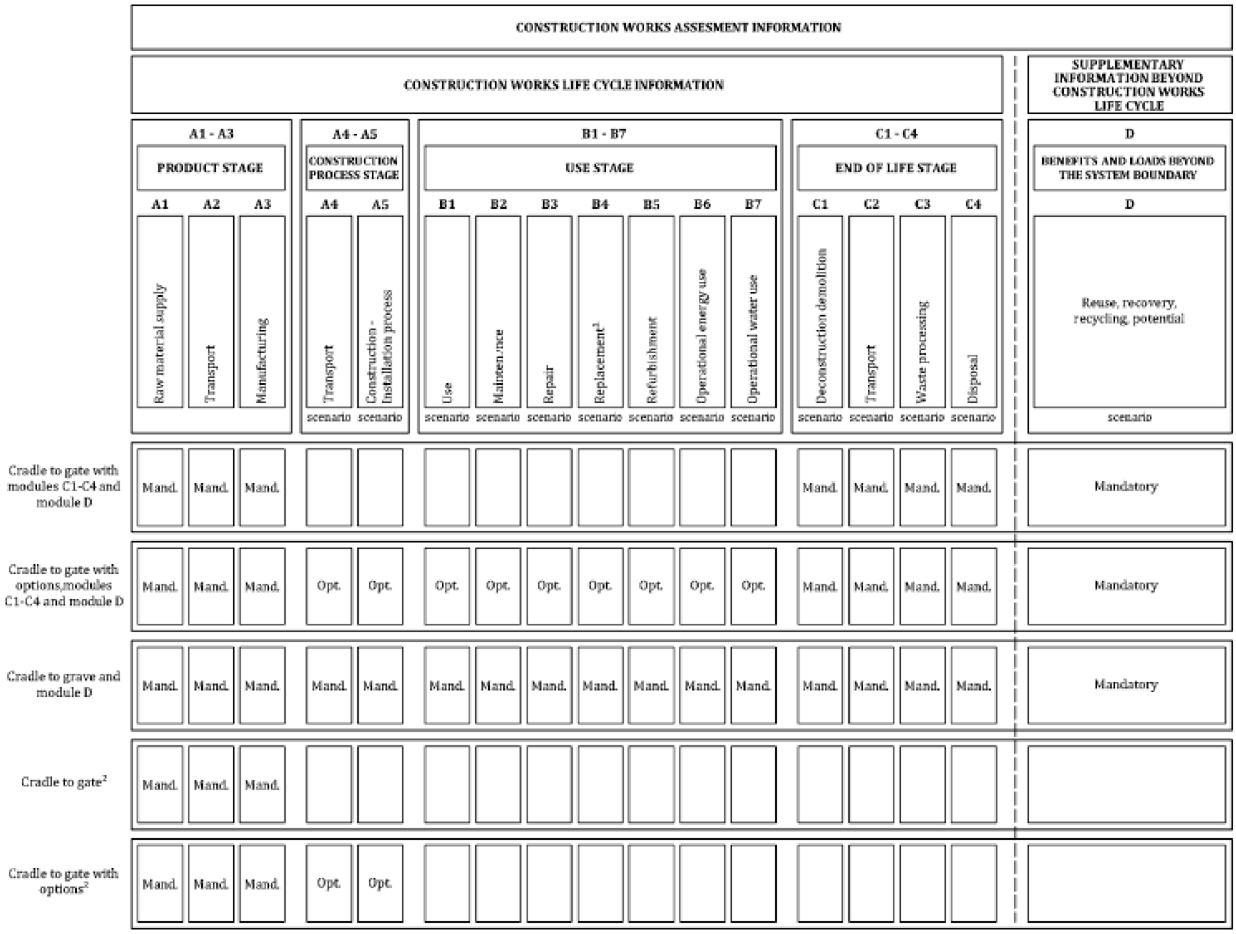


Figure 14. Types of EPD with respect to life cycle stages and modules covered for the assessment of construction works

According to EN15804:2012 + A2:2019, The amendments will include a new definition of types of EPDs including:

- Cradle-to-gate (A1-A3) with modules C1-C4 and module D
- Cradle-to-gate (A1-A3) with optional modules (B1-B7), C1-C4 and module D
- Cradle-to-grave (A1-C4) and module D
- Cradle-to-gate (A1-A3)
- Cradle-to-gate (A1-A3) with options (A4-A5)

This amendment gives more importance to module D regarding benefits and loads beyond the system boundary. Regarding data quality, the amendment includes further criteria to be considered such as geography coverage, a special section dedicated to biogenic carbon which should be separately declared, and additonal environmental impact indicators such as land use and water. This deliverable will be updated when EN15804:2019 is published.

Further PCRs specifically relates to pavement materials and activities have been developed by different institutions and are presented in section 2.2.2 of this deliverable.

Table 2. Main features of EN15804:2012+A2:2019 for the production of EPDs of construction products

<table>
<tr><th>Type of EPD</th><th>Mandatory Life cycle stages</th><th>Functional/ Declared unit</th><th>Cut off criteria</th><th>Data quality</th><th>Allocation</th><th>LCIA</th></tr>
<tr><td>Cradle-to-gate</td><td>A1-A3</td><td>Declared unit</td><td rowspan="5">- All inputs and outputs to a(unit) process shall be included in the calculation,for which data are available. Data gaps may be filled by conservative assumptions with averageor generic data. Any assumptions for such choices shall be documented.
- In case of insufficient input data or data gaps for a unitprocess, the cut-off criteriashall be 1 % of renewable and non-renewable primaryenergy usage and 1 % of the total mass input of that unit process. The total of neglected input flows per module, e.g. per module A1-A3, A4-A5, B1-B5, B6-
- B7, C1-C4 and module D shall be a maximum of 5 %of energy usage and mass.Conservative assumptions in combination with plausibility considerations and expert judgement can be used to demonstrate compliance with these criteria.
- Particular care should</td><td rowspan="5">- Data shall be as current as possible. Data sets used for calculations shall have been updated within the last 10 years for generic data and within the last 5 years for producer specific dataL
- Data sets shall be based on 1 year averaged dataL deviations shall be justified
- The time period over which inputs to and outputs from the system shall be accounted for is 100 years from the year for which the data set is deemed representative. A longer time period shall be used if relevant.
- The technological coverage shall reflect the physical reality for the declared product or product groupL
- Generic data: Guidance for the selection and use of generic data is</td><td rowspan="5">Co-production:
Allocation shall be avoided as far as possible by dividing the unit process to be allocated into different sub-processes that can be allocated to the co-products and by collecting the input and output data related to these sub? processes.
If it cannot be avoided:
- Allocation shall be based on physical properties (e.g. mass, volume) whenthe difference in revenue from the co-products is low.
- In all other cases allocation shall be basedon economic values-
- Material flows carrying specific inherent properties, e.g. energy content, elementary composition (e.g. biogeniccarbon content), shall always be allocated reflecting the physical flows, irrespective of the allocation chosen for the process.
Reuse, recycling and recovery:</td><td rowspan="5">Impact categories (core):
- climate change total
- depletion of abiotic resources (fossil)
- depletion of abiotic resources (elements)
- acidification of soil and water
- ozone depletion
- eutrophication
- photochemical ozone creation
- water use
Impact categories (additional):
- particulate matter emission
- ionizing radiation
- eco-toxicity
- human toxicity (cancer/non cancer effects)
- Land use</td></tr>
<tr><td>Cradle-to-gate with options</td><td>A1-A3 plus any option (B1-B7) optional, C1-C4 and D</td><td>Functional or Declared unit</td></tr>
<tr><td>Cradle-to-gate with options (A4- A5)</td><td>A1- A3 plus A4-A5</td><td>Declared unit</td></tr>
<tr><td>Cradle-to-gate with modules C1-C4 and module D</td><td>A1-A3 plus C1-C4 and D</td><td>Functional unit</td></tr>
<tr><td>Cradle-to-grave and module D</td><td>A1-C4 + D</td><td>Functional unit</td></tr>
</table>

			be taken to include material and energy flows known to have the potential to cause significant emissions into air and water or soil related to the environmental indicators of this standard. Conservative assumptions in combination with plausibility considerations and expert judgement can be used to demonstrate compliance with these criteria.	provided in CEN/TR 15941. Generic data shall be checked for plausibilityL	The end?of?life system boundary of the construction product system is set where outputs of the system under study, e.g. materials, products or construction elements, have reached the end?of?waste state. Therefore, waste processing of the material flows (e.g. undergoing recovery or recycling processes) during any module of the product system (e.g. during the production stage, use stage or end?of?life stage) are included up to the system boundary of the respective module as defined above.	

2.2.1.3 Economical assessment standard – ISO 15686:5

The economical assessment of pavement materials and activities has to be carried out using Life Cycle Costing (LCC) according to EN15643-5, specifically following the standard ISO 15686-5:2017 "Buildings and constructed assets – Service life planning Part 5: Life Cycle Costing". This standard provides requirements and guidelines for performing LCC to enable its practical use in the construction industry. As mentioned in Section 2.1.5 of this deliverable, LCC is a methodology for the systematic evaluation of the costs of an asset or its parts throughout its life cycle, while fulfilling the performance requirements and over a period of analysis. The final output of LCC is the calculation of two possible indicators: life cycle cost or whole life cost of the asset. It is important to notice the differentiation that ISO 15686-5 makes between both indicators as shown in Figure 15, defining:

- Life Cycle Cost: cost of an asset or its parts throughout its life cycle, while fulfillingthe performance requirements.
- Whole Life Cost: all significant and relevant initial and future costs and benefits of an asset, throughout its life cycle, while fulfilling the performance requirements.

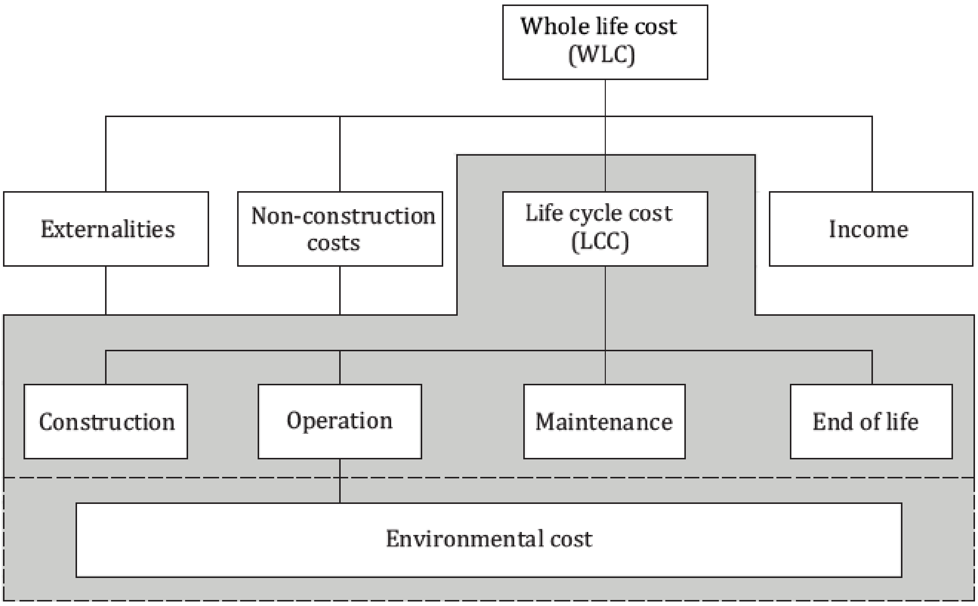


Figure 15. WLC and LCC in ISO 1568665

Therefore, the indicator Life Cycle Cost does not take into account the cost of externalities, being defined as quantifiable costs or benefits that occurs when the actions of organizations and individuals have an effect on people other than themselves, non-construction costs (such as site costs) and income (such as income from sales).

The detailed methodology described in ISO 15686-5:2017 to perform LCC of pavement materials and activities is part of the PavementLCM SA Guidelines and is described in detailed in D5.1.

2.2.1.4 Social assessment standard – ISO 15392

The social assessment of pavement materials and activities has to be carried out using the objectives and principles defined in ISO 15392 "Sustainability in building construction –

General principles“, according to EN15643-5. This standard established such objectives and principles for the three pillars of sustainability, and for social aspects it specifies that:

The consideration of social aspects is closely linked to the areas of concern “social infrastructure”, “cultural heritage” and “human health and comfort”. In describing and assessing construction works consideration is given, where relevant, to the aspects of health and comfort and the socio-economic as well as the cultural value of the property. Social aspects may relate to individuals (e.g. the users of a building) and/or to groups of people (e.g. local society).

2.2.2 Other references

Once the relevant standards related to SA in construction works have been presented, further guidelines and frameworks related to the environmental and economical assessment of systems are summarised to widen the basis of PavementLCM SA Framework.

2.2.2.1 Product Environmental Footprint (PEF) Guide

The Product Environmental Footprint (PEF) (European Commission, 2012) is a multi-criteria measure of the environmental performance of a good or service throughout its life cycle. PEF information is produced for the overarching purpose of helping to reduce the environmental impacts of goods and services. The PEF guide provides guidance on (1) how to calculate a PEF (e.g. how to perfom a PEF study) and (2) how to create product category specific methodological requirements for use in Product Environmental Footprint Category Rules (PEFCRs).

A PEF study should be performed following the phases in Figure 16, in which they have been compared to LCA phases seeing clear similarities.

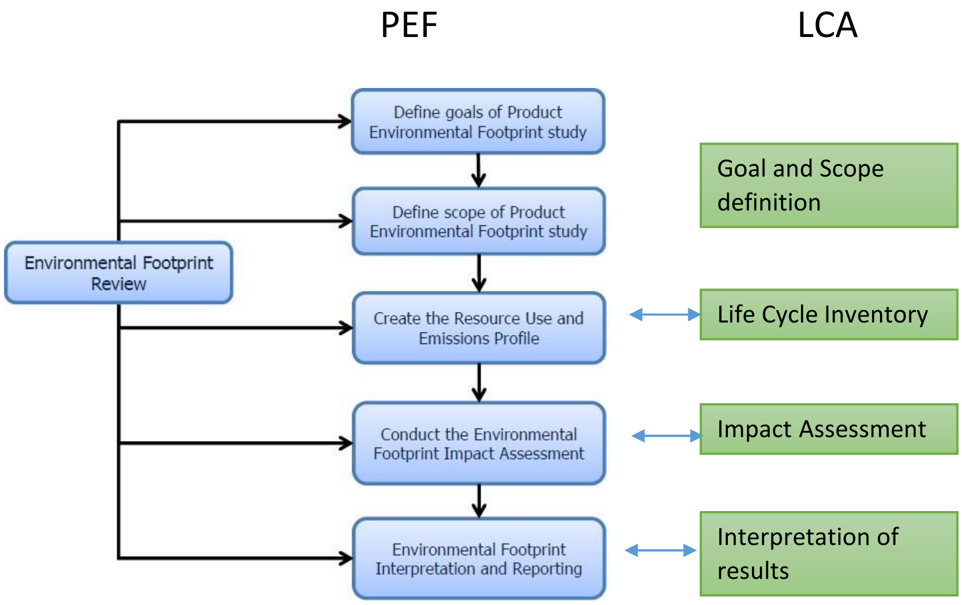


Figure 16. Phases of a PEF vs LCA study

Based on a life-cycle approach, the PEF guide provides a method for modelling the environmental impacts of the flows of material/energy and resulting emissions and waste streams associated with a product from a supply chain perspective (from extraction of raw materials, through use, to final waste management). PEF Guide provides therefore the recommendations shown in Table 3 related to the definition of functional or declared unit, cut‑off criteria, allocation procedures, data quality requirements and impact categories.

Table 3. Main features of PEF Guide to perform PEF studies

Life cycle stages	Functional/ Declared unit	Cut off criteria	Data quality	Allocation	EF impact categories
Cradle-to-grave as default approach, or different if otherwise specified in PEFCRs.	Functional unit	Not allowed	- Technological representativeness - Geographical representativeness - Time-related Representativeness - Completeness - Parameter uncertainty - Methodological Appropriateness and Consistency	Co-production (multifunctionality in PEF): - subdivision or system expansion -allocation based on a relevant underlying physical relationship (substitution may apply here) - allocation based on someother relationship. Recycling: Specific approach and formula to use	• Climate change • Ozone depletion • Ecotoxicity for aquatic fresh water • Human Toxicity cancer effects • Human Toxicity non-cancer effects • Particulate Matter/Respiratory Inorganics • Ionising Radiation human health effects • Photochemical Ozone Formation • Acidification • Eutrophication – terrestrial • Eutrophication – aquatic • Resource Depletion – water • Ecotoxicity (freshwater) • Land use • Water use • Resource use – mineral, fossil • Resource use, energy carriers

2.2.2.2 Product Category Rules for Asphalt materials and pavements

In addition to the EN 15804:2012 Sustainability of construction works – Environmental Product Declarations – Core rules for the product category of construction products, other institutions have developed more specific PCRs related to asphalt materials and pavements. EDGAR CEDR project performed the review of these type of documents until 2014 and it can be found in their deliverable 2.1 "Recommended Product Category Rules (PCRs) for bituminous materials and technologies", providing the information about:

- EN 15804 Sustainability of construction works – Environmental Product Declarations
- Core rules for the product category of construction products
- Norwegian Product Category Rules (NPCR) 18 Asphalt and crushed stone10.11.2010
- EPD UN CPC 375: Concrete
- CLF PCRs for concrete
- The International EPD System: UN CPC 53211: Highways (Except Elevated Highways), Streets and Roads v1.02
- ECOLABEL: an FP7 project.

Since 2014, further PCRs have been published by different institutions and associations and are presented here as following:

- National Asphalt Pavement Association (NAPA) 2017: Product Category Rules for Asphalt Mixtures (NAPA, 2017)
- European Asphalt Pavement Association (EAPA) 2017: Guidance Document For preparing Product Category Rules (PCR) and Environmental Product Declarations (EPD) for Asphalt Mixtures (EAPA, 2017)
- The International EPD System 2018: Product Category Rules for Asphalt Mixtures (The International EPD System, 2018a)
- The Norwegian EPD Foundation 2017: Product Category Rules for Asphalt (The Norwegian EPD Foundation, 2017)
- The International EPD System 2018: Product Category Rules for Highways (Except Elevated Highways), Streets and Roads v2.0 (The International EPD System, 2018b)

This section provides a brief description of each of the listed PCRs, including a comparison in Table 4 in terms of the system, life cycle stages, declared or functional unit, cut-off rules, data quality, allocation rules and life cycle impact categories that they specify.

2.2.2.2.1 National Asphalt Pavement Association (NAPA) 2017: Product Category Rules for Asphalt Mixtures

This set of PCRs is intended to support Environmental Product Declarations (EPDs) of asphalt mixtures produced in the United States of America. It was developed to accommodate the use and implementation of Type III EPDs that will provide the basis for determining cradle-to-gate environmental impacts for the production of asphalt mixtures in the United States of America, including the federal district and territories.

This PCR is based upon the “Product Category Rules for Preparing an Environmental Declaration for Product Group Asphalt and Crushed Stone (NPCR 18)” published by The Norwegian EPD Foundation in November 2010. Primary differences between this document and NPCR 18 are as follows:

- Geography: United States, including the federal district and territories
- Environmental Impact Methods: Tool for the Reduction and Assessment of Chemicaland Other Environmental Impacts (TRACI) 2.1 and
- Data Sources: Prescribed upstream inventories.

2.2.2.2.2 European Asphalt Pavement Association (EAPA) 2017: Guidance Document for preparing Product Category Rules

(PCR) and Environmental Product Declarations (EPD) for Asphalt Mixtures

These guidelines for product category rules (PCR) are intended for European companies (including companies located beyond the EU29) to prepare Environmental Product Declarations (EPDs) for asphalt mixtures. The guidelines were prepared by members of the “EAPA Task Group CFD”.

This document is based upon information gathered from relevant documentation from Norway, France, UK, USA e.g. “Product Category Rules for preparing an environmental declaration for product group asphalt and crushed stone” by The Norwegian EPD Foundation published in 2010.

The PCR based on this guidance is developed to accommodate the use and implementation of Type III Environmental Product Declarations that will provide the basis for comparing cradle-to-gate environmental impacts for the production of asphalt mixtures in Europe.

2.2.2.2.3 The International EPD System 2017: Product Category Rules for Asphalt Mixtures

This PCR specifies the requirements for the LCA study and the format and content of EPDs for “Bitumen and asphalt, natural asphaltites and asphaltic rock” and “Bituminous mixtures based on natural and artificial stone materials and bitumen, natural asphalt or related substances as a binder” in Europe.

This PCR covers asphalt mixtures and pavement components including life cycle approaches of cradle-to-gate, cradle-to-gate with options and cradle-to-grave.

2.2.2.2.4 The Norwegian EPD Foundation 2017: Product Category Rules for Asphalt

These product category rules (PCR) are intended for companies preparing an environmental product declaration (EPD) for asphalt (see chapter 6.1 for a definition of the product group). This document contains PCR part B for asphalt, which is the part of the PCR that is specific for asphalt products. Part A contains the requirements that are common for all construction products.

This PCR gives guidelines for the development of environmental product declarations (EPD) for asphalt; either cradle to gate, cradle to gate with options or cradle-to-grave and specifies the underlying requirements of the life cycle assessment (LCA).

2.2.2.2.5 The International EPD System 2018: Product Category Rules for Highways (Except Elevated Highways), Streets and Roads v2.0

This document provides Product Category Rules (PCR) for the assessment of the environmental performance of Highways (except elevated highways), streets and roads globally, and it is an updated version of the one published in 2013 (v1.0) with changes regarding:

1. System boundaries and the allocation of stages to upstream, core and downstream processes
2. Functional/declared unit
3. Impact indicators added
4. Additional environmental information

The PCR provides the information to perform the LCA for A1-A5 (mandatory), B1-B5 and B6-B7 (optional but recommended) and C1-C4 (optional) in the case of a declared unit, and for A1-A3, A4-A5, B1-B5, B6-B7, C1-C4 (mandatory) in the case of a functional unit.

Using the first version of this PCR, in 2013, Acciona Infrastructuras was the first company to produce the EPD for a section of a road the N-340 (Acciona Infraestructuras, 2013), national road in Spain.

2.2.2.2.6 PCR EPDItaly022 – Use of Highways, streets, roads and airfield

This document, published in 2021 within the EPDItaly Program, is a specific tool to reduce the environmental impacts linked with road infrastructures. In order to perform in a uniform way the Life Cycle Assessment and a subsequent EPD, a set of rules (Product Category Rules- PCRs) is provided. In particular, this publication gives the PCRs for “Use of Highways, Streets, Roads and Airfield“ according with the actual normative references (ISO and EN Standards). This document is valid until January 2026 and introduces some new aspects enriching the previous PCR 2013:20 related to the the same field:

- Different functional unit
- Different mandatory and optional modules defined and allocated depending on the infrastructures
- Introduction of two EPDs levels: Pre-project EPD and Post-project EPD
- Guidelines for the calculation of the impact arising during the use phase of the infrastructures.

Table 4. Summary of main features of PCRs for asphalt mixtures and pavements

	Object of assessment	System boundaries/LC stages	Functional / Declared Unit	Cut<off criteria	Data quality	Allocation	LCIA
NAPA 2017	Asphalt mixture	Cradle-to-gate (A1 to A3)	Declared unit 1 short tonne of asphalt mixture	1% of the total energy used in the foreground unit processes (i.e., fuels and electricity based on lower heating value) or 1% of the total mass inputs for the foreground unit processes (excluding fuels) whichever is lesser. Total sum < 5% Exceptions are specified	• Temporal Representativeness (Age) • Technological Representativeness • Geographical Representativeness (Geography) • Precision • Uncertainty • Completeness	According to ISO 14044 Recycled/reclaimed materials, such as RAP, RAS, GTR, and RFO, are treated as a waste material without economic value.	TRACI 2.1: • Global warming potential • Depletion potential of the stratospheric ozone layer • Acidification potential of land and water • Eutrophication potential • Smog formation potential
EAPA 2017	Asphalt mixture	Cradle-to-gate (A1 to A3)	Declared unit 1 metric tonne of asphalt mixture	1% of the total energy used in the foreground unit processes (i.e., fuels and electricity based on lower heating value) or 1% of the total mass inputs for the foreground unit processes (excluding fuels) whichever is lesser. Total sum < 5% Exceptions are specified	• Age (<5years) • Representativeness • Geography • Use local data when available, and then regional or national • Alternative data sources modified with the local energy mix may be used • Precision (two significant figures) • Units (metric units) • Completeness • Uncertainty (sensitivity analysis)	According to ISO 14044 Bituminous binder according to LCI of bitumen from Eurobitume Recycled materials: a) The upstream impacts are excluded b) Impacts associated with the processes involved in preparing the recycled material are included	European Reference Life Cycle Database (ELCD): • global warming; • ozone depletion; • acidification of land and water; • eutrophication; • photochemical ozone creation; • depletion of abiotic resources (elements) (from CML); • depletion of abiotic resources (fossil) (from CML).

						Additives: mass based allocation	

The International EPD System 2017	Asphalt mixture	Cradle-to-gate (A1 to A3)	Declared unit
			1 metric tonne of manufactured asphalt mixture
				Cut-off criteria to be met on the level of the modelled product system are the qualitative coverage of at least 99% of both the energy, the mass, and the overall relevance of the flows	• Age (<5years)
					• Representativeness (>5%)
					• Completeness
						According to ISO 14044
						Processes generating overall revenue of the order of 1% or less may be neglected.
						Other cases: table available
						If there is an inflow of recycled material to the production system, the recycling process and the transportation from the recycling process to where the material is used shall be included.
						If there is an outflow of material to recycling, the transportation of the material to the recycling process shall be included.
						Impacts associated with the processes involved in preparing the recycled materials for use in the asphalt mixture are
							According to EN 15804:
							• Global Warming Potential:
							  ○ Fossil
							  ○ Biogenic
							  ○ Land use/land transform
							  ○ Total
							• Acidification potential
							• Eutrophication potential
							• Formation of tropospheric ozone
							• Abiotic depletion potential – elements
							• Abiotic depletion potential – fossil
							• Ozone layer depletion
							• Use of resources (all)
							• Waste (all)

	Asphalt mixture	Cradle-to-gate with options (A1 to A4)	Declared unit 1 metric tonne of manufactured asphalt mixture delivered to the construction site				
	Pavement activity	Cradle-to-gate with options (A1 to A5)	Functional Unit A paved surface of $1m^2$, which fulfils the specified quality criteria during the Reference Service Life				
	Pavement activity	Cradle-to-gate with options (A1 to A5 + B1 and B4 minimum)	Functional Unit A paved surface of $1m^2$, which fulfils the specified quality criteria during the Reference Service Life of the construction				

			(default value of 40 years)			considered part of the system boundary. Landfilling has to be attributed to the studied process Incineration – see document	
The Norwegian EPD Foundation	Asphalt mixture	Cradle-to-gate with options (A1 to A3)	Declared Unit 1 tonne of manufactured asphalt mixture	As in EN15804	As in EN15804	As in EN15804 Allocation according to mass [kg] is used. Co-product allocation is relevant when several products are produced, transported or handled in the same process. For asphalt, this can occur for example when the asphalt raw materials (or their ingredients) are produced and transported or when asphalt is produced. In asphalt production and all transports, mass allocation shall be used Recycled asphalt used in new asphalt shall carry the burdens from the recycling process, however the transport from the place where it is removed to the recycling process shall be	The impact categories listed in EN 15804 shall be used, including the additional indicators listed in Clause 7.2.3
	Pavement activity	Cradle-to-gate with options (A1 to A5)	Functional Unit 1 m^2 surface covered with asphalt, which fulfils the specified quality criteria during the service life of asphalt surfacing.				
	Pavement activity	Cradle-to-gate with options (A1 to beyond A5)	Functional Unit 1 m^2 surface covered with asphalt, which fulfils the specified quality criteria during the Estimated Service Life of a construction work				

						included.	
The International EPD System 2018	Highways (except elevated highways), streets and roads	Cradle-to-gate (A1-A3 mandatory) Cradle-to-gate with options (A1-A3 mandatory + optional modules)	Declared unit 1 m^2 of road	Life cycle inventory (LCI) data for a minimum of 99 % of total inflows to the core module shall be included. Inflows not included in the LCA shall be documented in the EPD. It is important to emphasize that – in most cases – all available data shall be used. Using cut-off rules should not give the perceptions of "hiding" information but rather, to facilitate the data collection for practitioners	• Age (<5years) • Representativeness (>5%) • Completeness	As in 14040 If there is an inflow of recycled material to the production system, the recycling process and the transportation from the recycling process to where the material is used shall be included. If there is an outflow of material to recycling, the transportation of the material to the recycling process shall be included. The material going to recycling is then an outflow from the production system as an indicator Landfilling has to be attributed to the studied process Incineration – see document	• Global Warming Potential • Acidification potential • Eutrophication potential • Photochemical oxygen creation potential • Abiotic depletion potential – elements • Abiotic depletion potential – fossil • Ozone layer depletion • Use of resources • Waste
		Cradle-to-grave (A1-A3, A4-A5, B1-B7, C1-C4)	Functional unit 1 m^2 of road with a specific intended use				
PCR EPDItaly022 – Use of Highways, streets, roads and airfield	Highway streets, roads and airfield	For Roads and Highways: cradle-to-gate with options" (A1-A3, A4-A5, B1 – B7, C1-C4 + D optional)	Declared unit the entire road for all the mandatory life cycle stages	It can be possible to exclude materials or energy flows whose impact is lower than 1%. Total amount of excluded process shall	• Time-related representativeness • Geographical representativeness	Allocation shall be avoided; it is preferable separating the unit process and creating sub-processes. Therefore, the environmental data can be collected for each sub-process separately.	• Climate Change • Ozone Depletion • Human Toxicity – cancer effects (CE)* • Human Toxicity-non cancer effect (NCE)*

		from cradle-to-grave (A1-A3, A4-A5, B1-B7, C1-C4)	Functional unit the use of the road throughout the RSL in order to provide a service that enables a given volume of traffic to drive with safe, comfortable, economical and durable conditions in the full length of the road under analysis for all life cycle stages	not exceed 5% of total energy use and 5% of total mass inputs per module	• Technological representativeness • Primary data for core processes • Secondary data for those products/processes on which the producer has no influence	If it is not possible to further divide the unit process, allocation cannot be avoided and allocation criteria should be defined to solve the multifunctionality [ILCD-2010].	• Ecotoxicity* • Ionizing radiation human health effects • Particulate matter indicator (PM)/Respiratory inorganics • Photochemical Ozone creation • Eutrophication – terrestrial and aquatic • Acidification • Resource depletion - water • Depletion of resources- fossil, mineral • Land transformation

2.2.2.3 Federal Highway Administration Framework for LCA of Pavements

In 2010, the Federal Highway Administration (FHWA) launched the Sustainable Pavements Program to advance the knowledge and practice of sustainability as related to pavements. The program vision and mission statement is:

To advance the knowledge and practice of designing, constructing and maintaining more sustainable pavements through:

- Stakeholder engagement
- Education
- Development of guidance and tools

From 2010 to 2015 the FHWA Program developed a number of deliverables designed to assist roadway agencies in the implementation of more sustainable pavement practices using current knowledge and technology, achieving high level of accomplishment; some of those deliverables include:

- A comprehensive Reference Document on sustainable pavement systems.
- A Framework Document for pavement life cycle assessment (LCA).
- A series of 25 technical articles covering a range of sustainability topics.
- A compilation of technical resources on sustainability.
- Five Tech Briefs:
    - Pavement Sustainability.
    - Life-Cycle Assessment of Pavements.
    - Climate Change Adaptation of Pavements.
    - Strategies for Improving Sustainability of Asphalt Pavements.
    - Strategies for Improving Sustainability of Concrete Pavements.
- A series of webinars focusing on sustainability in all stages of the pavement life cycle.

The main features of the Framework Document for pavement life-cycle assessment (LCA) (Harvey et al. 2016) that are relevant for PavementLCM SA Framework are summarised in Table 5.

Table 5. Main features of FHWA Framework for Pavement LCA

System	Life cycle stages	Functional/ Declared unit	Analysis period	Cut off criteria	Data quality	Allocation	LCIA
Pavement	Cradle-to- grave as default approach, or different if otherwise specified in the goal of the study.	Functional unit: typically include a full pavement section (often expressed in lane-km or lane-mile that has to function for a period of time) Normalization of the functional unit, i.e. into a volumen, might be	Enough to capture the performance of the initial product or service and its effect through the life of at least the next subsequent major rehabilitation treatment, and preferably	A maximum cumulative indicator effect of five percent for all cutoff flows is the recommended threshold for each of the criteria (mass balance, energy balance, and environmental aggregated flows and impacts)	-Technological coverage - Geographical coverage - Time-related coverage - Completeness - Precision - Consistency - Reproducibility	Co-products: The preferred way to deal with assigning impacts to multi-outputs is to reflect the physical properties of the outgoing flows, such as mass or energy content. Reuse and recycling: All processes and	No particular recommendation on specific categories or indicators. Mentions to select those of interest

		reasonable	through the lives of following rehabilitation treatments or the next full reconstruction Typically: 30R40 years (as in LCC)			transportation needed to reuse or recycle the material are assigned to the product utilizing the recycled content, but the production of the original product is assigned to the first product's life cycle	

2.2.2.4 Federal Highway Administration Primer for Life Cycle Costing

In 2002, the Federal Highway Administration's (FHWA's) Office of Asset Management presented its Life-Cycle Cost Analysis Primer. This Primer was intended to provide sufficient background for transportation officials to investigate the use of life-cycle cost analysis (LCCA), or life-cycle costing (LCC) as in EU standards, to evaluate alternative infrastructure investment options. Additionally, the Primer demonstrates the value of such analysis in making economically sound decisions.

The Primer established the five steps to perform LCC:

1. Establish design alternatives
2. Determine activity timing
3. Estimate costs (agency and user)
4. Compute life-cycle costs
5. Analyse the results

These steps were briefly describer in Section 2.1.5 of this deliverable and are further detailed and used in PavementLCM SA Guidelines (D5.1).

2.2.3 EU projects on Sustainability Assessment in Pavement Engineering

The aim of this Section is to present the most recent and important EU project dedicated to SA in pavement engineering to provide an insight in methodological advancements and some examples of how it was performed.

2.2.3.1 Sustainability – National Road Administrations – SUNRA (2011 P 2013)

In 2011, the ERANET Road II project SUNRA was funded on the topic of defining sustainability from an NRA perspective, review and advice to NRAs on sustainability and a sustainability rating system that would allow policy to be influenced. The consortium was formed by TRL Limited (UK), VTI (Sweden), Ch2mHill (UK/Ireland), TNO (Netherlands) and DTU (Denmark). More specifically, their objectives were to:

- Provide a common definition of sustainable development within the context of European road authorities.
- Provide a common system of measurement of sustainability performance at NRA level through the development of a metric or metrics.
- Provide a framework for a road-project level rating system that enables interventions at the appropriate project stage and for different project types.
- Provide suggested intervention routes through procurement and Life Cycle Cost (LCC).
- Test the definition, metric(s) and rating system with a number of NRAs.

The results are further reviewed here based on the different deliverables they produced to highlight the initial work that NRAs should develop to start introducing SA in their practices.

Framework Part 1 – Sustainability Definition

The focus of this framework is to support National Road Administrations (NRAs) in Europe in adopting definitions of sustainability, which can guide their sustainability efforts, and eventually help their strategic and project level activities to achieve more sustainable results. It sets out the conceptual and procedural elements that enable an NRA:

- To recognise important principles and notions of sustainability and transport.
- To develop its own definition, taking into account already available ones; and
- To commit to its implementation through review and adjustment of existing frameworks and practices.

The resulting framework suggests a procedure with four steps. For each of the steps the framework suggests key elements to consider and specific outputs to deliver. The steps are:

1. Interpretation of sustainability and transport. Here the NRA appreciates the sustainability and transport principles and impacts and adopts a level of ambition for its sustainability principles. The NRA is to consider key existing definitions and principles of sustainable development, and key ideas on how these relate to the context of the transport system and road sector. This will help the NRA to appreciate fundamental aspects of sustainability and how sustainability applies to NRAs and will help them adopt a scope and level of ambition of their sustainability efforts. The interpretation of sustainability in the context of sustainability should be summarised in a note, and the scope should refer to a level of aspiration.

2. Impact and influence review. NRA should consider its more specific role in and possible contributions to sustainability, taking into account impacts, context and influence. This will include the identification of impacts of main concern and the planning of a review of the key contributions the NRA can make to influence sustainability further, through mandates, resources, existing priorities and activities.

3. Crafting a strategic commitment/definition. The NRA crafts a definition and strategic commitment to sustainability, including, among others, an expression of an overall commitment to sustainable development, adoption of sustainable principles, an indication of the impact categories of particular concern to the NRA and the level of ambition.

4. Implementation. The NRA will adopt an action plan for how the commitment will be communicated, plus the strategy and next steps in the application and integration of the commitment in relevant NRA documents, procedures and activity areas.

This framework provides two documents. A report explaining all the thinking process and creation of the framework also providing references, and a second short document describing in detail the four steps above, to be used by NRAs as a handy guide.

This framework for Sustainability Definition represents the first step for a NRA to start understanding sustainability towards its implementation.

Framework Part 2 – Measures to Improve Sustainability

This framework aims at identifying how to measure sustainable development performance at a strategic level, with the resulting objective to develop a metrics framework that NRAs with different levels of sustainability knowledge and structures can use to improve sustainability performance.

In order to ensure that NRAs with different levels of commitment and reporting capabilities can benchmark themselves against the framework, it is proposed that a staged approach is used for measuring performance. The framework has four levels, with one being the lowest and four being the highest (Figure NTS2). It is expected that NRAs will begin by achieving level one, before they then start to move up through the framework as they consider it to be appropriate for their organisation. The levels within the framework can be described as follows:

- → Level 1 – the NRA is monitoring a number of its own current priorities in terms of sustainability.
- → Level 2 – the NRA is monitoring a wide range of priorities in terms of sustainability.
- → Level 3 – the NRA is monitoring wider issues that demonstrate its contribution to sustainable transport.
- → Level 4 – the NRA is monitoring issues that demonstrate its wider contribution sustainable development.

In the same way than Framework 1, Framework 2 provides two documents. A report explaining all the thinking process and creation of the framework also providing references, and a second short document describing in detail the four levels above, to be used by NRAs as a handy guide.

It is important to mentioned that the metrics at the 4 levels defined were developed for projects, programmes and the board of NRAs to ensure that sustainability can be considered at all levels within NRAs. In this regard, different metrics are recommended for each level in the framework and in NRAs and described. Finally, the metrics are also classified into 24 topics to help NRAs make choices about what the metric to take depending on the issue they want to address.

Framework 3 – Rating System for Roads

This framework provides a project level tool for scoping project level sustainability topics, setting appropriate targets, selecting indicators and recording results. This framework is the focus of this document.

2.2.3.2 AllBack2Pave - AB2P (2013-2015)

In 2012, CEDR launched the call for Recycling in which the project AllBack2Pave (AB2P) was funded to evaluate the feasibility of going towards 100% recycling of asphalt pavements into surface courses. Led by the Technische Universität Dresden in Germany, together with the University of Nottingham in the UK and University of Palermo in Italy, the project started in November 2013. To facilitate the deployment of lean concepts and lean production practices, the investigation was implemented in close collaboration with the private sector, including asphalt mixing plants, chemical additives producers and waste material managers.

The main objectives of the project were:

- To establish, through laboratory tests on binders and asphalt mixes, whether the use of high rates of RA was feasible in developing mixes with a high level of durability.
- To develop the so-called "AllBack2Pave end-user manual" on how to best produce cost-effective and quality asphalt mixes with high RA content.

As a contribution for those, the project also aimed at:

- Characterising the environmental impact (LCA) and economic impact (LCCA) of the defined technology taking into account the European level of the project and by adapting the study to normal practice in at least UK, Germany and Italy.
- Collaborating with partners specialized in sustainability assessment of road pavements, in order to define a state of-the-art on sustainability impact indicators of road pavements and to broadly assess the sustainability of the investigated technology.

Therefore, for PavementLCM Framework for Sustainability Assessment, two deliverables are of particular interest: D5.2 Economic and Environmental Impact of the AllBack2Pave technologies and D5.3 Sustainability Assessment of the AllBack2Pave technologies.

D5.2 Economic and Environmental Impact of the AllBack2Pave technologies

In this deliverable, AB2P provided the results of the difference in the environmental and economic performance over the next 60 years, between the currently maintained typical European major road asphalt pavements and scenarios in which the currently used asphalt mixtures are replaced by the AllBack2Pave (AB2P) asphalt mixes: eight asphalt mixtures for wearing course containing up to 90% Reclaimed Asphalt (RA). In order to take into account the European level of the project, three case studies were considered: Italy for South Europe, Germany for Central Europe and UK for North Europe. The crafting of the case studies and the impact assessments, carried out by means of Life Cycle Assessment (LCA) and Life Cycle Cost Analysis (LCCA), were structured and explained in order to be taken as benchmarks for those who want to perform a similar analysis (i.e. technical personnel of road authorities).

The environmental impact of the pavements with AB2P technologies was assessed through a carbon footprint exercise for each case study, following the steps in Figure 17, which highlight the importance of considering the different maintenance scenarios when performing a life cycle analysis. The project presented the full life cycle stages of road asphalt mixtures as in Figure 18.

Figure 17. Environmental Impact assessment of AB2P technologies (AB2P, 2015)

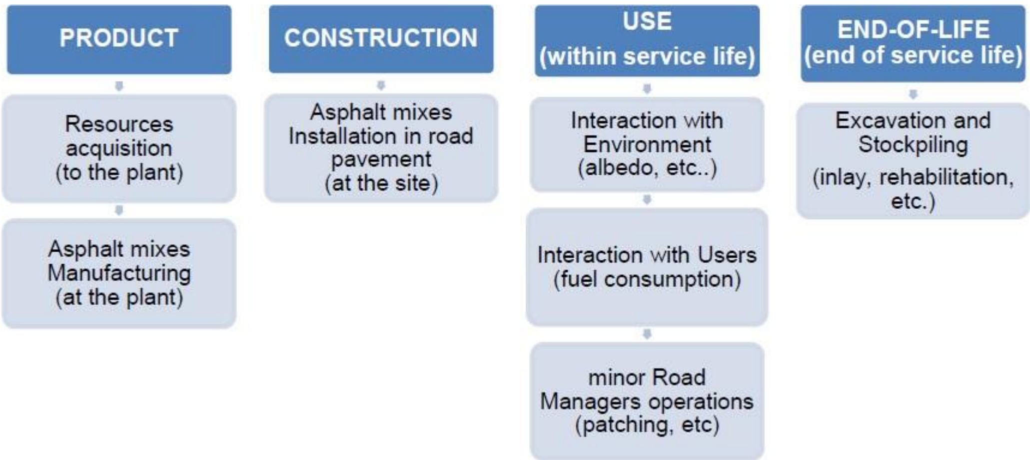


Figure 18. Life cycle stages for road pavements (AB2P, 2015)

The environmental assessment was then performed using two approaches:

- Firstly, the life cycle of the technologies was considered as “cradle-to-laid + end-of- life”. This means that the use phase of the life cycle was removed from the study. This significant assumption was made considering that the lifetime interactions of asphalt mixes with vehicle operations (i.e. variation in rolling resistance) and environment (i.e. change in asphalt albedo) of all the AB2P asphalt mixes, shouldbe the same as the conventional asphalt mixes currently used in each case study.
- Secondly, an analysis period of 60 years was considered, taking then into account the road managers operations for maintenance in the use stage. The analysis period was chosen to allow for at least one maintenance operation of the base course.

Further important features of the assessment are:

- Functional unit: defined as the weight in tonnes of asphalt mixture to be manufactured and used during the inlay procedures of the selected case studies for 1km, considering the geometrical characteristics of the roads in the case studies.
- Reference service life (RSL): this parameter only plays a role in the second approach. In the case of the considered asphalt pavement structure, the RSL was provided directly from the interested road authorities or obtained from literature for each country. For the different asphalt mixtures studied, it was considered equaldue to the lack of more precise information.

- Cut-off rules: to simplify the analysis, processes/activities that altogether do not contribute to more than 1% of the total environmental impact for any impact category are omitted from the inventory analysis. The “1%-rule” is based on the inflow of materials to the system, provided no exceptional environmental concerns exist.
- Allocation procedures: In order to reward recycling practices into the new mixture, 100:0 rule was adopted in favour of the recycled content method.

The assessment was conducted on this basis using the tool asPECT v4.0. The results were presented by case study (Italy, Germany and UK) and identifying hotspots in the life cycle. Cradle-to-gate was identified as the most impactful stage in terms of carbon footprint, and within this stage, the hotspots was different depending on the country (i.e. raw materials sourcing, transport to plant or heating and mixing). In general, appreciable CO_2e savings (up to almost 50%) were observed for the AB2P mixtures relative to baselines, to a greater or lesser degree, depending on the mixture recipe and the case study. These savings derived primarily from recycled content that was incorporated in the mix but from the average shorter transportation distances of RA (usually stockpiled in the asphalt plant itself) with respect to virgin aggregates. In all the cases, the main parameter that governs the amount of emission remain the durability which in this study was considered the same for each design alternatives, but it should be subject of a sensitivity analysis.

Regarding the economic assessment, LCCA was performed. The project-level LCCA process begins with the development of strategy alternatives to accomplish the structural and performance objectives of a project. The analyst then defines the schedule of initial and future activities involved in implementing each of the alternatives. Next, the costs of these activities are estimated. Best practice LCCA calls for including not only direct agency expenditures (e.g., construction or maintenance activities), but also costs to the project’s users that result from agency work zone operations. However, LCCA comparisons are always made between mutually exclusive competing alternatives, therefore it needs only consider differential costs between alternatives. Costs common to all alternatives cancel out, these cost factors are generally noted and excluded from LCCA calculations. For this reason in order to compare the different design alternative in each of the case study, only the cost to manufacture a ton of the considered asphalt is included (cradle-to-gate) and the maintenance operations in each case study for an analysis period of 60 years. On this basis, the following steps will be used for the analysis:

1) Establish alternative pavement design strategies for the analysis period
2) Determine performance periods and activity timing
3) Estimate agency costs
4) Compute Net Present Value (NPV)

For the computation of the NPV, a deterministic approach was applied using a fixed discount rate as following:

- South Europe (Italy) = 5%
- Central Europe (Germany) = 3%
- North Europe (UK) = 3.5% for the first 30 years and 3% for the remaining 30 years

As conclusion, the LCCA, despite being a very simplified version highlighting only differences between design alternatives, provided a clear evidence of the economic savings due to the maximisation of the recycling of RA. In fact as general trend, incorporating up to 60 R 90% of RA in all the asphalt courses implies a cost reduction that ranges between 25% and 60% of the cost of the baselines alternatives. Also for this analysis durability of the asphalt mixes is a main parameter and it was underlined that the obtained results are a consequence of the assuming the same durability for all AB2P technologies.

AB2P demonstrated the importance of performing the environmental and economic assessment of new technologies to allow for informed decision-making including sustainability aspects since there undoubtedly differences for each case study.

D5.3 Sustainability Assessment of the AllBack2Pave technologies

This deliverable focused on analysing existing tools and methodologies to allow decision making on what is a sustainable practice in asphalt road pavements. The methodology was then used to decide whether using the AB2P asphalt mixes within the current European road maintenance practices was a more sustainable solution. This deliverable is structured in two steps:

- Firstly, a review and comparison of freely available tools to perform a pavement LCA was carried out.
- Secondly, two sustainability rating systems "GreenPave" and "BE^{2}ST" were used to assess AB2P technologies and finally provided recommendations for a possible "CEDR Sustainability Assessment methodology".

In the first step, there is a first differentiation between pavement components (e.g. wearing course, binder course, etc.) and road pavements life cycles, as shown in Figure 19 and 20. AB2P suggested that the life cycle of a pavement component starts with the product stage being the acquisition of materials and manufacturing the asphalt mixture in the case of the asphalt layers, continues with the construction stage for their installation and finishes with the end of life when the layer is dismantled. On the other hand, a road pavement life cycle consists of a product stage considering the installation of all the pavement components, followed by the use stage and it does not have a clear end of life, since the pavement will be rehabilitated. This differentiation is further developed in PavementLCM Framework (Chapter 7 and in D5.1).

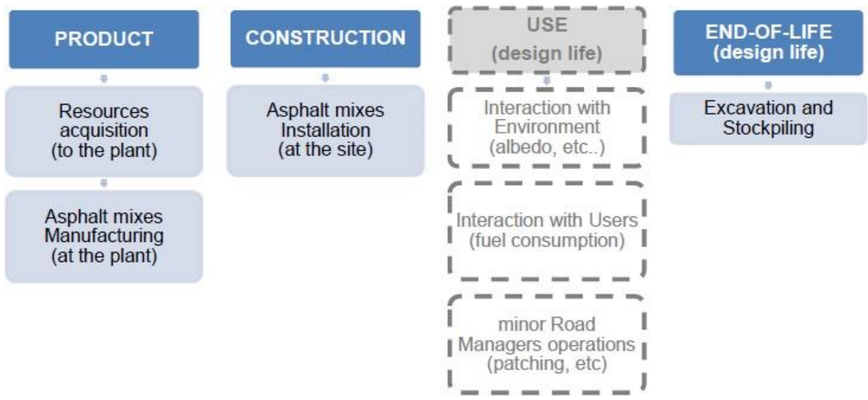


Figure 19. Proposed LC stages for pavement components (AB2P, 2015)

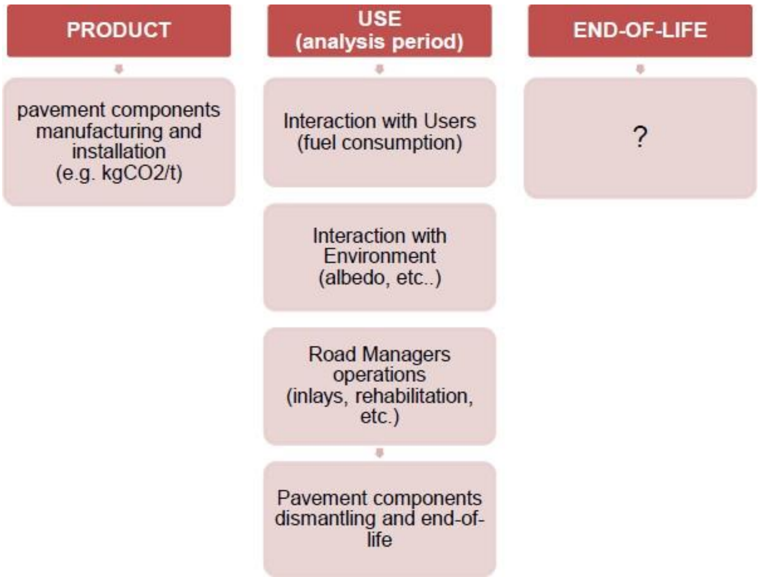


Figure 20. Proposed LC stages for road pavements (AB2P, 2015)

The comparison of tools was performed using asPECT, ECORCE M and Carbon Road Map. AB2P concluded that each tool has its own benefits and limitations, however results obtained for specific AB2P case studies were very different. Even if the trend line is the same as regards the comparison of mixtures within the same tool, results coming from Carbon Road Map are over-estimated compared to the other tools. In particular, the use of equipment is characterised by the highest values and this leads to the suspicion that there was some mistake in the tool database. On the other hand, results obtained from asPECT and ECORCE M are similar and they lead to the same considerations and recommendations.

Regarding the recommendations for a CEDR Sustainability Rating System, AB2P concluded that the sustainability assessment methodology should:

- be a comparative analysis based on improving current design practices, so allowing a relative measure of sustainability performance
- be user-friendly and freely available to CEDR members
- be tailored to be used at least at design stage
- have a preliminary layer allowing pavement performance analysis and assessing life-cycle maintenance and rehabilitation strategies for a certain case study.

Furthermore, the Sustainability Assessment exercise should:

- incorporate CF/LCA and LCCA
- allow incorporating innovative pavement technologies
- include and suggest best practices to be updated at EU level through survey of CEDR members but also considering already existing metrics developed within existing Sustainability Rating systems.
- allow performing a rating tailored at EU/local level through surveys with stakeholders to define sustainability metrics for road pavements and deciding the weighting of each metric
- consider the important findings of existing tools/methodologies to swap to more quantitative-based sustainability assessment of road pavements.

2.2.3.3 Evaluation and Decision Process for Greener Asphalt Roads – EDGAR (2014-2016)

In 2013, CEDR launched the call for Energy Efficiency in which the project EDGAR was funded to help NRAs in the process of selecting new materials and technologies for pavements towards the reduction of energy consumption and emission of CO_2 in the transport sector. Specifically, the project aimed at:

1. Select appropriate sustainability criteria/rules;
2. Collect available data on all sustainability aspects for new materials and technologies and "green bituminous mixtures", and summarize it in a summary report;
3. Propose a refined, quick and qualitative classification system for the assessment of the recyclability of the "green asphalt" when it will have reached the end-of-life;
4. Select the best tools for the quantitative evaluation of sustainability;
5. Provide a methodology for assessing any emerging material or technology and to determine its overall sustainability, utilising these appropriate tools, considering also the durability of the bituminous mixtures.
6. Demonstrate this methodology for a number of selected test cases.

Regarding objective 1, EDGAR proposed a basket of sustainability indicators based on a review of the available PCRs for asphalt materials and technologies which was further refined after:

- The outcome of the normalisation of four generic asphalt EPDs The review of existing bituminous technologies and past research
- Input from the Advisory Group and Project Executive Board

Based on this process, a final set of indicators and tool to measure them was proposed as displayed in Figure 21.

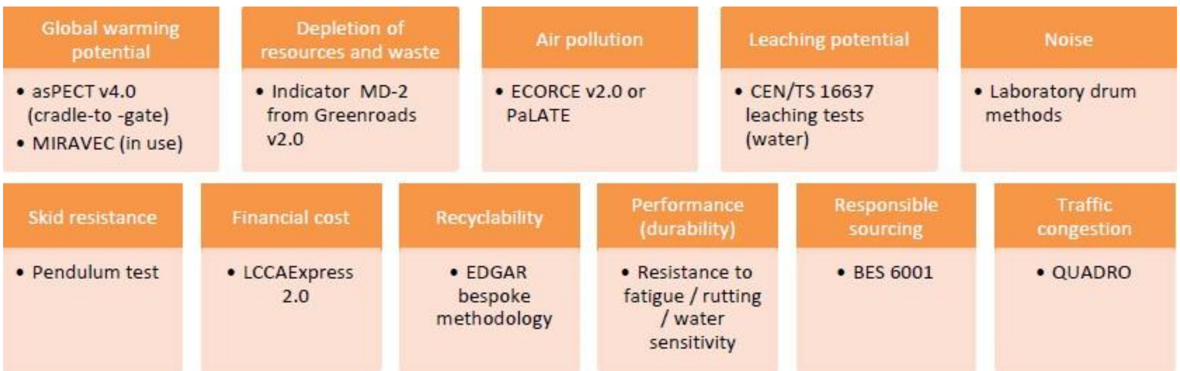


Figure 21. EDGAR methodology dashboard

Regarding objective 2, an extensive literature review about the sustainability performance was carried out for the following technologies:

- Technologies to reduce the production temperature compared to hot mix asphalt
- Cold or semi-cold production technologies
- The use of reclaimed asphalt
- The use of materials from secondary sources (other than reclaimed asphalt)

- The use of modified or alternative binders
- The use of various types of additives for various purposes

The review was structured analysing such technologies according to several sustainability criteria: global warming potential, use of energy and material resources, air pollution, recyclability at the end of life, health and safety and financial implications. The impact on performance is also discussed, because of the importance of the expected lifetime and maintenance when sustainability is assessed over the full life cycle. As a result of this review, they were able to provide the matrix of considerations shown in the Figure, to help NRAs start the decision-making process of adopting new technologies considering sustainability criteria according to their proposed set of indicators.

Technologies / Applicable sustainability indicator(s)	Global warming potential	Depletion of resources & waste management	Air pollution	Leaching potential	Noise	Skid resistance	Financial cost	Recyclability	Performance (durability)	Responsible sourcing	Traffic congestion
Warm and half-warm asphalt technologies											
Foam	green	blue	green	blue	blue	blue	orange	blue	orange	blue	green
Organic additives	orange	blue	green	orange	blue	blue	orange	orange	orange	orange	green
Chemical additives	orange	blue	green	orange	blue	blue	orange	orange	orange	orange	green
Cold and semi-cold asphalt technologies											
Emulsion	green	blue	green	blue	blue	blue	orange	blue	orange	blue	green
Foam	green	blue	green	blue	blue	blue	orange	blue	orange	blue	green
Asphalt recycling											
Plant	green	green	green	blue	orange	orange	green	blue	orange	green	orange
In situ	green	green	green	blue	orange	orange	green	blue	orange	green	orange
Secondary and open-loop recycled materials											
Steel slag	orange	green	blue	orange	orange	green	green	orange	orange	green	orange
Fly ash	orange	green	blue	orange	blue	blue	green	orange	orange	green	orange
Crumb rubber	orange	green	red	orange	green	blue	green	orange	orange	green	orange
Shredded roofing	orange	green	red	orange	orange	orange	green	orange	orange	green	orange
Crushed glass	orange	green	blue	orange	orange	red	green	blue	orange	green	orange
Alternative and modified binders											
Bio-binders	orange	blue	orange	orange	blue	blue	orange	orange	orange	orange	orange
Sulphur	green	blue	red	orange	blue	blue	orange	orange	orange	orange	orange
PMB	orange	blue	blue	blue	green	blue	orange	orange	green	blue	green
Additives											
Anti-stripping agents	green	blue	blue	orange	blue	orange	orange	blue	green	orange	green
Pigments	blue	blue	blue	orange	blue	blue	orange	orange	orange	orange	orange
Fibres	blue	blue	blue	blue	blue	orange	blue	blue	green	orange	green
Rejuvenators	orange	green	orange	orange	blue	blue	orange	orange	orange	orange	orange

Figure 22 Matrix of considerations for asphalt technologies (EDGAR, 2015)

In the Figure, gaps in the evidence base that have been determined against each family of technologies are marked with an orange symbol (□). If a clear negative has been identified then a red symbol is used (□). Potential positive claims are indicated with a green symbol (□). If the anticipated impact is unknown or neutral then a blue symbol is used (□). In the deliverable, it is stated that the matrix should never be used to 'tally-up' positive, negative and neutral symbols; it should only be used as a decision aid to assist NRAs in deciding where the case for using a particular technology may be formed.

From the Figure, it can be concluded that preliminary, the asphalt technologies with higher positive potential impact are cold mixtures with emulsion and foam, recycling in plant or in situ and use of steel slag and crumb rubber.

As the final objective, EDGAR developed a decision-making context and support for NRAs to adopt new materials and technologies in the Figure.This methodology presents six steps in the decision process for implementing a new technology or materials. The full details about the six steps can be found in their deliverable but some highlights related to the sustainability assessment, and therefore concerning PavementLCM are summarised here.

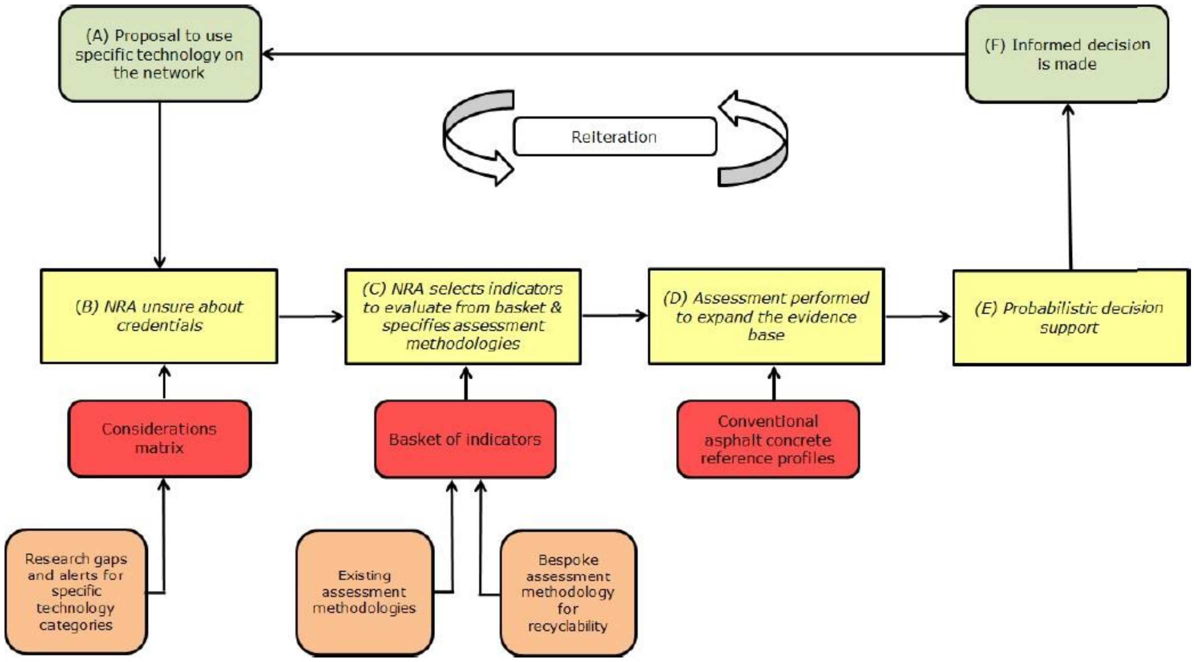


Figure 23 – Decision making context and support from EDGAR (EDGAR, 2019)

In Figure 23, the boxes in red are the specific contributions of EDGAR to the decision process. In this regard, for step (B), EDGAR provided NRAs with a matrix in which the impact of alternative technologies and materials on some indicators (GWM, air pollution, noise, cost, etc.) is classified as positive, negative, neutral or unknown according to current knowledge to provide the NRA a base about such technology or material and decide whether more information is needed to take an informed decision (Figure 23). In step (C), EDGAR provides a basket of indicators for the sustainability assessment of new technologies and materials and recommendations about how to obtain them. To define this basket, an extensive review of the state of the art and practice was carried out and the priorities for the selection were established as: (i) the indicator should focus on bituminous technologies and (ii) its calculation should not require too much data or be time intensive. Once the indicators are obtained, they proposed a 4-step global evaluation methodology (step E in the Figure 23) using multi-attribute decision making based on ELECTRE III and Evidential Reasoning (ER). The results and advancements of EDGAR regarding the calculation of the indicators are further used in PavementLCM Framework for Sustainability Assessment.

2.2.3.4 Life Cycle Engineering approach to develop a novel EU-harmonized sustainability certification system for cost-effective, safer and greener road infrastructures - LCE4ROADS (2013-2016)

LCE4ROADS was a 36-month FP7 project, funded by the European Commission, aiming at defining criteria and provide recommendations, supporting and motivating relevant stakeholders and industry to include greener, more cost-effective and safer technologies in their road construction, maintenance and renewal projects. In order to achieve the expected results, the complete work plan moved from the definition of the new certification/rating methodology considering existing relevant labelling approaches, plus the analysis of road products, to the development of guidelines and a software tool that, thanks to the direct involvement of CEN in the project, would motivate future EU-harmonized certification approaches for roads. One of the main contributions of LCE4ROADS was the CEN Workshop Agreement (CWA) 17089 in 2016, which provided 21 indicators for the sustainability assessment of roads as shown in Table 6.

Table 6. Sustainability Performance Indicators in CWA 17089

Sustainability Pillar		SPI	
Environmental	Parameter	1	Primary materials consumption
		2	Secondary materials used
		3	Materials or components to be reused, recycled, and exported energy
		4	Energy used
		5	Waste
	Impact categories	6	Global warming potential (GWP)
		7	Formation potential of tropospheric ozone (POCP)
		8	Depletion potential of the stratospheric ozone layer (ODP)
		9	Acidification potential of soil and water (AP)
		10	Eutrophication potential (EP)
		11	Abiotic depletion potential for non-fossil resources (ADP-elements)
		12	Abiotic depletion potential for fossil resources (ADP-fossil fuels)
		13	Human toxicity potential (HTP)
		14	Ecotoxicity potential (ETP)
Economic	**Cost**	15	Whole life cost
Social	**Comfort**	16	Comfort index
	Safety	17	Safety audits and safety inspections
	Resilient	18	Adaptation to climate change
	Noise	19	Tyre-pavement noise
	Sources	20	Responsible sourcing
	Congestion	21	Traffic congestion due to maintenance activities

2.2.3.5 Sustainable Pavements and Railways Innovative Training Network - SUP&R ITN (2013-2017)

SUP&R ITN was a 48-month FP7 project, funded by the European Commission, aiming at developing sustainable technologies for pavements and railways and advance in their sustainability assessment. For the latter, SUP&R ITN firstly conducted a review on methodologies and techniques for the sustainability rating of transport infrastructures.

From this review, SUP&R ITN concluded that “sustainable road pavements be assessed in a more systematic method. Many sustainability assessment tools have been developed for roads which have a more general scope than pavements. Given that the differences in the scopes of roads and road pavements can lead to significantly different objectives, it is not recommended that a road sustainability assessment tool be used to assess the sustainability of road pavements. Instead, the sustainability of road pavements can be assessed over a much narrower set of quantitative indicators, and the results can be reported based on a systematic assessment of outcomes".

Based on such conclusion, SUP&R ITN Multi Criteria Decision Analysis (MCDA) Tool was developed to perform the sustainability assessment of roads' pavements. The steps to use the tool are:

1) Select indicators. The tool includes a series of recommended indicators, selected after performing a literature review and proposed, together with the method of measurement, as shown in Figure 24. However, the user can select between those, add and remove indicators as convenient.
2) Define alternatives. The tool allows the definition of alternatives by introducing the performance of each of them against the selected indicators. This step defines the "Evaluation Matrix".
3) Filter evaluation matrix. The normalized evaluation matrix is subjected to a set of mathematical and statistics analysis. As a result, the user is able to:
    a. Evaluate if an alternative is already performing much worse than the others, and if that is the case, eliminate it if desired.
    b. Evaluate the potential correlation of indicators. If it is concluded that there is a statistically significant correlation between two indicators, one of them will be enough to predict their total behaviour, and the other one can be disregarded, as a user decision.
4) Weighting. The SUP&R ITN MCDA methodology comprises two weighting approaches -subjective and objective-, each one featuring two alternative weighting methods. The subjective approach determines the weights of the indicators based exclusively on preference information of indicators provided by the user, whereas in the objective approach weights are determined by solving mathematical models without any consideration of the users' preferences.
5) Define PROMOTHEE method parameters. The user must select a preference function for each indicator and define the values of the corresponding thresholds.
6) MCDA Results. The results provide the ranking of the alternatives.
7) Perform Sensitivity Analysis. The last step of the SUP&R ITN MCDA methodology consists of performing a sensitivity analysis to investigate how variations across a set of parameters and assumptions affect the robustness of the reported ranking, and thereby the relative merits of the alternatives being considered and compared.

SUP&R ITN MCDA Tool is freely available for any MCDA practitioner at www.superitn.eu.

Indicators	Methodologies/tool
Global warming indicator	LCA tools, such as SimaPro, OpenLCA, GaBi[1]
Energy demand	Cumulative Energy Demand (CED)
Secondary materials consumption	Based on the mixture formulation and type of components[2]
Materials to be reused or recycled	Asphalt mix formulation
Water consumption	Water depletion
Acidification indicator of soil and water	LCA tools
Eutrophication indicator	LCA tools
Ozone depletion indicator	LCA tools
Particulate matter	LCA tools
Safety audits & safety inspections	European Directive 2008/96/EC on road infrastructure safety management
User comfort	Area above or below the pavement performance prediction model, depending on its monotony
Noise reduction	CNOSSOS-EU method for strategic noise mapping following adoption as specified in the Environmental Noise Directive 2002/49/EC
Traffic congestion	HCM, RealCost, QUADRO, Visum
Life cycle highway agency Costs (LCHAC)	Bids, authorities guidelines
Life cycle road user costs (LCRUC)	Fuel costs: Swedish National Road and Transport Research Institute (VTI)'s rolling resistance (RR) model

Figure 24. SUP&R ITN indicators and methodology to measure (SUP&R ITN, 2017)

2.3 Conclusions and recommendations

Chapter 1 was focused on firstly providing the necessary background on Sustainability, Sustainable Development, Sustainability Assessment, Life Cycle Thinking and Techniques to help NRAs to understand their importance and usefulness to start introducing these practices in their organisations. From this background, the following conclusions and recommendations are drawn:

- There is a current need and pressure to move toward the achievement of the Sustainable Development Goals in every field. Pavement engineering has a strong influence in the three pillars of sustainability (energy consumption, GHG emissions, noise, costs, etc.) and the commitment of NRAs to decrease negative impacts on them is required.
- To do this, NRAs should create their own Sustainability Strategy to identify their specific role and possible contributions to sustainability, taking into account impacts, context and influence. This would include the identification of impacts of main concern and the planning of a review of the key contributions the NRA can make to influence sustainability further, through mandates, resources, existing priorities and activities.
- Sustainability Assessment (SA) is the evaluation of the environmental, social and economic impact 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. The most commonly used methodologies are: performance assessment, life cycle techniques and sustainability rating systems.
- The standard EN 15643-5 Sustainability Assessment Framework for civil engineering works is the umbrella under which PavementLCM SA Framework has to be built according to several key points of the standard:

  - Environmental, social and economic performance must be assessed.
  - Technical and functional requirements must be taken into account.
  - The assessment should use a life cycle approach.
  - The assessment should use quantifiable indicators measured without value judgements.

- Given the importance of analysing the three pillars of sustainability, PavementLCM suggests to move from the use of the term “green asphalt or pavement” to “more sustainable asphalt or pavement” including in this way the three dimensions of sustainability and the fact there is no “absolute” sustainability, but more sustainable options.
- Life Cycle Approaches and Techniques are tools to apply (i.e. materialise) Life Cycle Thinking (LCT) which “*is about going beyond the traditional focus on production site and manufacturing processes to include environmental, social and economic impacts of a product over its entire life cycle”.* LCT helps to make choices by allowing the identification of the critical activities or points in the whole life cycle of a product or system causing the highest environmental, social and economic impacts. This enables developing strategies and policies for their mitigation and minimisation, involving the appropriate stakeholder to take actions towards Sustainable Development.
- Life Cycle Assessment, Life Cycle Cost and Social Life Cycle Assessment are the specific methodologies proposed to evaluate each of the pillars of sustainability when performing the SA of civil engineering works, and consequently to be used in pavement engineering.

Secondly, the SoA focused on reviewing the available standards and guidelines to perform SA, and present the main EU projects related to SA in pavement engineering. From this review, the following conclusions can be drawn:

- There is a lack of standards defining calculation methods for the SA of civil engineering works. In this regard, PavementLCM SA Framework has to focus on developing such methods defining (See section7):
  - Objects of assessment
  - Functional/declared units
  - System boundaries/LC stages to include in the assessment
  - Analysis period
  - Cut - off rules
  - Allocation procedures
  - Data quality requirements
  - Sustainability Assessment indicators
  - Recommendations for the presentation of results
- EN 15643-5 provides the general framework to define those elements and presents the rest of standards to comply with to perform the environmental, economic and social assessment of civil engineering works, which are:
  - ISO 14040, ISO 14044, EN 15804 for environmental assessment
  - ISO 15686-5 for economical assessment

  - ISO 15392 for social assessment
- There is a series of PCRs available to perform the LCA of asphalt mixtures and pavements. For each element of interest:
  - Object of assessment. It is important to distinguish between asphalt mixtures (pavement materials in general) and pavement activities. These concepts must be defined in PavementLCM Framework
  - Functional or declared unit. The most common declared unit used for asphalt mixtures is 1 tonne of manufactured asphalt mixture. The most common functional unit for pavement activities is 1 m^2 of paved surface which fulfil the specified quality criteria during the analysis period
  - System boundaries/Life Cycle stages to include in the assessment. The system boundaries and life cycle stages to study depends on the goal of the SA and are different for asphalt mixtures and pavement activities. These concepts must be defined in PavementLCM Framework
  - Cut - off rules. The most common rule is to have a Life cycle inventory (LCI) with data for a minimum of 99 % of total inflows.
  - Allocation procedures. As in EN15804 for most of the PCRs, it is recommended to avoid allocation. If this is not possible, in the case of coR production mass allocation should be used. In the case of recycling, recycled materials should carry the burdens from the recycling process, including the transportation from where the material is obtained to the recycling process site.
  - Data quality requirements. There is a series of quality criteria to check for the use of data, these are:
    - Temporal Representativeness (Age)
    - Technological Representativeness
    - Geographical Representativeness (Geography)
    - Precision
    - Uncertainty
    - Completeness

    Recommendations for scoring data against these criteria must be provided in PavementLCM SA Framework.
  - LCIA. There are differences in the use of impact categories and indicators for LCA. The indicators to use must be defined in PavementLCM SA Framework.
- There are a series of EU efforts dedicated to the development of SA indicators, being: EDGAR, LCE4ROADS with the definition of CWA17089 and SUP&R ITN. PavementLCM SA Framework will use these efforts to define to use in the SA of pavement materials and activities

3. Interviews with National Road Authorities

3.1 Introduction

One of the main objectives of PavementLCM is to develop the framework for sustainability assessment for National Road Authorities presented in this deliverable. Therefore, as a first step in work package 2, it was essential to understand the culture of sustainability assessment in different NRAs to be able to tailor the PavementLCM framework to be useful for them.

Therefore, a questionnaire was produced with seven sections:

1. Identification
2. Sustainability assessment
3. Green asphalt
4. Sustainability data
5. Uncertainty and decision‐making
6. Circular economy
7. Further comments

Which were used as a base to undertake interviews and guide the conversations. The full questionnaire can be found in Annex I of this deliverable. The main results of the sections of sustainability assessment and green asphalt are summarised in this deliverable because of their relevance for the creation of the PavementLCM SA Framework, and the rest of results will be used in other work packages.

In total, eleven interviews were conducted between the University of Nottingham and TNO as following:

1. Vejdirectoratet (Denmark)
2. Highways England (England)
3. Lithuanian Road Administration (Lithuania)
4. Trafikverket (Swedish Transport Administration)
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)

3.2 Results

To begin with, five questions were set as an introduction asking about awareness of sustainability assessment and how much value (1‐10) the interviewee gives to 1)

Sustainability assessment; 2) Environmental assessment; 3) Economic assessment; 4) Social assessment.

The results are in average:

Awareness of sustainability assessment: 8.7

Value of sustainability assessment: 7.9

Value of environmental assessment: 7.8

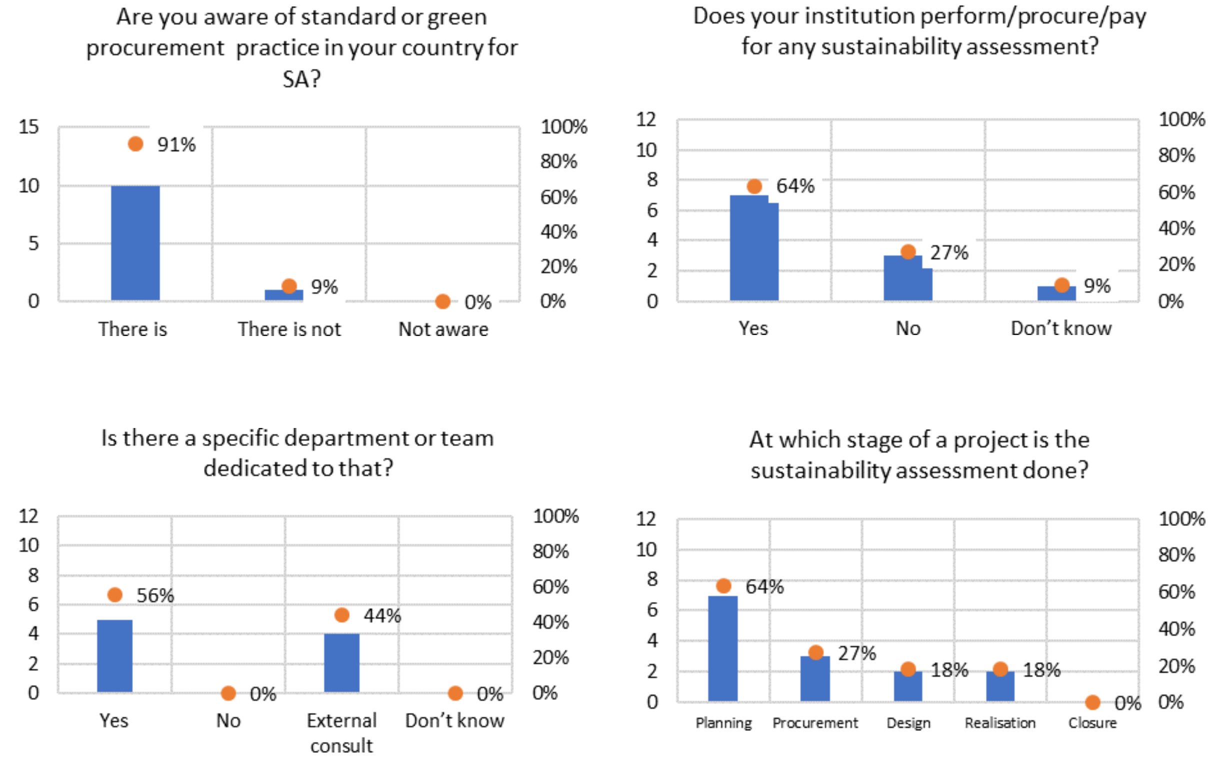
Value of economical assessment: 8.5

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. The most valued pillar is the economic, followed by environmental and finally social.

3.2.1 Multiple - choice questions about Sustainability Assessment Practices

The next set of questions were set as multiple choice about the sustainability assessment practices of each institution. Results are shown in Figure 25



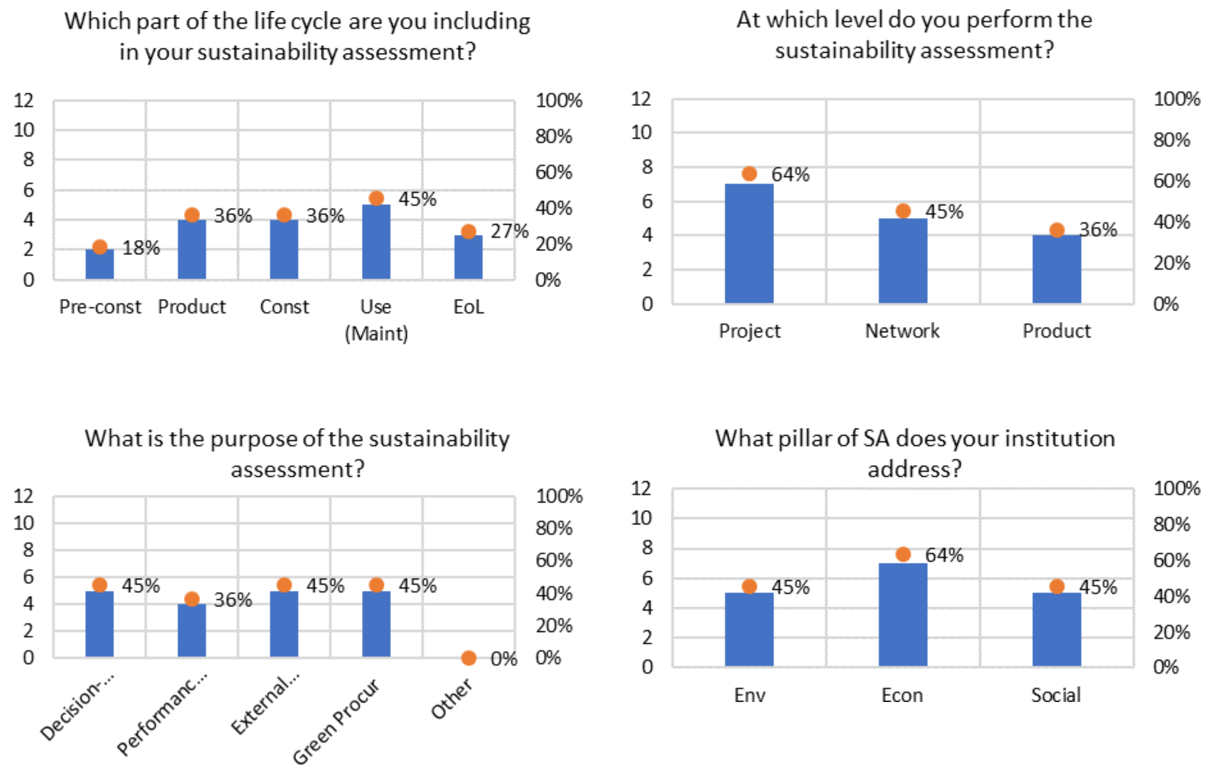


Figure 25 - Results of the multiple -choice questions 1

From Figure 25 the following conclusions can be drawn:

- 91% of interviewees are aware of Sustainability Assessment Standards
- 64% of the institutions perform some type of Sustainability Assessment, with a specific department (most of the cases) or an external consultant
- 64% of the institutions perform the assessment at the planning phase of projects, including mainly the product, construction and maintenance stages
- 64% of the assessments are perform at project level, followed by network level and finally product level
- The main purpose is to help decision making, followed by green procurement and as an external requirement
- The most assessed pillar of sustainability is economy

3.2.2 Awareness and use of Sustainability Assessment indicators

The indicators proposed in the CWA 17089 were presented in the questionnaire and four options were given to the interviewee to select about his/her knowledge and use of each:

- 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 are shown in Figure 26.

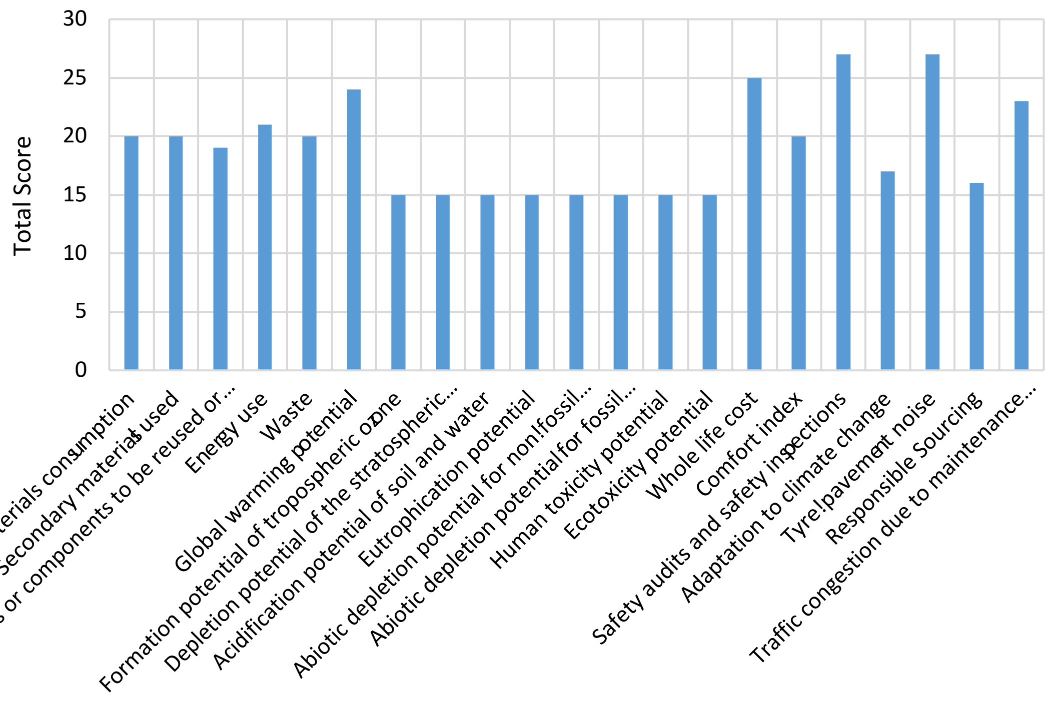


Figure 26. Total score of CWA 17089 indicators for sustainability assessment

Analysing Figure 26, if a threshold of 20 points is taken to consider an indicator as relevant, the relevant indicators in sustainability assessment practices for NRAs are:

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

This list of relevant indicators was used as an initial point to further screen and select indicators for SA in PavementLCM Framework.

3.2.3 More sustainable asphalt (originally green asphalt)

This section was used to identify the priorities of NRAs for the study of more sustainable asphalt (green asphalt in the moment of the questionnaire). For this purpose, 10 choices regarding more sustainable asphalt were given and the interviewees were asked to choose and rank 5 of them from the most to the least important. 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.

After analysing the results, the NRA priorities identified in order of preference are:

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

These priorities were used to design the case studies for the SA exercise and durability exercises in WP3 and WP4 respectively, and for the selection of the SA indicators in PavementLCM Framework.

3.2.4 Best practices regarding Sustainability Assessment

The questionnaire produced was used as a basis for discussion during the interviews. In this regard, during the discussions, best practices between NRAs regarding SA were identified and are summarised here:

- ✓ England: Use of LCC to allocate budget at strategic level based on the type of treatment for maintenance. Sustainability Strategy Developed (available online).
- ✓ 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 (available online).
- ✓ 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

3.3 Conclusions

After carrying out and analysing the results of the interviews, the following conclusions can be drawn:

- There is a very wide range of practices and different level of knowledge and implementation of sustainability assessment between the different 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
- The most important indicators for NRAs are:
    - Primary materials consumption
    - Secondary materials used
    - Energy use
    - Waste
    - Global Warming Potential
    - Whole life costs
    - Comfort index
    - Safety audits and inspections
    - Tyre‐pavement noise
    - Traffic congestion due to maintenance operations

This represents the first screening of for the definition of a set of indicators for PavementLCM SA Framework.

- The NRAs' priorities for the study and development of more sustainable asphalt mixtures are:
    5. Improved durability
    6. Reduced noise
    7. Warm Mix Asphalt
    8. 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 aims at creating a platform to allow such transfer of knowledge between NRAs.

4. 1st CEDR PavementLCM Workshop on Sustainability Assessment

4.1. Introduction

The 1st CEDR PavementLCM Advisory Workshop was held on the 25th June 2019 at the University of Nottingham. It was organised aiming at creating a platform for as many stakeholders as possible to learn about sustainability assessment of pavement materials and pavement activities. The workshop was tailored for the CEDR Project Executive Board (PEB) and National Road Authorities (NRAs), but it was extended to LCA practitioners, researchers, policy makers in the asphalt industry and road pavement construction sector. The objectives of the workshop were:

- To share knowledge, practices and opinions for the implementation of Sustainability Assessment (SA) in NRAs in Europe
- To provide an opportunity to be directly in touch with PavementLCM consortium to understand the work being carried out and provide feedback
- To provide insight on Sustainability Assessment practices from experts, NRAs and PavementLCM approach (framework, green asphalt, uncertainty, sustainability and durability)
- To agree on the “More Sustainable asphalt technologies” and “Case studies” to be considered for the sustainability/durability assessment
- To share the first results of PavementLCM with emphasis in the Sustainability Assessment (SA) Framework and obtain feedback from PEB and all attendees to ensure the work is aligned with the expectations

The final attendance was as following (not including PavementLCM consortium representatives):

National Road Authorities:

1. Robert Karlsson, Trafikverket, Sweden
2. Gundards Kains, Latvian State Roads, Latvia
3. Gints Alberins, Latvian State Roads, Latvia
4. Dirk Van Troyen, Flemish Road Authority, Belgium
5. Matthew Wayman, Highways England, England
6. Guita Berg, Vejdirektoratet, Denmark
7. Finn Thoegersen, Vejdirektoratet, Denmark
8. Niels Dujardin, Vejdirektoratet, Denmark
9. Christian Axelsen, Vejdirektoratet, Denmark

Industry:

1. Jose Luis Escolano, RPS group, UK
2. Federico Perrotta, AECOM, UK
3. Martyn Jones, AECOM, UK
4. David Markham, Tarmac, UK
5. Laurent Porot, Kraton, Netherlands

Academia:

1. Rita Kleiziene, Vilnius Gediminas Technical University, Lithuania
2. Thomas Mattinzioli, Universidad de Granada, Spain

3. Ahmed Abed, University of Nottingham, UK
4. Miomir Miljkovic, University of Niš, Serbia (On-line)
5. Ali Azhar Butt, UC Davis, US (On-line)
6. Alexander Passer, TU Graz, Austria (On-line)

The agenda of the workshop was tailored to include presentations from the consortium to show the current progress of PavementLCM, external presentations from representatives of EU projects related to the definition of SA indicators (EDGAR and LCE4ROADS) and to advances in SA practices (standards and examples of application). Two hours of discussion were established dividing the attendees in groups with different topics as following:

- Definition of More Sustainable asphalt and identification of PLCM case studies
- How should we use SA results?
- How to move towards harmonisation?
- How do we introduce SA in organisations? (i.e. road authorities)

The main aim of the workshop regarding the development of PavementLCM SA Framework was to obtain feedback about the current state of development and agree about the set of indicators to include in it and that is the information reported here. The complete results of the workshop were delivered in a stand -alone document together with the presentations and a questionnaire about the quality of the workshop.

4.2. Feedback for PavementLCM SA Framework

Regarding the principles, structure and content of PavementLCM SA Framework, it proposes specific calculation methods for two objects of assessment: 1) Pavement Materials and 2) Pavement Activities. The principles, structure and content presented were appreciated and accepted by the attendees. The presented probabilistic approach to introduce uncertainty in SA was also appreciated and it is stated that it has to be delivered in a simple way.

Regarding the selection of indicators for SA, the audience agreed that in order to introduce SA in road authorities, at this stage, a small set of indicators should be selected (maximum 5-6). The final indicators selected were chosen amongst those included in EN 15804, CWA 17089 and EDGAR project and also based on:

- Results of the interviews
- Data availability on freely available tools for their quantitative assessment

The final list of chosen indicators and their description is shown in Table 7:

Table 7. Proposed Set of indicators for PavementLCM SA Framework

Indicator	Object of assessment	Description
Global Warming Potential	Pavement materials and activities	Generally accepted equivalent of GHG accumulation, describes the relevance of emissions for the global warming effect and is the characterisation factor describing the radiative forcing impact of one mass-based unit of a given GHG relative to that carbon dioxide over a given period. It shall be expressed in kg CO_2 equivalent, see EN 15804
Energy use	Pavement	Includes a quantification of the energy required during the life cycle of

	materials and activities	the object of assessment. It should be divided in renewable and non-renewable, and can be split as defined in EN 15804
Secondary materials consumption	Pavement materials and activities	Includes a quantification of the material recovered from previous use or from waste which substitutes primary materials. It can be expressed by mass units or as percentage of recycled materials used related to the total consumption
Cost	Pavement materials	All significant and relevant costs and benefits of the object of assessment
Cost	Pavement activities	All significant and relevant costs and benefits of the object of assessment, throughout life cycle, while fulfilling the performance requirements, see CWA 17089
Tyre-pavement noise	Pavement activities	The type of pavement used has an impact on the tyre-road noise levelon a given road. This indicator is expressed as reduction of tyre-pavement noise level in dB compared to the reference pavement
Laboratory Performance	Pavement materials	Durability contribution due to laboratory performance-related properties of pavement materials
Service Life of pavement components (durability)	Pavement activities	Estimated Service Life of the pavement components, The methodology, tailored for wearing courses only, will be defined in WP4 of PavementLCM
Air pollution	Pavement materials and activities	Assessing pollution potential on the basis of air pollution (non-CO2 emissions), evaluating particulate matter and photochemical oxidation potentials

Furthermore, it was established that a “More Sustainable pavement material” can be identified only through a comparative analysis with currently used materials. The audience agreed that the 5 indicators must be used for this comparison are:

6. Global Warming Potential
7. Energy use
8. Secondary materials consumption
9. Cost
10. Laboratory Performance

Similarly, a “More Sustainable pavement activity” can be identified only through a comparative analysis with current practices. The audience agreed that 6+1 indicators must be used for this comparison:

8. Global Warming Potential
9. Energy use
10. Secondary materials consumption
11. Cost
12. Tyre-pavement noise
13. Service Life of pavement components (Durability)
14. OPTIONAL: Air pollution

5. 2nd CEDR PavementLCM Workshop on "Sustainability Assessment for road Pavement"

5.1. Introduction

This sections cointains the contents and feedback from the international workshop organised on December 2020 (16 – 17/12/2020) in collaboration with EAPA to discuss and develop important key concepts together with other stakeholders such as NRAs, academics and with the aim of discuss and develop the following key areas:

- Theory, framework, standards and regulations of Sustainability Assessment
- PAVEMENTLCM framework for sustainability assessment of asphalt mixes and road pavements
- Implementation of sustainability assessment practice for both the asphalt mixtues and road pavement industries
- Hands-on practice on the elaboration of EPD for asphalt pavements and LCA of road pavements Next steps on Sustainability Assessment of asphalt pavements.

The Webinar was moderated by EAPA Technical Director Breixo Gómez and Davide LoPresti, Coordinator of the Project PavementLCM.

5.2. Programme

Day 1 – 14:00 – 17:00 – Wednesday 16 December 2020 State of the art of SA in EU + Workshop 1

Day 1 - Wednesday 16 December 2020: State of the art of SA in EU + workshop	
14h00-14h20	Openings: *Steve Philipps, CEDR Secretary General* *François Chaignon, EAPA President*
14h20-14h40	Sustainability Assessment: Theory/frameworks/standards/regulations *Lucia Monforte Guillot* *Member of ISO/TC59/SC17/WG5 and CEN/TC350/WG6* *Manager of Environmental and CSR Department at FCC Construccion (ES)*
14h40-15h00	Pavement LCM Framework for asphalt mixtures and Road Pavements *Davide Lo Presti, PAVEMENT LCM Coordinator* *Univ. Palermo (IT)/Univ. Nottingham (UK)*
15h00-15h10	Coffee break
15h10-15h30	Implementation of Sustainability Assessment: LCA for asphalt contractors and use of LCA for asset management *Rob Hofman, Rijkswaterstaat (NL)*
15h30-15h50	Recommendations for implementation of sustainability assessment for NRAs *Elizabeth Kejizer, TNO (NL)*
15h50-17h00	Workshop 1 – Elaboration of EPD for asphalt mixtures *Geir Lange, Norwegian Contractors Association (NO)*
17h00	Summary of Day 1 and closing

Figure 27 – Workshop Program Day 1

For the opening, Mr Steve Phillips, Secretary General of the Conference of European Directors of Roads and Mr. François Chaignon, President of EAPA, gave respective speeches in which, among other things, highlighted the great advances that Asphalt Sector is producing on Sustainability and need of collaboration between all the stakeholders to tackle the current and future challenges.

The first technical presentation was given by Lucía Monforte, Head of the Environmental and CSR Department of FCC Construcción. Lucía presented the work undertaken at international and European level in the development of Standards for assessing the sustainability of civil engineering works and explained the main contents of prEN 17472.

Then, Davide LoPresti presented the Pavement LCM Framework for asphalt mixtures and Road Pavements.

After a short coffee break, Rob Hofman, who works for Rijkswaterstaat, the Public Administration in The Netherlands, and is a very active member of the Conference of European Directors of Roads (CEDR), gave a presentation on the implementation of Sustainbility Assessment and, in particular, on the use of LCA for contractors and for asset management.

In the next presentation, Elisabeth Keijzer, sustainability consultant who works in the Dutch research institute TNO, spoke about the practical side of sustainability for National Road Administrations and gave 12 recommendations for NRAs on do’s and don’ts when implementing sustainability assessment.

At the end of the first day, a hands-on practice was organised and participants could login into the EPD tool “LCA.no” to elaborate their own EPD. For this, Geir Lange gave an introduction to the Environmental Product Declaration system in Norway and then, Ole Iversen, guided the participants through the practical exercise.

Geir has worked since 2010 in Veidekke, the largest Asphalt Contractor in Norway and has been involved in the development of the PCR and the LCA tool currently used in Norway. Ono the other hand, Ole is the CTO of LCA.no, has worked with online tools for EPD and LCA for 5 years and specifically with asphalt EPDs since 2016, when they started the project with EBA and Veidekke.

Summary and videos are in our website: https://www.pavementlcm.eu/2020/11/30/secondRpavementlcmRworkshopReapaRwebinarRsustainabilityRassessmentRofRasphaltRpavements/

Day 2 – 14:00 – 17:00 – Thursday 17 December 2020 Next steps in SA + Workshop 2

2nd Day - Thursday 17 December 2020: Next steps in SA	
14h00-14h20	European PCR for EPD of asphalt mixtures *Breixo Gomez, EAPA (BE)*
14h20-14h40	Benchmarking of Asphalt mixtures – RILEM *Ana Jimenez Del Barco Carrion, University of Granada (ES)*
14h40-15h00	Introducing Uncertainty in Sustainability Assessment *Tony Parry, University of Nottingham (UK)*
15h00-15h20	Methodology for Durability assessment *Bjorn Kalman, VTI (SE)*
15h20-15h30	Coffee break
15h30-15h50	FHWA Sustainable Pavements Program and SPTWG *Heather Dylla, Federal HighWay Administration (USA)*
16h50-16h20	Integrating Life Cycle Assessment into Planning and Project Delivery *Milena Rangelov, Federal HighWay Administration (USA)*
16h20-17h00	Workshop 2 – FHWA LCA Framework and LCA Tool *Joep Meijer – The Right Environment Ltd (USA)* *John Harvey – University of California, Davis (USA)*
17h00	Summary of Day 2 and closing

Figure 28 – Workshop Program Day 2

Breixo Gomez opened the second day of the Webinar by presenting the efforts that nowadays are being made to develop European Product Category Rules (PCR) for the elaboration of Environmental Product Declarations (EPD) of asphalt mixtures, which not only comply with the strong European policy but also meet the needs of the stakeholders involved in the construction of asphalt pavements.

After this, Ana Jiménez del Barco, MSC Research Fellow at the Construction Engineering Laboratory of the University of Granada (Spain), presented the work being carried out as part of the RILEM TC 279 Valorisation of Wastes and Secondary Materials for Roads, within TG5 Life Cycle Assessment. This international collaborative effort is focused on obtaining (1) LCA benchmarks for conventional asphalt mixtures and (2) environmental recommendations for the use of asphalt mixtures containing wastes and secondary materials, focused on the comparison with the benchmarks.

The next Speaker was Professor Tony Parry, who works in the Nottingham Transportation Engineering Centre at the University of Nottingham (UK). He presented the approach taken to include uncertainty in the interpretation of lifecycle assessment results in the CEDR Pavement LCM project.

Björn Kalman, Research director at Pavement Technology, Swedish National Road and Transport Research Institute, presented a Methodology for Durability Assessment.

After the coffee break, Heather Dylla and Milena Rangelov presented updates on the USA Sustainable Pavement Program activities. This presentation provided an overview of LCA fit into infrastructure planning and project delivery. Additionally, in the light of Buy Clean acts in the USA, this presentation reflected on the current status of EPDs, harmonization, and future developments. Lastly, this presentation provided an overview of the creation of a newproject-level tool, LCAPave. The tool uses EPDs and public background datasets in LCA analysis and enables stakeholders to inform pavement design and decision-making using environmental impacts.

At the end of the technical presentations, Joep Meijer and John Harvey organized another workshop, in which they showed the FHWA LCA Framework and LCA tool. Joep is the Founder and President of The Right Environment Ltd. Boulder, Colorado. Among many other things, he is one of the leading authors of the national standard for environmental product declarations (EPDs) in the Netherlands and is involved in similar efforts in Europe and North-America through his seat in the ASTM committee for Sustainable Construction and the Federal Highway Administration's (FHWA) Sustainable Pavements Technical Working Group. On the other hand, John is Professor of Civil and Environmental Engineering at the University of California, Davis, Director of the UC Pavement Research Center, and Director of the City and County Pavement Improvement Center. He is Principal Investigator for projects for research, development and implementation for a wide range of pavement materials, design, asset management, cost, and environmental topics for the California Department of Transportation, Federal Highway Administration, Federal Aviation Administration, CalRecycle, the California Air Resources Board, the Transportation Research Board, other state DOTs and industry.

The event was eventually closed by EAPA Secretary General Carsten Karcher and Oliver Ripke, Head of the project executive board of the CEDR call for "new Materials" 2017, which includes the project PavementLCM. Both thanked Organisers, Speakers and Participants for the successful Webinar and supported the continuation of this initiative, organising future events, which will again bring together Road Administrations, Industrials, Researchers and Academics to discuss and define the future steps on Sustainability Assessment in the Asphalt Paving Sector.

(source: https://www.pavementlcm.eu/2020/11/30/second-pavementlcm-workshop-eapa-Webinar-sustainability-assessment-of-asphalt-pavements/)

During both the days a high number of partecipants was recorded. In particular on the 16th of December 139 people attended against the 119 on the 17th.

After the webinar, viewers were invited to give their feedback on the event and to express some further suggestions.

In total 35 registrants responded and the results collected show the event was really appreciated. In fact, on the basis of a rating score between 1 and 5 (with 1 very bad R 5=very good), the average score is of 4,44/5, evidence of a positive feedback.

In particular people were asked to express their evaluation on the overall webinar, on the way it was announced, on the interest of the programme proposed and their satisfaction on the online platform.

All the the participants who left a comment were really enthusiastic. Some suggestions are reported below and should be useful for a next webinar.

5.3. Results of the survey after the webinar

1. What is for you the overall rating of this Webinar? (1=very bad P 5=very good)
35 registrants responded
Avg. Rating 4.57

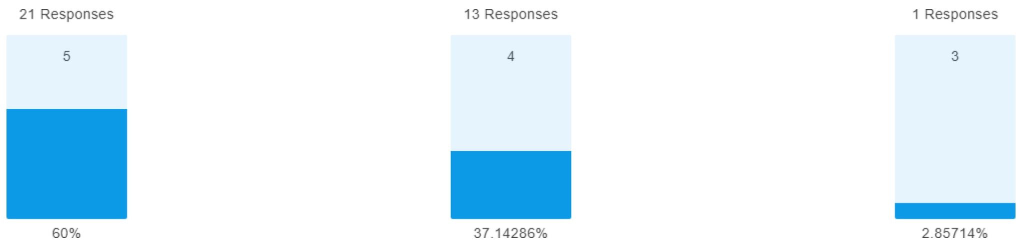


Figure 29 – Survery Results

2. How interesting was the programme? (1=very bad P 5=very good)
35 registrants responded
Avg. Rating 4.6

Figure 30 R Survery Results

3. How good was the announcement of the Event? (1=very bad P 5= very good)
35 registrants responded
Avg. Rating 4.17

Figure 31 R Survery Results

4. How satisfactory was the online platform? (1=very bad P 5=very good)
35 registrants responded
Avg. Rating 4.43

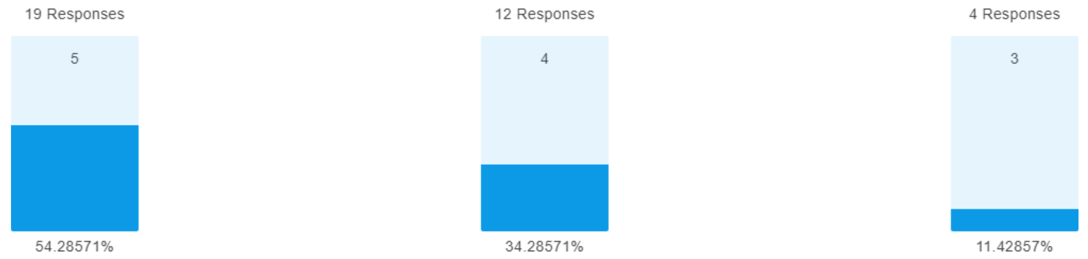


Figure 32 R Survery Results

5. Do you have any further suggestion?
7 registrants responded

- Can you share the video of the webinar?
- No suggestion- It was a really interesting and useful webinar
- Thank you very much for the organisation and the content. The only suggestion would be to have an open Q&A or Chat. I couldn't see all the questions and answers.
- Great sharing and comparison of USA & EU progress, issues and opportunities
- Maybe we could see the questions of the participants
- It would have been nice to see who the other participants were.
- Repeat this format, it was nice :)

6. Feedback received after the Webinar in the “Questions” box:

- Thank you- Very good webinar :)
- Great 2Rdays, well done everyone-
- Thank you for this very interesting webinar
- Thank you for organizing webinar, it is very nice to participate on line, and hopply after the pandemic we will still have the ability to connect other workshop online too. It was nice to see you again. Have a nice upcoming Christmas season :)
- Thank you for the Webinar-
- Many thanks for this very relevant and interesting seminar.

7. Participation

Day 1:

Total number of attendees: 139

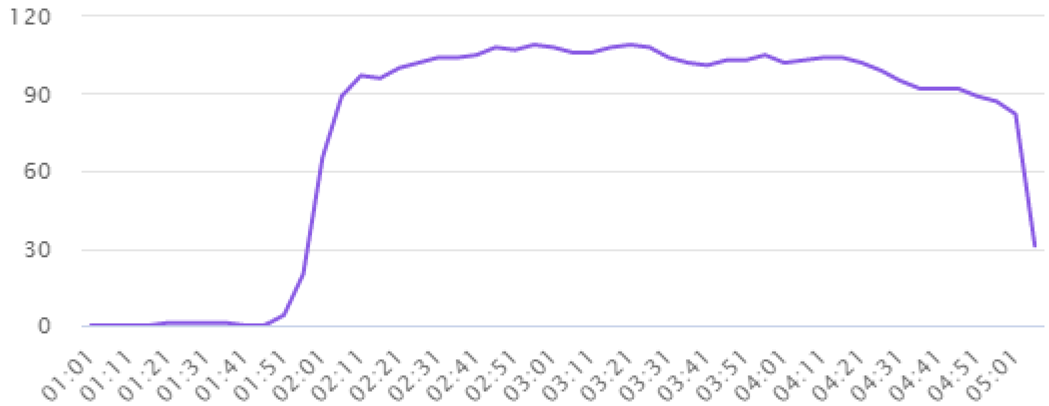


Figure 33 – Number of attendees - Day 1

Day 2:

Total number of attendees: 119

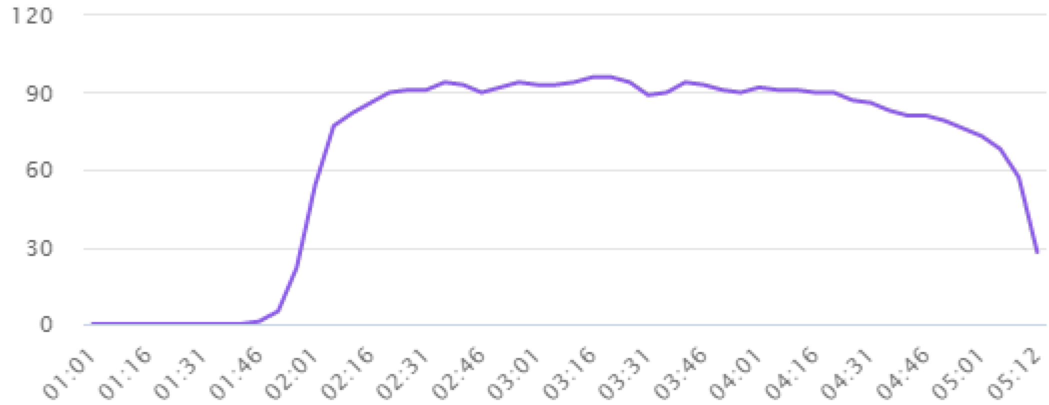


Figure 34 - Number of attendees - Day 2

6. 3rd CEDR PavementLCM Workshop on "Durability assessment of more sustainable asphalt mixtures"

6.1. Introduction

The 3rd CEDR PavementLCM Advisory Workshop was held on the 28th May 2021 through an online platform. The workshop was tailored for the CEDR Project Executive Board (PEB) and National Road Authorities (NRAs) and it was aiming at having feedback from PEB members with regards to durability of road pavement layers.

More general, the objectives of the workshop were:

- To share knowledge, practices and opinions for the implementation of durability within Sustainability Assessment (SA) in NRAs in Europe
- To gather an expert opinion on the reference estimated service life of wearing courses in Europe
- To share experience on the factors affecting the estimated service life of wearing courses in Europe

6.2. Programme

The agenda of the workshop was tailored to include presentations from the consortium to show the current progress of PavementLCM, and with a second part dedicated to gather expert opinion through a workshop.

AGENDA

Friday, May 28, 2021

WORKSHOP (28/05021): Durability of (more sustainable) road pavement layers
10AM – 1PM CET – on Microsoft TEAMS

10:00 Welcome and Introduction – Davide Lo Presti (20 mins)
10:20 Methodology for durability assessment – Tony Parry (20 mins)
10:40 Durability questionnaire results – Standard mixture – Tony/Bjorn/Luis? (20 mins)
11:00 Laboratory results of more sustainable asphalt mixes – Bjorn (20 mins)
11:20 BREAK – 10mins
11:30 – 12.50 Interactive session

- Discussion about durability of pavement layers with more sustainable asphalt mixture (45 mins)
  - What is durability of pavement layers with more sustainable asphalt mixes?
  - What is deterioration mode of pavement layers with more sustainable asphalt mixes?
- What do you think are the factors related to estimation of durability? (30 mins)
  - Expert results
  - Laboratory results
  - Upscaling experience results (APT, living lab)
  - What else should we ask Asphalt Contractors?

12:50 Closure

Figure 35 – Workshop Agenda

Figure 36 – Teams Meeting

The final attendance was as following (including PavementLCM consortium representatives):

National Road Authorities:

1. Robert Karlsson, Trafikverket, Sweden
2. Oliver Ripke, Bast, Germany
3. Mehdi Kalantari, Bast, Germany
4. Joralf Aurstad, Norwigian Road Authority, Norway
5. Matthew Wayman, Highways England, England
6. Finn Thoegersen, Vejdirektoratet, Denmark
7. Matteo Pettinari, Vejdirektoratet, Denmark
8. Rob Hofman, Rijkswaterstaat, The Netherlands

Academia:

9. Davide Lo Presti, University of Nottingham and University of Palermo
10. Tony Parry, University of Nottingham
11. Luis Neves, University of Nottingham
12. Bjorn Kalman, VTI, Sweden
13. Gabriella Buttitta, University of Palermo
14. Rita Kleiziene, Vilnius Gediminas Technical University, Lithuania

6.3. Discussion about durability of pavement with more sustainable asphalt mixtures

As a mean to estimate the durability of pavements when historical data is not available, a set of surveys had been developed and distributed to NRA experts from different countries. In this section, we describe the surveys, the obtained results and the methodology used to estimate the durability of pavements based on these. The analysis presented here can be further detailed once more survey responses are collected and it becomes possible to split the cohort depending on geography, climate, level of expertise, etc.

The work is based on two surveys (deatils in Annex II). The first addresses the durability of common and widely used surfacing materials, while the second estimates the durability of new surfacing materials, based on the durability of the first.

6.3.1. Traditional surfacing materials

The first survey analysed the performance of two typical materials, denoted SMA16 and PA16, considering different levels of traffic.

The survey was divided in 5 sections as follows:

- Background: country of origin, level of detail of existing asset managementdatabases, experience and use conditions for analysed surface mixes
- Failure modes: identification of most likely failure modes for different traffic volumes
- Durability of standard mixes: data on the expected, worst case and best casescenarios of durability of standard mixes under different traffic loads
- Factors affecting durability: estimates of the impact on durability of standard mixes ofchanges in traffic volume and rain patterns.

The survey was delivered using Microsoft Forms using the link https://forms.office.com/Pages/ResponsePage.aspx?id=7qe9Z4D970GskTWEGCkKHmGuYb2fJVNNmbEI3NOoC_VUNFlWMjRPMzExUUpIM1UwQ05QTExQM0wxQy4u

The full details of the first survey can be found in Annex II.a.

The results presented indicate that SMA16 is, fundamentally, used for high volume roads, whereas PA16 is used much less frequently and, fundamentally, on higher volume roads.

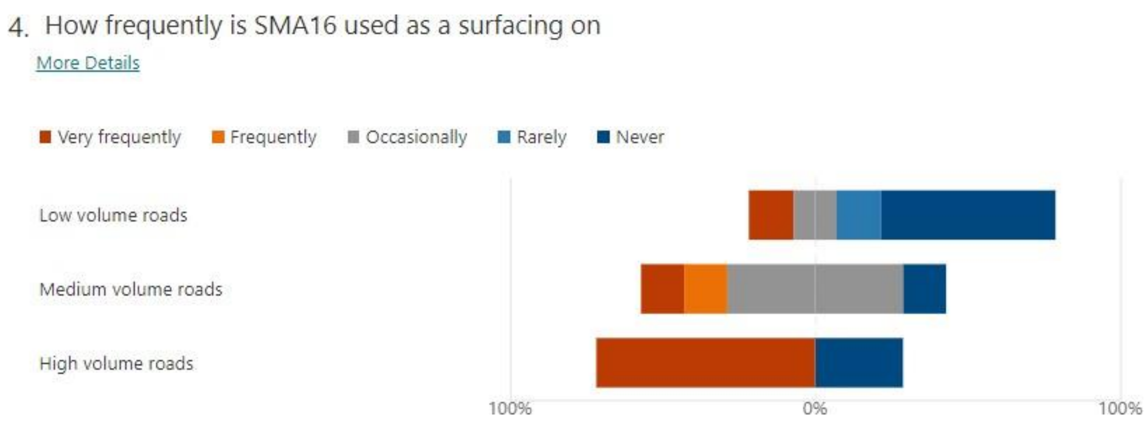


Figure 37 - Responses to survey regarding the type of roads SMA16 is used on

5. How frequently is PA16 used as a surfacing on

More Details

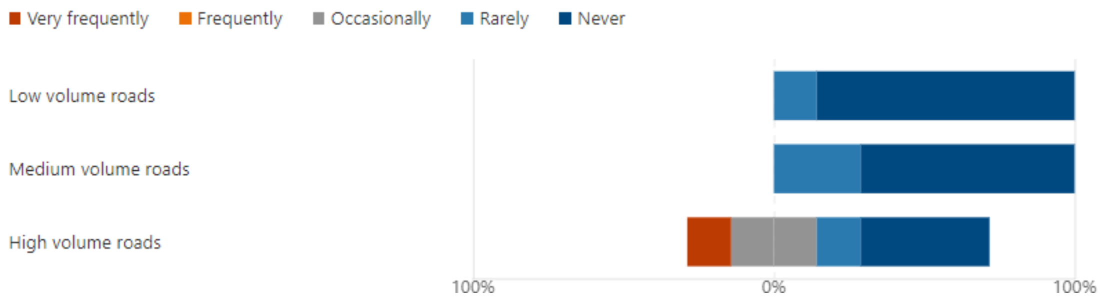


Figure 38. Responses to survey regarding the type of roads PA16 is used on

6. Distresses triggering pavement resurfacing.

Classify each type of distress in terms of how likely it is that its presence triggered the decision to resurface for SMA16.

More Details

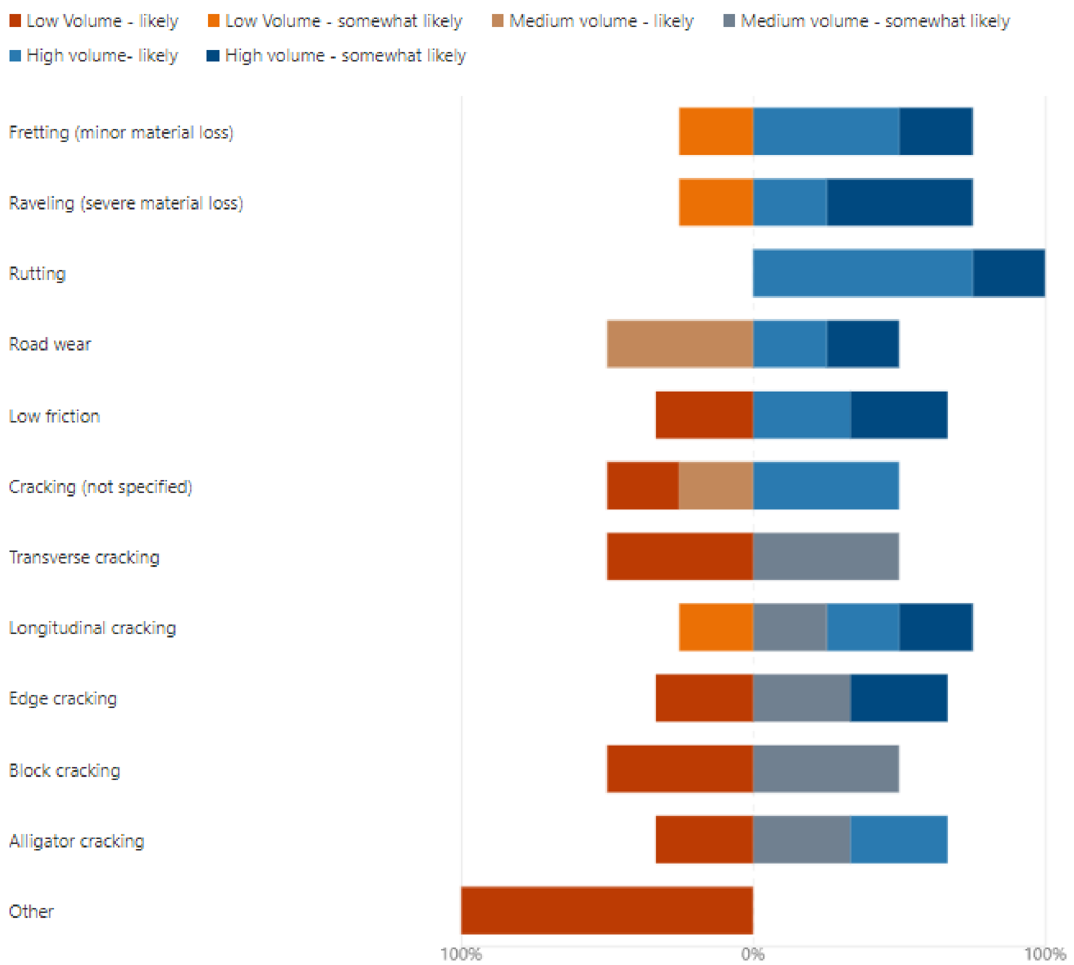


Figure 39. Failure mechanisms for SMA16

When the more frequent failure modes of SMA16 are analysed (see Figure 39), it is clear that there is a clear differentiation of failure modes with the traffic levels. For high volumes of traffic, the main mechanisms are fretting, ravelling, rutting and low friction. For low traffic roads, the main observable form of deterioration is cracking (transverse, longitudinal, edge, bock and alligator). When analysing PA16, there is a significant smaller number of responses, as several experts did not feel confident or experienced enough to make a clear decision. However, the failures modes expected by experts (Figure 40) are similar to those described for SMA16.

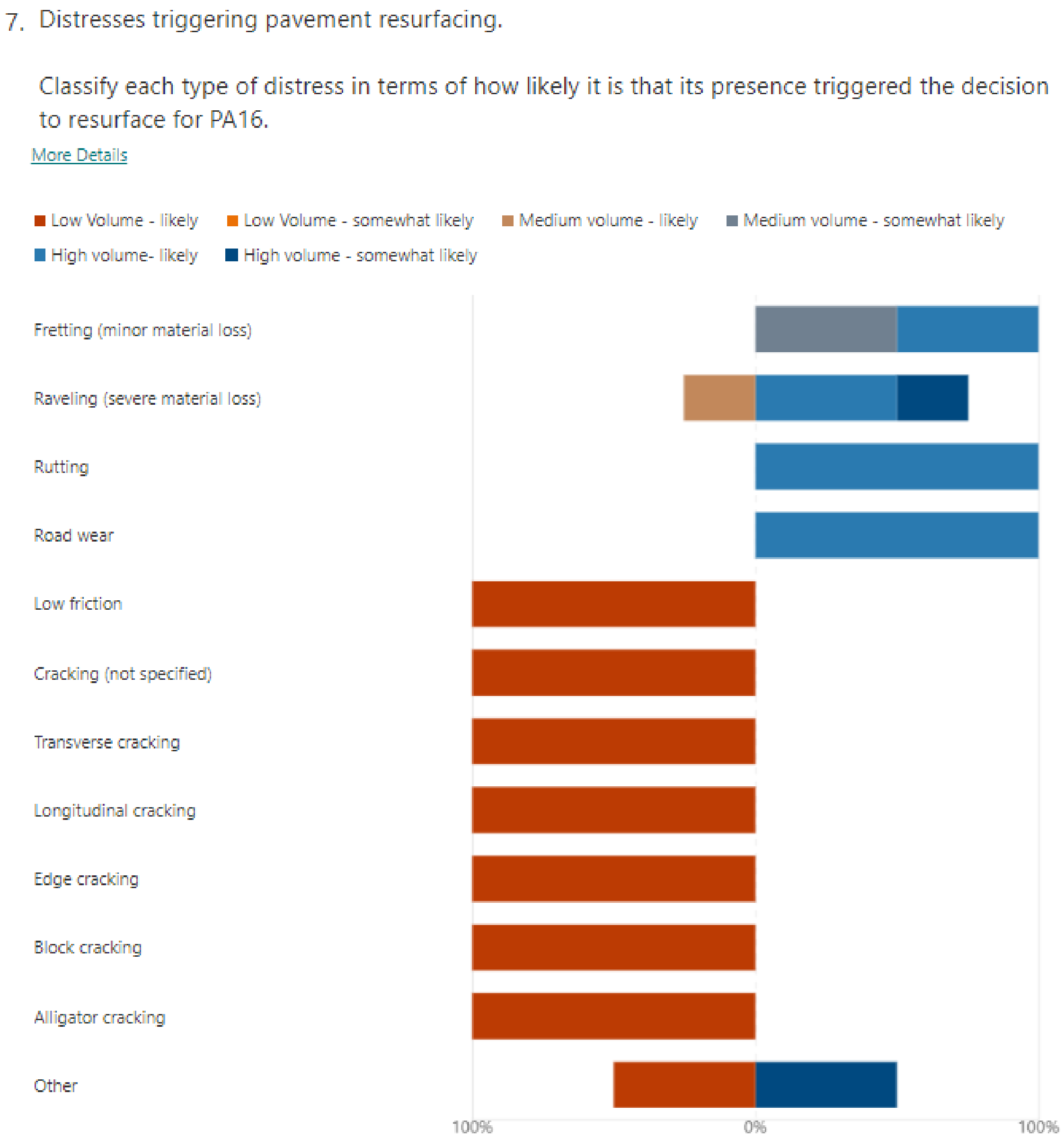


Figure 40. Failure mechanisms for PA16

The next block of questions focused on the predicted durability of surfaces built using different mixes. As an example, for SMA16 on high volume roads, the responses of experts are shown in Table 8

Table 8 R Durability estimates for SMA16 used in high traffic roads

Expert	Expected durability (years)	Worst case durability (years)	Best case durability (years)
1	15	12	25
2	10	4	20
3	10	3	12
4	15	10	17
5	7	4	12

The results seem to indicate that most experts agree regarding the mean durability of these surfacing material. However, the results show that the question might not have been clear enough when asking for the worst and best case scenarios. In fact, although the question mentioned that a worst case scenario referred to the worst 10% surfaces, some experts seem to have understood this as a much more pessimistic estimate. It is difficult to believe that 10% of all pavements last only 3 or 4 years, when the average is 10 years. This raises the question of the difficulty of estimating the probability of occurrence of rare events considering humans tend to overestimate those (Attneave, 1953; Trommershäuser et al., 2008).

6.3.2. More sustainable surfacing materials

The second survey focuses on innovative pavements mixed and aims at quantifying the durability of those compared to traditional solutions. The survey was divided in

- Background: country of origin, level of detail of existing asset management databases, experience and use conditions for analysed surface mixes
- Failure modes: identification of most likely failure modes for different traffic volumes
- Durability of novel mixes compared with standard mixes: relative expected durability, level of confidence in response
- Factors affecting durability: estimates of the impact on durability of novel mixes of changes in traffic volume and rain patterns.

The survey conducted focuses on SMA11 containing 10% of reclaimed asphalt. The results of the survey indicate that there is a large set of potential forms of distress relevant for this type of surface mix. For high traffic volume roads (see Figure 41) the critical modes seem to be freeting, raveling, rutting and edge cracking). For low volume roads, there seems to be much less experience and the only modes identified by more than one expert are transverse cracking and block cracking.

When analysing the durability of SMA11 (10% RA) versus SMA16, the results indicate that the first will be:

- Equally or more durable (up to 5%) than SMA16 for low traffic roads
- Probably more durable (up to 5%) than SMA16 for medium traffic roads
- Probably equally durable that SMA16 for high traffic roads, although significant disagreement exists amongst experts

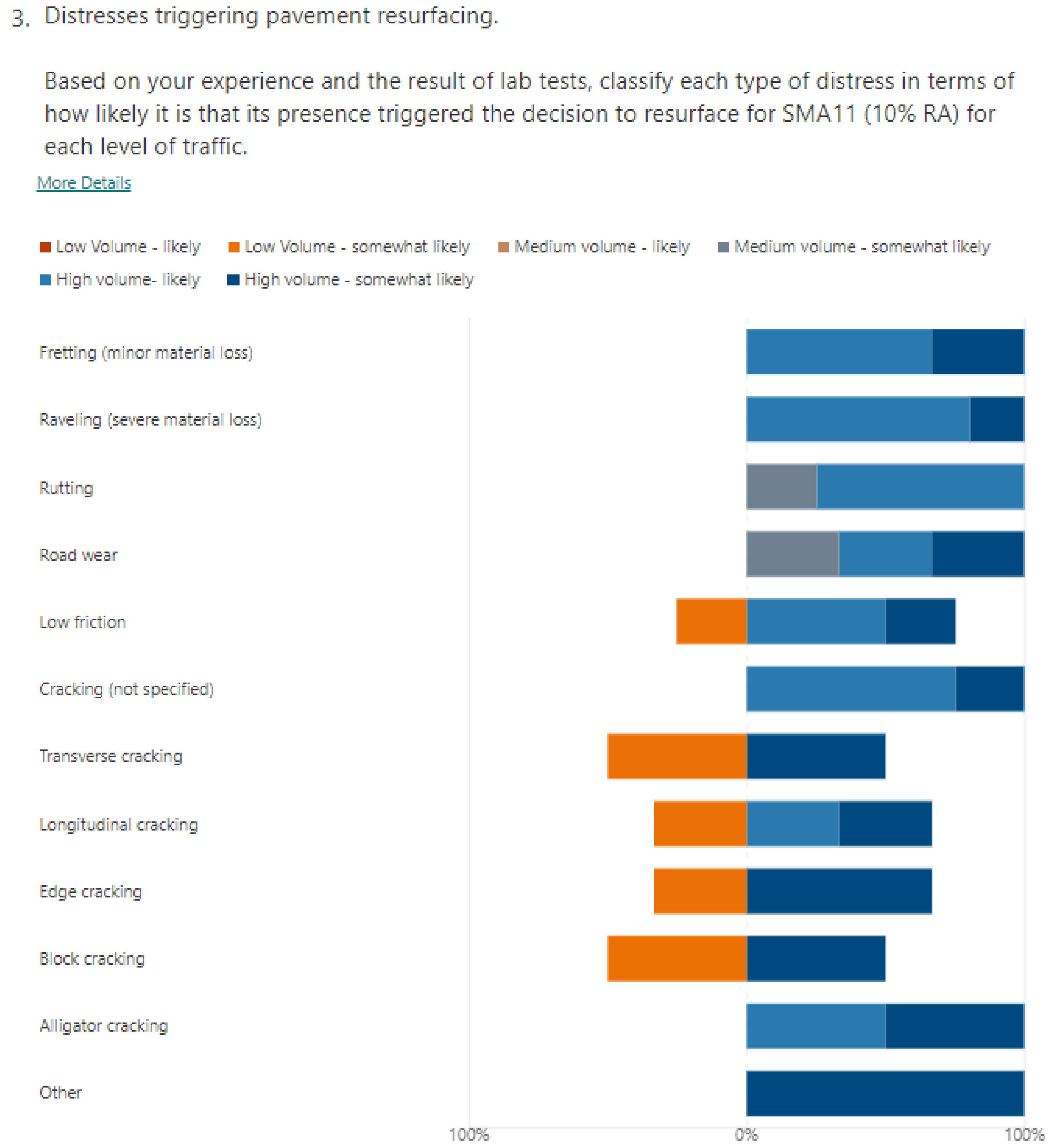


Figure 41. Failure mechanisms for SMA11 (10% RA)

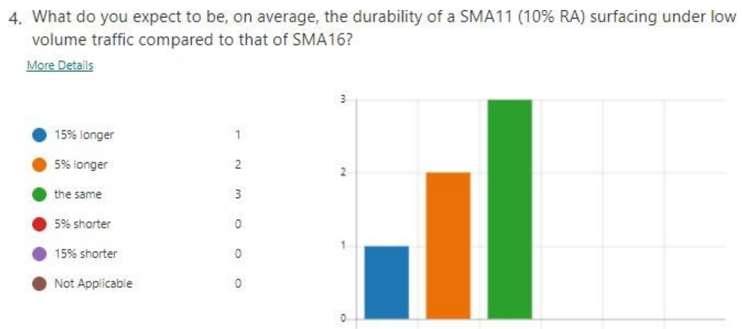


Figure 42. Relative durability of SMA11 (10% RA) vs SMA16 for low volume roads

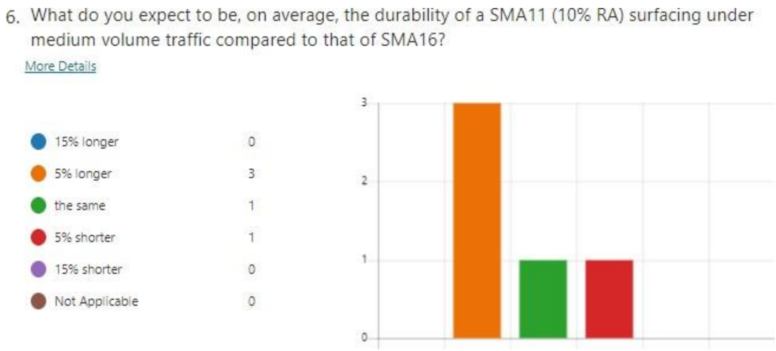


Figure 43. Relative durability of SMA11 (10% RA) vs SMA16 for medium volume roads

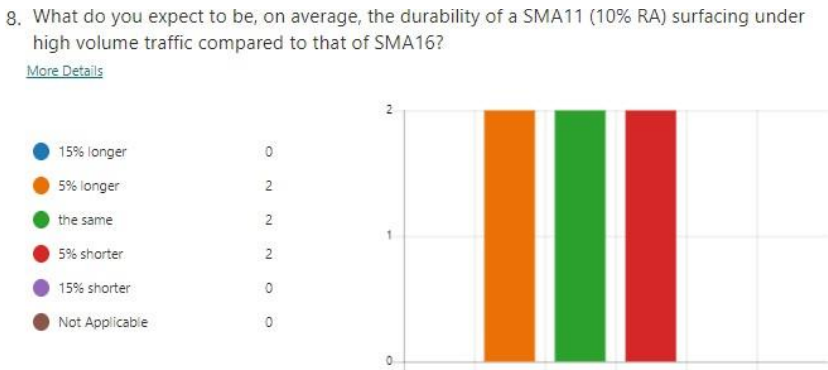


Figure 44. Relative durability of SMA11 (10% RA) vs SMA16 for high volume roads

The experts present very different levels of confidence in their estimates (significantly higher than those defined for traditional mixes), as shown in Figure 45. The perceived confidence is not, however, correlated to the estimates of durability.

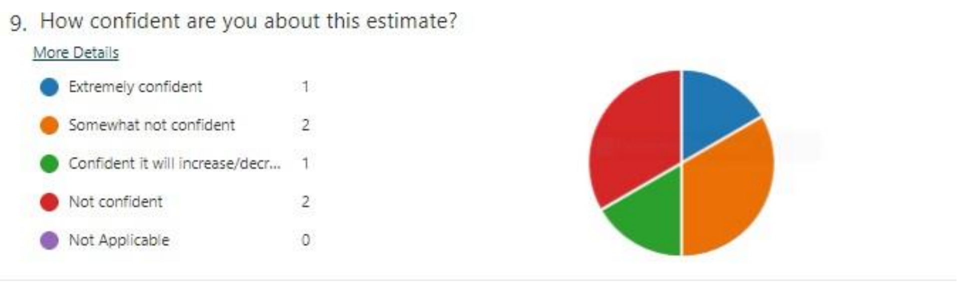


Figure 45. Confidence in durability estimates for SMA11 (10% RA) for high volume roads

6.3.3. References

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6.4. NRA's experience on factors affecting durability

What do you think are the factors related to estimation of durability? and what is currently used to try estimating it

- Results of laboratory tests
  - Moisture sensitivity tests
  - Performance‐related tests [rutting, cracking (visual)]
  - Netherlands: ravelling from drilling cores (product development)
  - Germany: ITS in cold condition; stiffness, fatigue, friction after polishing

- Quality control during production and paving operations
  - Infrared cameras
  - Paver?
  - On‐site density (radiometric) + target value for compaction level
  - Whether condition (temperature, mm of rain in that day, wind in that day, time of the day)
  - Indicator related to bonding through tack coat (best practice: do not drive on it),
  - Certified workmanship

- Accelerated Pavement Testing
  - Germany, Netherlands (only for research purposes)

What do you, or could you, ask Asphalt Contractors to predict the durability of pavement components?

- Norway: quality plan of contractors for each job (maybe templates from NRA?)
- Germany: Asphalt recycling quality control plan
- UK: Sector scheme with credits to achieve some quality targets
- UK: live labs for 2 years to check functional and technical indicators

Which other technical and functional requirement to you want to monitor?

- Texture (skid resistance)
- Permeability (NL twice a year cleaning of PA)
- Void content

7. Conclusions and Recommendations

These two deliverables (D2.1a and D2.1b) aim at providing the PavementLCM Sustainability Assessment Framework for pavement materials and activities for NRAs.

For this purpose, Chapter 2 offers an introduction to Sustainability Assessment (SA) in pavement engineering. SA is an approach for exploring the combined environmental, social and economic impacts of products and systems. Such assessment can also assist decision-making and strategic planning for National Road Authorities (NRAs).The section aims at helping NRAs to increase their understanding of SA by providing:

1. A background on Sustainability and Sustainable Development, how to introduce them in their institutions, basic concepts of Sustainability Assessment, Life Cycle Thinking, Life Cycle Approaches and Techniques.
2. State-of-the-Art of Sustainability Assessment of pavement materials and activities presented covering available standards, guidelines and previous projects.

The third chapter presents the results of the interviews undertaken with NRAs to understand the current practices in SA and their priorities for the definition of SA indicators. Chapters 3 to 6 show the feedback received in the three CEDR PavementLCM Advisory Workshop as a support in building the PavementLCM SA Framework. Finally, Chapter 7 introduces the framework.

The following conclusions and recommendations divided in topics can be drawn:

<u>Background and State-of-the-Art in Sustainability Assessment for NRAs</u>

- There is a current need and pressure to move toward the achievement of the Sustainable Development Goals in every field. Pavement engineering has a strong influence in the three pillars of sustainability (energy consumption, GHG emissions, noise, costs, etc.) and the commitment of NRAs to decrease negative impacts on them is required.
- To do this, NRAs should create their own Sustainability Strategy to identify their specific role and possible contributions to sustainability, taking into account impacts,

context and influence. This would include the identification of impacts of main concern and the planning of a review of the key contributions the NRA can make to influence sustainability further, through mandates, resources, existing priorities and activities.

- Sustainability Assessment (SA) is the evaluation of the environmental, social and economic impact 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. The main tools to perform are: performance assessment, life cycle techniques and sustainability rating systems.
- The standard EN 15643‐5 Sustainability Assessment Framework for civil engineering works is the umbrella under which PavementLCM SA Framework has to be built according to several key points of the standard:
    - Environmental, social and economic performance must be assessed.
    - Technical and functional requirements must be taken into account.
    - The assessment should use a life cycle approach.
    - The assessment should use quantifiable indicators measured without value judgements.
- Given the importance of analysing the three pillars of Sustainability, PavementLCM suggests to move from the use of the term “green asphalt or pavement” to “more sustainable asphalt or pavement” including in this way the three dimensions of sustainability and the fact there is no “absolute” sustainability, but more sustainable options.
- Life Cycle Approaches and Techniques are tools to apply (i.e. materialise) Life Cycle Thinking (LCT) which “*is about going beyond the traditional focus on production site and manufacturing processes to include environmental, social and economic impacts of a product over its entire life cycle”.* LCT helps to make choices by help identifying the critical activities or points in the whole life cycle of a product or system causing the highest environmental, social and economic impacts and therefore enable to develop strategies and policies for their mitigation and minimisation, involving the appropriate stakeholder to take actions towards Sustainable Development.
- Life Cycle Assessment, Life Cycle Cost are the specific methodologies proposed to evaluate each of the pillars of sustainability when performing the SA of civil engineering works, and consequently to be used in pavement engineering.
- There is a lack of standards defining calculation methods for the SA of civil engineering works. In this regard, PavementLCM SA Framework has to focus on developing such methods. defining:
    - Objects of assessment
    - Functional/declared units
    - System boundaries/LC stages to include in the assessment
    - Analysis period
    - Cut-off rules
    - Allocation procedures
    - Data quality requirements
    - Sustainability Assessment indicators
    - Recommendations for the presentation of results

- There are a series of EU efforts dedicated to the development of SA indicators, being: EDGAR, LCE4ROADS with the definition of CWA17089 and SUP&R ITN. PavementLCM SA Framework used these efforts to define to use in the SA of pavement materials and activities.
- As a result of the knowledge transfer activities (interviews, questionnaires and advisory workshops), it is clear how European NRAs are activing very differently in terms of sustainability assessment practices.
- Amongst those interviewed, the Netherlands and Scandinavia are leading the way, while UK and Germany are implementing some practices.
- Continuous knowledge transfer of SA practices amongst NRAs could be beneficial
- It is important that NRAs provides asphalt contractors and asphalt manufacturers with the necessary guidelines and elements to produce EPDs and provide all the necessary information to allow NRAs performing life cycle management exercises
- Reference service life (durability) is a key concept that needs to be assessed by asphalt contractors and/or road owners

Knowledge transfer activities

- As a result of the knowledge transfer activities (interviews, questionnaires and advisory workshops), it is clear how European NRAs are activing very differently in terms of sustainability assessment practices.
- Amongst those interviewed, the Netherlands and Scandinavia are leading the way, while UK and Germany are implementing some practices.
- Continuous knowledge transfer of SA practices amongst NRAs could be beneficial.

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ANNEX I. Questionnaire

ANNEX I.a: PavementLCM – Questionnaire WP2

SECTION 0. INTRODUCTION

What is Sustainability Assessment of Civil Engineering Works?

"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." **– EN 15643-5:2017**

What is PavementLCM Project?

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. From this point of view, Life Cycle Assessment (LCA), Life cycle costing (LCC) and life cycle approached looking at social aspects are becoming popular techniques aimed at helping the different stakeholders in the process. However, the lack of a standard framework to perform Life Cycle Management (LCM) of road infrastructures means decisions are very much dependent on the analyst's work and assumptions, which can lead to considerable differences amongst methodologies and finally results cannot be comparable from one case to another. This is not least the case for assumptions concerning the durability of new materials, which is a necessary part of any life cycle analysis. However, discrepancies are still present within National Road Authorities (NRAs) but even amongst researchers and it is in the interest of every stakeholder that a harmonised framework and clear user-friendly guidelines are created to allow LCM analyses to be made with confidence.

PavementLCM is a 2 year international project which will be carried out by a multi sectoral consortium to deliver a complete package to allow NRAs to carry out harmonised LCM exercises for Green Asphalt, as well as providing training and user-friendly guidelines to support their widespread use. The specific objectives of PavementLCM are:

- To create a general LCM framework with templates and case studies to carry out harmonised sustainability assessments of both asphalt mixtures and road pavements and to transfer the knowledge with a training tailored to NRAs.
- To create the Pavement LCM lookup tool as a user-friendly tool to help members of NRAs to find most appropriate datasets, methodologies and results of previous LCM studies for a specific situation.
- To produce datasets of sustainability data and durability data of identified Green Asphalts for selected case studies, based on existing sustainability datasets and novel durability testing.
- To provide NRAs with a methodology and recommendations for coping with uncertainty of datasets of LCM exercises, both inputs and results, as well as roadmaps towards data harmonization at EU level.

- To produce guidelines and recommendations towards using LCM results within a multicriteria sustainability assessment (complying with CWA 17089 and EN15804).

What do you expect from PavementLCM to help your institution to perform LCM?

SECTION 1. IDENTIFICATION

1. **Name (this will be kept confidential):**
2. **Age (this will be kept confidential):**
3. **Nationality (this will be kept confidential):**
4. **Role:**

Researcher	Project Manager	Engineer	Senior Engineer	Consultant
Designer	Other (please specify):			

5. **Name of institution:**
6. **Country:**
7. **When was the institution founded (approx.):**
8. **Status:**

Public	Private

9. **Aim of the institution (pick as many as necessary):**

Research	Consultancy	Design	Construction	Management
NRA	Other (please specify):			

10. **Number of employees:**

0R9	10R99	100R999	1000R4999	>=5000

11. Your work focuses on (pick as many as necessary):

Road materials	Road pavement	Pavement design	Maintenance	Management
Research	Consultancy		Other (please specify):	

SECTION 2. SUSTAINABILITY ASSESSMENT PRACTICES

1=minimum, 10=maximum	1	2	3	4	5	6	7	8	9	10
1. How aware of sustainability assessment are you?										
2. How much value do you give to sustainability assessment of pavements?										
3. How much value do you give to Environmental assessment of pavements?										
4. How much value do you give to Economic assessment of pavements?										
5. How much value do you give to Social assessment of pavements?										

6. Are you aware of any standard or green procurement practice in your institution's country on sustainability assessment?

I am aware there is	I am aware there is not	I am not aware

6.1. If there is, please specify them:

7. Does your institution perform/procure/pay for any sustainability assessment?

Yes	No	Don't know

7.1. If yes, (if not go to 7.2.)

7.1.1. Is there a specific department or team dedicated to that?

Yes	No	Use an external consultant	Don't know

7.1.2. At which stage of a project is the sustainability assessment done? (pick as many as necessary)

Planning	Procurement	Design	Realisation	Closure

7.1.3. Which part of the life cycle are you including in your sustainability assessment? (pick as many as necessary)

\

Pre-construction stage (A0)	Product stage (A1-A3)	Construction stage (A4-A5)	Use stage (B1-B8)	End of life (C1-C4)
	- Raw materials supply - Transport - Manufacturing	- Transport - Installation	- Use - Maintenance - Repair - Replacement - Operational energy use - Other operational processes - Users utilisation	- Deconstruction - Transport - Waste processing for reuse, recovery and recycling - Disposal

*Nomenclature of the stages refers to 15804 Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products

7.1.4. What is the purpose of the sustainability assessment? (pick as many as necessary)

Decision-making	Performance measurement	External requirement From who:	Green Procurement	Other (please specify):

7.1.5. At which level do you perform the sustainability assessment? (pick as many as necessary)

Project level	Network level	Product level

7.1.6. Do you follow any guideline/standard for sustainability assessment?

EN 15804:2012 Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products	EN 15643-5:2017 Sustainability of construction works – Sustainability assessment of buildings and civil engineering works
Guidance for preparing Product Category Rules and Environmental Product Declaration for asphalt mixtures (EAPA)	Product Category Rules for asphalt mixtures (NAPA)
Product Category Rules – part B for Asphalt (The Norwegian EPD Foundation)	Environmental Product Declaration N-340 Road (Acciona)
Product Category Rules Highways, Streets and Roads (EPD)	Others (please specify):

\

CWA 17089 Indicators for the sustainability assessment of roads	

7.1.7. What pillars of sustainability assessment does your institution address? (pick as many as necessary)

Environmental	Economic	Social

7.1.8. How aware are you of these indicators? (To see the definition of the indicators go to Annex I.a at the end of this document):

Pillar	**Indicator**	Not aware	Aware but not using	Aware and using	It is critical
Environmental	Primary materials consumption				
	Secondary materials used				
	Materials or components to be reused or recycled and exported energy				
	Energy use				
	Waste				
	Global warming potential				
	Formation potential of tropospheric ozone				
	Depletion potential of the stratospheric ozone layer				
	Acidification potential of soil and water				
	Eutrophication potential				

	Abiotic depletion potential for non‐fossil resources				
	Abiotic depletion potential for fossil resources				
	Human toxicity potential				
	Ecotoxicity potential				
Economic	Whole life cost				
Social	Comfort index				
	Safety audits and safety inspections				
	Adaptation to climate change				
	Tyre-pavement noise				
	Responsible Sourcing				
	Traffic congestion due to maintenance activities				

* These indicators refer to CWA 17089 Indicators for the sustainability assessment of roads

	Indicator	Aware but not using	Aware and using	It is critical
Any other indicators				

7.1.9. Which tools are you aware of and how well do you know them?:

Pillar	**Tool**	Not aware	Aware but not using	Aware and using
Environmental	SimaPro			
	GaBi			
	OpenLCA			
	Aspect			
	Ecorce			
	DuboCalc			
	Palate			
	VTTI/UC Pavement LCA Tool			
	CHANGER			
	Groen Beton Tool			
	SEVE			
	Other, please specify:			
Economic	RealCost			
	ACPA LCCA			
	LCCOST			
	HDM			
	LCCRCO2 tool			
	Other, please specify:			
Social	SimaPro			
	GaBi			
	OpenLCA			
	AlertINFRA software			
	Other, please specify:			

7.2. If not (from question 7),

7.2.1. What sort of incentive do you think is needed to start performing sustainability assessment?

Monetary	Mandatory	More training	Other, please

\

			specify:

8. Are you aware of the standard EN 15643Z5:2017 Sustainability of construction works – Sustainability assessment of buildings and civil engineering works, and the underlying standard EN 15804 Environmental Product Declarations of building products?

Yes	No	Don't know

9. Would you be interested in sustainability assessment training?

Yes	No

9.1. If so, what would you like to be trained in?

How to set up LCA	How to do green procurement	How to combine environmental and cost aspects
Other, please specify:		

9.2. What type of training would you appreciate the most?

Guidelines	OnRline training	HandsRon training
Other, please specify:		

SECTION 3. GREEN ASPHALT

10. Do you have objectives regarding green asphalt? If so, please specify?

11. What are you doing to make your asphalt greener?/What initiatives are you taking for developing green asphalt?

12. What key words do you associate with green asphalt? (tick as many as needed)

Low rolling resistance	Reduced noise	Porous asphalt	Warm Mix Asphalt
Cold Mix Asphalt	Improved durability	Recycling	Secondary materials
By‑products	Bio‑materials	Other, please specify:	

13. What practice do you use to make greener asphalt? (tick as many as needed)

Low rolling resistance	Reduced noise	Porous asphalt	Warm Mix Asphalt
Cold Mix Asphalt	Improved durability	Recycling	Incorporation of secondary materials
Incorporation of By‑products	Incorporation of Bio‑materials	Other, please specify:	

14. Please list the criteria from question 12 from most to least important for you:

1.
2.
3.
4.
5.

15. What practice would you like to use to make greener asphalt within the coming 5 years? (tick as many as needed)

Low rolling resistance	Reduced noise	Porous asphalt	Warm Mix Asphalt
Cold Mix Asphalt	Improved durability	Recycling	Incorporation of

			secondary materials
Incorporation of By-products	Incorporation of Bio‑materials	Other, please specify:	

16. What evidences would you need to start/increase the implementation of green asphalt?

Economic benefits	Environmental benefits	Mechanical performance	Durability	Social benefits
Other, please specify:				

SECTION 4. SUSTAINABILITY DATA

17. Are you aware of datasets with sustainability data (i.e. environmental, cost and/or social impact information) of road products?

Yes, namely: (for example, ecoinvent, ILCD database, nationalEPD databases like the Dutch NMD, etc.)	No

18. If yes, are you able to share this data?

Yes, the following data could be shared: … …	No

SECTION 5. UNCERTAINTY and DECISION‑MAKING

19. How confident do you feel on the results you obtain/use regarding environmental impact?

Very Confident	Reasonably confident	Depends on the asset/process	Not very confident
Useless			

20. Do you have confidence in the data (i.e., cost, durability, environmental impact) you use for making decisions regarding new types of asphalt?

Very Confident	Reasonably confident	Depends on the asset/process	Not very confident
Useless			

21. How do you take uncertainty/accuracy into account in your decisionZmaking?

I do not consider variability	I consider pessimistic values	I consider optimistic values

22. Do you use multiZcriteria decision methods?

Yes	No

22.1. If yes,

What method?

For what purpose?

SECTION 6. CIRCULAR ECONOMY

23. Are you familiar with the concept of Circular Economy and its principles?

Yes	No

23.1 If yes, which principles of Circular Economy are you familiar with? (tick as many as needed) (To see the definition of these principles go to Annex I.b at the end of this document)

- Design out/minimise waste
- Use waste as resource (recycle, reuse)
- Prioritize regenerative resources

- Preserve and extend what is already made
- Other, please specify:

23.1.1. Which of those principles have already been introduced within established pavement life cycle management practices?

- Design out/minimise waste
- Use waste as resource (recycle, reuse)
- Prioritize regenerative resources
- Preserve and extend what is already made
- Other, please specify:

23.1.2. Which practices are you using to implement those principles for Circular Economy?

23.1.3. If these principles are currently not implemented into practices, which reasons/challenges are impeding it? Is there a future strategy to implement them?

24. Are there any current metrics/indicators to assess the level of circularity of these practices and/or the pavement management process?

Yes	No

24.1. If yes, which are these metrics/indicators? (To see the definition of these metrics go to Annex I.b at the end of this document)

- Product Material Circularity Index (MCI_P) *[Ellen MacArthur foundation (EMF)]*
- Company Material Circularity Index (MCI_C) *[Ellen MacArthur foundation (EMF)]*
- End of Life recycling input rate *[Available in the EU's Raw Material Scoreboard and in EC Monitoring framework for the CE (under development)]*
- Resource Efficiency *[EU Resource Efficiency scoreboard (EURES)]*
- Other, please specify:

24.2. If no, which reasons/challenges are impeding their development? Is there a future strategy to define them?

25. Has a "Roadmap" towards Circular Economy been produced/published, to achieve more sustainable and circular management of asphalt pavements?

Yes	No

25.1. If yes, could you please provide us with a copy or link to find it

25.2. If not, which are the current challenges, posing as obstacles towards the production of such a roadmap? Is there a future strategy to produce one?

SECTION 7. OTHER

26. Are there any other aspects related to sustainability of road projects which have not been addressed in the previous questions?

27. Do you have any other remarks or comments?

ANNEX I.b: CWA 17089 Indicators definition

Pillar	Indicator	Definition
Environmental	Primary materials consumption	Quantification of each type of primary materials used for the road structure (including water)
	Secondary materials used	Quantification of the material recovered from previous use or from waste which substitutes primary materials.
	Materials or components to be reused or recycled and exported energy	Quantification of all materials used in the project that has potential to be recycled or reused instead of being disposed. Includes the exported energy, declared per energy carrier
	Energy use	Quantification of the energy required for the product stage, construction, maintenance or rehabilitation of the road for developing the processes involved (transport included).
	Waste	Quantification of the waste generated as substance or object which the holder discards or intends or is required to discard
	Global warming potential	Equivalent of greenhouse gas accumulation, describes the relevance of emission for the global warming effect and is the characterisation factor describing the radiative forcing impact of one mass‐based unit of a given greenhouse gas relative to that of carbon dioxide over a given period of time.
	Formation potential of tropospheric ozone	Photochemical Ozone Creation Potential is the maximum quantity of ozone formed for each volatile organic compound taken individually, spanning 5 days following its release, compared to the level of ozone produced for the same quantity of ethylene released.
	Depletion potential of the stratospheric ozone layer	Ozone Depletion Potential is the potential of a substance to destroy the ozone layer in the atmosphere. It is the relative amount of degradation to the ozone layer it can

		cause, with Trichlorofluroromethane being fixed at an ODP of 1.0.
	Acidification potential of soil and water	Acidifying pollutants cause a wide variety of impacts on soil, groundwater, surface waters, biological organism, ecosystems and materials. It is the ratio of the number of potential H^+ proton equivalents per unit mass of substance to the reference sulfur dioxide value.
	Eutrophication potential	Incudes all impacts due to excessive levels of macro -nutrients in the environment caused by emissions of nutrients to air, water and soil.
	Abiotic depletion potential for non - fossil resources	Related to the extraction of non -renewable resources such as minerals and metals due to inputs in the system.
	Abiotic depletion potential for fossil resources	Related to the extraction of energy resources considering their Lower Heating Value
	Human toxicity potential	This category concerns effects of the toxic substances on the human environment. Each toxicity potential is calculated using USES‐LCA, describing fate, exposure and effects of toxic substances.
	Ecotoxicity potential	Refers to the impact on ecosystems, as a result of emissions of toxic substances to air, water and soil. Ecotoxicity is correlated with the toxic effects of substances causing the direct or indirect disappearance of the animal or vegetal species of an ecosystem.
Economic	Whole life cost	All significant and relevant initial and future costs and benefits of the road asset, throughout the life cycle, while fulfilling the performance requirements.
Social	Comfort index	Subjective feeling of a vehicle driver or passenger while driving along a road, as this depends on multiple variables. COST354 model includes IRI, Rutting, Texture, Surface defects and Cracking
	Safety audits and safety inspections	Relates to the EU procedures for safety management of road infrastructures associated to road safety impact assessments (RSIA), road safety audits (RSA) and inspections (RSI). It is a qualitative indicator (are these procedures followed?)
	Adaptation to climate change	Percentage of the project budget dedicated to handle climate adaptation
	Tyre -pavement noise	Reduction of tyre -pavement noise level in dB compared to the reference pavement
	Responsible Sourcing	Voluntary commitment of an organization to take into account social and environmental considerations in the relation with suppliers to ensure long -term sustainability
	Traffic congestion due to maintenance activities	Reduction of the availability of the road due to maintenance activities

ANNEX I.c: Circular Economy and Metrics definition

PRINCIPLES

Design out/minimise waste = Waste minimization means preventing or decreasing the amount of waste being generated through waste prevention, recycling, or purchasing recycled and environmentally preferable products. Another practice is to optimize the design of the product by minimizing the required materials and to design the components of the product in such a way that they could be reutilized at their end of life without being discarded off as wastes.

Use waste as resource (recycle, reuse) = Utilise waste streams as a source of secondary resources and recover waste for reuse and recycling and is grounded on the idea that waste does not exist. It is necessary here to design out waste, meaning that both the biological and technical components (nutrients) of a product are designed intentionally in such a way that waste streams are minimalized. Using RA or other appropriate materials that are considered wastes, to substitute raw materials utilized for the production of asphalt mixtures.

Prioritize regenerative resources = Ensure renewable, reusable, non -toxic resources are utilised as materials and energy in an efficient way. Ultimately the system should aim to run on 'current sunshine' and generate energy through renewable sources. An example of this principle is The Biosphere Rules framework for closed -loop production which identifies Power Autonomy as one of nature's principles for sustainable manufacturing. It requires that energy efficiency be first maximized so that renewable energy becomes economical. It also requires that materials need to be non -toxic to be able to recirculate without causing harm to the living environment.

Preserve and extend what is already made = While resources are in -use, maintain, repair and upgrade them to maximise their lifetime and give them a second life through take back strategies when applicable. This could mean that a product is accompanied with a pre -thought maintenance programme to maximise its lifetime, including a buyback program and supporting logistics system. Second hand sales or refurbish programs also falls within this element.

METRICS

Product Material Circularity Index (MCI_P) [Ellen MacArthur foundation (EMF)]

- An indicator that assigns a score between 0 and 1 to a product assessing how restorative or linear the flow of the materials for the product and how long and intensely the product is used compared to similar industry -average products.

Company Material Circularity Index (MCI_C) [Ellen MacArthur foundation (EMF)]

- An indicator that assigns a score between 0 and 1 to a company assessing how restorative or linear the flow of the materials for the company's products and how long and intensely the company's products are used compared to similar industry -average products.

End of Life recycling input rate [Available in the EU's Raw Material Scoreboard and in EC Monitoring framework for the CE (under development)]

- The indicator measures, for a given raw material, how much of its input into the production system comes from recycling of "old scrap" i.e. scrap from end -of -life products. The EOL-RIR does not take into account scrap that originates from manufacturing processes ("new scrap").

Resource Efficiency [EU Resource Efficiency scoreboard (EURES)]

- The Resource efficiency scoreboard is a tool / user interface for presenting key indicators relating to natural resources. For this scoreboard, a limited set of already available indicators was selected, covering as many as possible of the themes and subthemes identified in the Roadmap to a resource efficient Europe. It is a three -tier system based on a lead indicator, a dashboard of indicators and a set of theme specific indicators:
    - Lead Indicator – one lead indicator has been selected to try and represent the change in use of natural resources. There is no indicator that can fully achieve this goal, but the lead indicator still heads up the scoreboard to provide a focus on resource productivity, defined as the ratio between gross domestic product (GDP) and domestic material consumption (DMC).
      (https://ec.europa.eu/eurostat/web/environmental-data-centre-on-natural-resources/resource-efficiency-indicators/resource-efficiency-scoreboard/lead -indicator)
    - Dashboard Indicators – these provide an additional 'dashboard' or selection of indicators to complement the lead indicator. They focus on four areas of resource management: materials, water, carbon and land.
      (https://ec.europa.eu/eurostat/web/environmental-data-centre-on-natural-resources/resource-efficiency-scoreboard/dashboard-indicators)
    - Thematic Indicators – as the scope of 'natural resources' is large theme specific indicators are required to show progress in a range of key areas. The thematic indicators are grouped into subsections, along the following lines:
        - Transforming the economy
        - Waste, green taxes (or environmental taxes), eco-innovation
        - Nature and ecosystems
        - Biodiversity, air, marine, land and soils
        - Key areas
        - Energy, food, buildings, transport

      (https://ec.europa.eu/eurostat/web/environmental-data-centre-on-natural-resources/resource-efficiency-indicators/resource-efficiency-scoreboard/thematic-indicators)

ANNEX II.a: Durability Assessment Questionnaire (WP4) – conventional wearing courses

Pavement LCM: WP4 Questionnaire Pavement Durability

* Required

Introduction

1. Which country (or administrative part of a country) is your pavement expertise in? *

2. Is there a procedure and database in your country where the distress and possible other reasons for pavement maintenance operations are detailed? *

◯ Yes

◯ No

7/3/2021

Pavement LCM: WP4 Questionnaire Pavement Durability

This questionnaire will evaluate your assessment of the durability of a new type of sustainable SMA versus a traditional solution. Your decisions can be informed by both your professional experience and the results of laboratory tests carried out on both mixes.

* Required

Introduction

1. Which country (or administrative part of a country) is your pavement expertise in? *

2. Is there a procedure and database in your country where the distress and possible other reasons for pavement maintenance operations are detailed? *

- ◯ Yes
- ◯ No

7/3/2021

Standard asphalt mixes

1. In the following we are looking at the performance of SMA16 and SMA11 (10% RA) on low, medium, and high-volume roads.

Low volume roads, medium volume roads and high-volume roads in this questionnaire, are defined as having AADT between 100 to 400, 401 to 4000 and above 4000, respectively.

3. Distresses triggering pavement resurfacing.

Based on your experience and the result of lab tests, classify each type of distress in terms of how likely it is that its presence triggered the decision to resurface for SMA11 (10% RA) for each level of traffic.

	Low Volume - likely	Low Volume - somewhat likely	Medium volume - likely	Medium volume - somewhat likely	High volume- likely	High volume - somewhat likely
Fretting (minor material loss)	◯	◯	◯	◯	◯	◯
Raveling (severe material loss)	◯	◯	◯	◯	◯	◯
Rutting	◯	◯	◯	◯	◯	◯
Road wear	◯	◯	◯	◯	◯	◯
Low friction	◯	◯	◯	◯	◯	◯
Cracking (not specified)	◯	◯	◯	◯	◯	◯
Transverse cracking	◯	◯	◯	◯	◯	◯
Longitudinal cracking	◯	◯	◯	◯	◯	◯
Edge cracking	◯	◯	◯	◯	◯	◯
Block cracking	◯	◯	◯	◯	◯	◯
Alligator cracking	◯	◯	◯	◯	◯	◯
Other	◯	◯	◯	◯	◯	◯

7/3/2021

Durability of novel mixes: SMA11 (10% RA)

In this section you will be asked to estimate the durability of SMA11 (10% RA) under low, medium and high traffic conditions relative to the standard SMA16.

4. What do you expect to be, on average, the durability of a SMA11 (10% RA) surfacing under low volume traffic compared to that of SMA16?

- 15% longer
- 5% longer
- the same
- 5% shorter
- 15% shorter
- Not Applicable

5. How confident are you about this estimate?

- Extremely confident
- Somewhat not confident
- Confident it will increase/decrease
- Not confident
- Not Applicable

7/3/2021

6. What do you expect to be, on average, the durability of a SMA11 (10% RA) surfacing under medium volume traffic compared to that of SMA16?

- ◯ 15% longer
- ◯ 5% longer
- ◯ the same
- ◯ 5% shorter
- ◯ 15% shorter
- ◯ Not Applicable

7. How confident are you about this estimate?

- ◯ Extremely confident
- ◯ Somewhat not confident
- ◯ Confident it will increase/decrease
- ◯ Not confident
- ◯ Not Applicable

8. What do you expect to be, on average, the durability of a SMA11 (10% RA) surfacing under high volume traffic compared to that of SMA16?

- ◯ 15% longer
- ◯ 5% longer
- ◯ the same
- ◯ 5% shorter
- ◯ 15% shorter
- ◯ Not Applicable

7/3/2021

Standard asphalt mixes

1. In the following we are looking at the performance of SMA16 and PA16 (porous asphalt) on low, medium, and high-volume roads. In case there is limited data on performance of mixes with nominal mean aggregate size (NMAS) of 16mm, give your estimates based on mixes with NMAS 11 or 8.

Low volume roads, medium volume roads and high-volume roads in this questionnaire, are defined as having AADT between 100 to 400, 401 to 4000 and above 4000, respectively.

3. If there is limited data on performance of mixes with NMAS 16 and you will be making estimates based on mixes with NMAS 11 or 8, indicate this below

- ◯ I have enough data to estimate performance of NMAS16
- ◯ I don't have enough data to estimate performance of NMAS16 and will be using NMAS11 or NMAS8

4. How frequently is SMA16 used as a surfacing on

	Very frequently	Frequently	Occasionally	Rarely	Never
Low volume roads	◯	◯	◯	◯	◯
Medium volume roads	◯	◯	◯	◯	◯
High volume roads	◯	◯	◯	◯	◯

5. How frequently is PA16 used as a surfacing on

	Very frequently	Frequently	Occasionally	Rarely	Never
Low volume roads	◯	◯	◯	◯	◯
Medium volume roads	◯	◯	◯	◯	◯
High volume roads	◯	◯	◯	◯	◯

7/3/2021

9. How confident are you about this estimate?

- ◯ Extremely confident
- ◯ Somewhat not confident
- ◯ Confident it will increase/decrease
- ◯ Not confident
- ◯ Not Applicable

7/3/2021

6. Distresses triggering pavement resurfacing.

Classify each type of distress in terms of how likely it is that its presence triggered the decision to resurface for SMA16.

	Low Volume - likely	Low Volume - somewhat likely	Medium volume - likely	Medium volume - somewhat likely	High volume- likely	High volume - somewhat likely
Fretting (minor material loss)	○	○	○	○	○	○
Raveling (severe material loss)	○	○	○	○	○	○
Rutting	○	○	○	○	○	○
Road wear	○	○	○	○	○	○
Low friction	○	○	○	○	○	○
Cracking (not specified)	○	○	○	○	○	○
Transverse cracking	○	○	○	○	○	○
Longitudinal cracking	○	○	○	○	○	○
Edge cracking	○	○	○	○	○	○
Block cracking	○	○	○	○	○	○
Alligator cracking	○	○	○	○	○	○
Other	○	○	○	○	○	○

7/3/2021

Factors affecting durability for SMA11 (10% RA). Load and environmental factors.

In this section you will be asked to estimate the change in durability of SMA11 (10% RA) surfacing when conditions change.

10. The first road has 8000 AADF (Annual average daily flow, 1-way traffic). The second road has 6000 AADF. Estimate the increase of service life for the second road compared to the first road

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

11. The first road has 16000 AADF . The second road has 12000 AADF. Estimate the increase of service life for the second road compared to the first road

- ◯ 0-5 %
- ◯ 5 15 %
- ◯ 15-25 %
- ◯ 25-35 %

12. The first road has 400 AADF . The second road has 300 AADF. Estimate the increase of service life for the second road compared to the first road.

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

7/3/2021

7. Distresses triggering pavement resurfacing.

Classify each type of distress in terms of how likely it is that its presence triggered the decision to resurface for PA16.

	Low Volume - likely	Low Volume - somewhat likely	Medium volume - likely	Medium volume - somewhat likely	High volume- likely	High volume - somewhat likely
Fretting (minor material loss)	◯	◯	◯	◯	◯	◯
Raveling (severe material loss)	◯	◯	◯	◯	◯	◯
Rutting	◯	◯	◯	◯	◯	◯
Road wear	◯	◯	◯	◯	◯	◯
Low friction	◯	◯	◯	◯	◯	◯
Cracking (not specified)	◯	◯	◯	◯	◯	◯
Transverse cracking	◯	◯	◯	◯	◯	◯
Longitudinal cracking	◯	◯	◯	◯	◯	◯
Edge cracking	◯	◯	◯	◯	◯	◯
Block cracking	◯	◯	◯	◯	◯	◯
Alligator cracking	◯	◯	◯	◯	◯	◯
Other	◯	◯	◯	◯	◯	◯

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13. The first road has 8000 AADF but twice as many days with (wet) freeze-thaw cycles as the second road which also has 8000 AADF . Estimate the increase of service life for the second road compared to the first road.

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

14. The first road has 400 AADF but twice as many days with (wet) freeze-thaw cycles as the second road which also has 400 AADF . Estimate the increase of service life for the second road compared to the first road.

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

15. The first road has 8000 AADF but twice as many wet days as the second road which also has 8000 AADF . Estimate the increase of service life for the second road compared to the first road.

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

7/3/2021

Durability of standard mixes: SMA16

In this section you will be asked to estimate the durability of SMA16 under low, medium and high traffic conditions. We would like you to provide an average estimate, a worst case scenario and a best case scenario.

8. What do you expect to be, on average, the durability of a SMA16 surfacing under low volume traffic (in years)?

9. What do you expect to be, in a worst case scenario (bottom 10%), the durability of a SMA16 surfacing under low volume traffic (in years)?

10. What do you expect to be, in a best case scenario (top 10%), the durability of a SMA16 surfacing under low volume traffic (in years)?

11. What do you expect to be, on average, the durability of a SMA16 surfacing under medium volume traffic (in years)?

12. What do you expect to be, in a worst case scenario (bottom 10%), the durability of a SMA16 surfacing under medium volume traffic (in years)?

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16. The first road has 400 AADF but twice as many wet days as the second road which also has 400 AADF . Estimate the increase of service life for the second road compared to the first road.

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

7/3/2021

13. What do you expect to be, in a best case scenario (top 10%), the durability of a SMA16 surfacing under medium volume traffic (in years)?

14. What do you expect to be, on average, the durability of a SMA16 surfacing under high volume traffic (in years)?

15. What do you expect to be, in a worst case scenario (bottom 10%), the durability of a SMA16 surfacing under high volume traffic (in years)?

16. What do you expect to be, in a best case scenario (top 10%), the durability of a SMA16 surfacing under high volume traffic (in years)?

17. How confident are you in these estimates?

- Extremely confident
- Somewhat confident
- I am confident in the mean value
- Not confident

7/3/2021

Durability of standard mixes: PA16

In this section you will be asked to estimate the durability of PA16 under low, medium and high traffic conditions. We would like you to provide an average estimate, a worst case scenario and a best case scenario.

18. What do you expect to be, on average, the durability of a PA16 surfacing under low volume traffic (in years)?

19. What do you expect to be, in a worst case scenario (bottom 10%), the durability of a PA16 surfacing under low volume traffic (in years)?

20. What do you expect to be, in a best case scenario (top 10%), the durability of a PA16 surfacing under low volume traffic (in years)?

21. What do you expect to be, on average, the durability of a PA16 surfacing under medium volume traffic (in years)?

22. What do you expect to be, in a worst case scenario (bottom 10%), the durability of a PA16 surfacing under medium volume traffic (in years)?

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23. What do you expect to be, in a best case scenario (top 10%), the durability of a PA16 surfacing under medium volume traffic (in years)?

24. What do you expect to be, on average, the durability of a PA16 surfacing under high volume traffic (in years)?

25. What do you expect to be, in a worst case scenario (bottom 10%), the durability of a PA16 surfacing under high volume traffic (in years)?

26. What do you expect to be, in a best case scenario (top 10%), the durability of a PA16 surfacing under high volume traffic (in years)?

27. How confident are you in these estimates?

- ◯ Extremely confident
- ◯ Somewhat confident
- ◯ I am confident in the mean value
- ◯ Not confident

7/3/2021

Factors affecting durability for SMA16. Load and environmental factors.

In this section you will be asked to estimate the change in durability of SMA16 surfacing when conditions change.

28. The first road has 8000 AADF (Annual average daily flow, 1-way traffic). The second road has 6000 AADF. Estimate the increase of service life for the second road compared to the first road

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

29. The first road has 16000 AADF . The second road has 12000 AADF. Estimate the increase of service life for the second road compared to the first road

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

30. The first road has 400 AADF . The second road has 300 AADF. Estimate the increase of service life for the second road compared to the first road.

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

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31. The first road has 8000 AADF but twice as many days with (wet) freeze-thaw cycles as the second road which also has 8000 AADF . Estimate the increase of service life for the second road compared to the first road.

- 0-5 %
- 5-15 %
- 15-25 %
- 25-35 %

32. The first road has 400 AADF but twice as many days with (wet) freeze-thaw cycles as the second road which also has 400 AADF . Estimate the increase of service life for the second road compared to the first road.

- 0-5 %
- 5-15 %
- 15-25 %
- 25-35 %

33. The first road has 8000 AADF but twice as many wet days as the second road which also has 8000 AADF . Estimate the increase of service life for the second road compared to the first road.

- 0-5 %
- 5-15 %
- 15-25 %
- 25-35 %

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34. The first road has 400 AADF but twice as many wet days as the second road which also has 400 AADF . Estimate the increase of service life for the second road compared to the first road.

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

7/3/2021

ANNEX II.b: Durability Assessment Questionnaire (WP4) – more sustainable wearing courses

Pavement LCM: WP4 Questionnaire Pavement Durability

This questionnaire will evaluate your assessment of the durability of a new type of sustainable SMA versus a traditional solution. Your decisions can be informed by both your professional experience and the results of laboratory tests carried out on both mixes.

* Required

Introduction

1. Which country (or administrative part of a country) is your pavement expertise in? *

2. Is there a procedure and database in your country where the distress and possible other reasons for pavement maintenance operations are detailed? *

   ◯ Yes

   ◯ No

7/3/2021

Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

Standard asphalt mixes

1. In the following we are looking at the performance of SMA16 and SMA11 (10% RA) on low, medium, and high-volume roads.

Low volume roads, medium volume roads and high-volume roads in this questionnaire, are defined as having AADT between 100 to 400, 401 to 4000 and above 4000, respectively.

3. Distresses triggering pavement resurfacing.

Based on your experience and the result of lab tests, classify each type of distress in terms of how likely it is that its presence triggered the decision to resurface for SMA11 (10% RA) for each level of traffic.

	Low Volume - likely	Low Volume - somewhat likely	Medium volume - likely	Medium volume - somewhat likely	High volume- likely	High volume - somewhat likely
Fretting (minor material loss)	◯	◯	◯	◯	◯	◯
Raveling (severe material loss)	◯	◯	◯	◯	◯	◯
Rutting	◯	◯	◯	◯	◯	◯
Road wear	◯	◯	◯	◯	◯	◯
Low friction	◯	◯	◯	◯	◯	◯
Cracking (not specified)	◯	◯	◯	◯	◯	◯
Transverse cracking	◯	◯	◯	◯	◯	◯
Longitudinal cracking	◯	◯	◯	◯	◯	◯
Edge cracking	◯	◯	◯	◯	◯	◯
Block cracking	◯	◯	◯	◯	◯	◯
Alligator cracking	◯	◯	◯	◯	◯	◯
Other	◯	◯	◯	◯	◯	◯

7/3/2021

Durability of novel mixes: SMA11 (10% RA)

In this section you will be asked to estimate the durability of SMA11 (10% RA) under low, medium and high traffic conditions relative to the standard SMA16.

4. What do you expect to be, on average, the durability of a SMA11 (10% RA) surfacing under low volume traffic compared to that of SMA16?

- ◯ 15% longer
- ◯ 5% longer
- ◯ the same
- ◯ 5% shorter
- ◯ 15% shorter
- ◯ Not Applicable

5. How confident are you about this estimate?

- ◯ Extremely confident
- ◯ Somewhat not confident
- ◯ Confident it will increase/decrease
- ◯ Not confident
- ◯ Not Applicable

7/3/2021

6. What do you expect to be, on average, the durability of a SMA11 (10% RA) surfacing under medium volume traffic compared to that of SMA16?

- ◯ 15% longer
- ◯ 5% longer
- ◯ the same
- ◯ 5% shorter
- ◯ 15% shorter
- ◯ Not Applicable

7. How confident are you about this estimate?

- ◯ Extremely confident
- ◯ Somewhat not confident
- ◯ Confident it will increase/decrease
- ◯ Not confident
- ◯ Not Applicable

8. What do you expect to be, on average, the durability of a SMA11 (10% RA) surfacing under high volume traffic compared to that of SMA16?

- ◯ 15% longer
- ◯ 5% longer
- ◯ the same
- ◯ 5% shorter
- ◯ 15% shorter
- ◯ Not Applicable

7/3/2021

9. How confident are you about this estimate?

- ◯ Extremely confident
- ◯ Somewhat not confident
- ◯ Confident it will increase/decrease
- ◯ Not confident
- ◯ Not Applicable

7/3/2021

Factors affecting durability for SMA11 (10% RA). Load and environmental factors.

In this section you will be asked to estimate the change in durability of SMA11 (10% RA) surfacing when conditions change.

10. The first road has 8000 AADF (Annual average daily flow, 1-way traffic). The second road has 6000 AADF. Estimate the increase of service life for the second road compared to the first road

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

11. The first road has 16000 AADF . The second road has 12000 AADF. Estimate the increase of service life for the second road compared to the first road

- ◯ 0-5 %
- ◯ 5 15 %
- ◯ 15-25 %
- ◯ 25-35 %

12. The first road has 400 AADF . The second road has 300 AADF. Estimate the increase of service life for the second road compared to the first road.

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

7/3/2021

13. The first road has 8000 AADF but twice as many days with (wet) freeze-thaw cycles as the second road which also has 8000 AADF . Estimate the increase of service life for the second road compared to the first road.

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

14. The first road has 400 AADF but twice as many days with (wet) freeze-thaw cycles as the second road which also has 400 AADF . Estimate the increase of service life for the second road compared to the first road.

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

15. The first road has 8000 AADF but twice as many wet days as the second road which also has 8000 AADF . Estimate the increase of service life for the second road compared to the first road.

- ◯ 0-5 %
- ◯ 5-15 %
- ◯ 15-25 %
- ◯ 25-35 %

7/3/2021

16. The first road has 400 AADF but twice as many wet days as the second road which also has 400 AADF . Estimate the increase of service life for the second road compared to the first road.

- 0-5 %
- 5-15 %
- 15-25 %
- 25-35 %

7/3/2021