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Sustainability Assessment for road pavements: PavementLCM framework

Deliverable D2.1b

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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 to significantly update the Framework and the entire deliverable.

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.

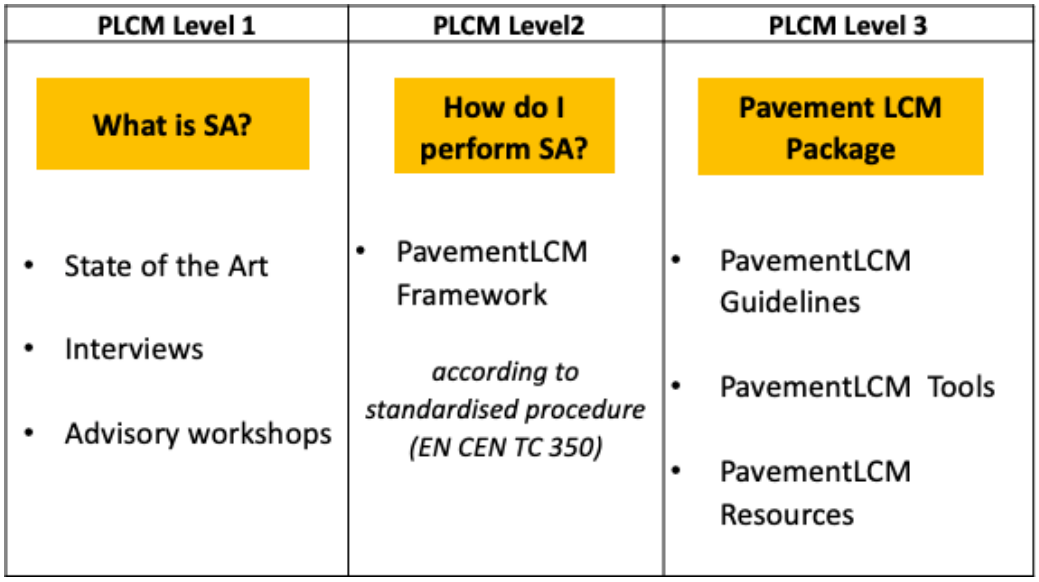


Figure 1- PavementLCM project structure and deliverables

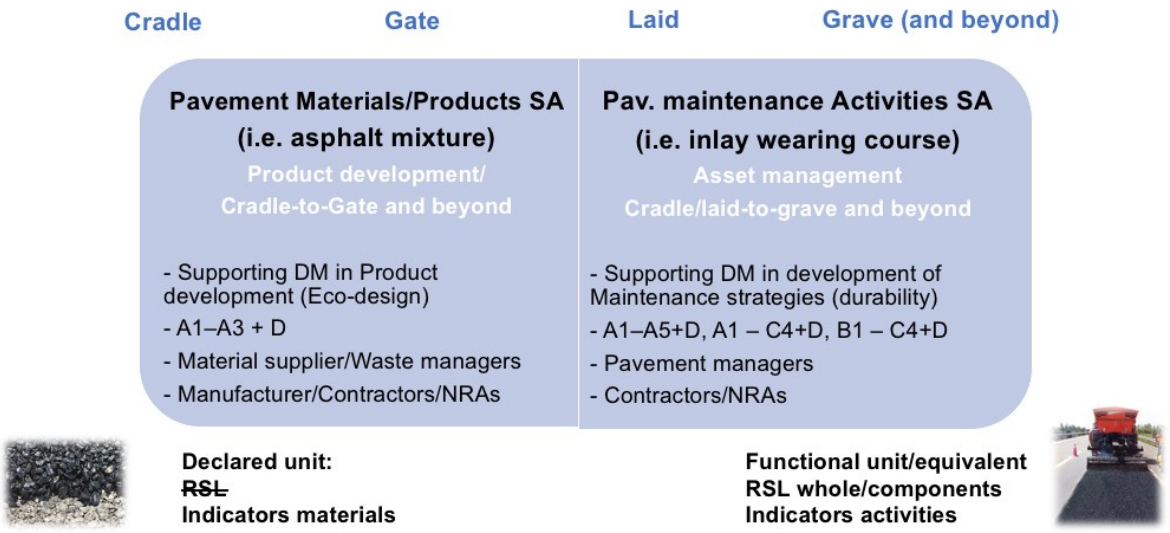
Goal and Scope

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 (D2.1a)
- 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 (D2.1a)
- To create and implement a platform for knowledge transfer through a series of tailored advisory workshops and 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 (D2.1a)
- To propose the PavementLCM Framework for SA road pavements which considers the findings of the intense literature review and as well as complying with the most recent EN standards on "Sustainability of Construction Works".

Results: PavementLCM SA Framework

As defined earlier, the PavementLCM Sustainability Assessment Framework provides recommendations and guide NRAs to setup the SA of two systems: *pavement materials* and *pavement activities*.



1.2 - PavementLCM SA Framework

This framework for SA complies with the most recent standards on “Sustainability of Construction Works“ and does not replace any standard and/or Product Category rules (PCR) to carry out SA, LCA and LCCA, whose requirements should always be met. On the contrary, PavementLCM SA Framework aims at complementing them and propose a stretegic structure to favour the implementation of those practice within National Road Authorities as well as other stakeholders.

The Framework can be used by NRAs with the support of suppliers and provide the details to to perform sustainability assessment exercises related to the evaluation of:

1. Development of pavement materials/products (material/product manufacturers)
    a. Innovation in pavement materials/products (manufacturers/NRAs)
2. Installation of pavement components (contractors)
    a. Innovation in pavement installation (contractors/NRAs)
3. Pavement Life cycle Management activities (NRAs)
    a. Construction of new roads and/or large maintenance projects
    b. Evaluation and comparison of maintenance strategies

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

Background and State of the Art in Sustainability Assessment for NRAs

- 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 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, 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.

Knowledge transfer activities

- 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).
    - 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.

PavementLCM Sustainaibility Assessment Framework

- PavementLCM SA Framework has been developed to provide recommendations and guide NRAs, as well as asphalt manufacturers and asphalt contractors, to perform the SA of two systems: pavement materials and pavement activities. In this regard, it aims at contrubiting filling the current gap in EU standards defining calculation methods for pavement materials and activities.
- In accordance to the standard EN 15643-5, PavementLCM SA Framework covers the assessment of the three pillars of sustainability (environmental, economic and social) as well as functional and technical requirements. For this, a set of indicators is proposed for the SA of pavement materials and pavement activities
- The Framework can be used by NRAs with the support of suppliers and provide the opportunity to perform sustainability assessment exercises related to the evaluation of:
    - Innovation in pavement materials and technologies (with support frommaterial/product manufacturers)
    - Innovation in the installation of pavement components (with support fromcontractors)
- Construction of new roads and/or evaluation and comparison of maintenance strategies

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1. PavementLCM Sustainability Assessment Framework

In light of the background established in previous sections, the recommendations for any SA exercises in the field of construction works, should meet the requirements of the standard EN 15643-3. Hence, as general features in this framework:

- Environmental, social and economic performance are assessed.
- Technical and functional requirements are taken into account.
- The assessment uses quantifiable indicators measured without value judgements. The indicators in EN15804, EDGAR and CWA 17089 for the SA of pavement materials and activities are used as the basis for PavementLCM Framework.
- The assessment uses a quantitative evaluation of indicators by using, mainly, life cycle techniques. Based on the indicators in the CWA 17089, the environmental and economic indicators will be measured using a life cycle approach through LCA and LCCA respectively, while the social indicators use a different approach.

This framework for SA does not replace any standard and/or Product Category rules (PCR) to carry out SA, LCA and LCCA, whose requirements should always be met. On the contrary, PavementLCM SA Framework aims at complementing them and propose a strategic structure to favour the implementation of those practcie within National Road Authorities as well as other stakeholders.

The definition of these elements is based on the standards, guidelines and projects previously reviewed, as well as in the results of the interviews and feedback from advisory workshops carried out within WP2 whose results are reported in the previous sections.

On this regard, PavementLCM SA Framework is focused on defining:

- Road Pavement Model and SA Scope
- Objects of assessment and Functional Unit to include in the assessment
- Sustainability Assessment indicators

1.1 Road Pavement model and SA scope

By definition, a pavement system is considered as the structure constructed (for motorized and non-motorized transport) above the native undisturbed subgrade soil, typically constructed in distinct layers and including compacted or stabilized subgrade, bound or unbound subbase(s)/base(s), and the wearing surface. Broadly, this encompasses pavement structures in a number of different facility types, such as highways, streets, roads, shoulders and parking areas (Harvey et al., 2016).

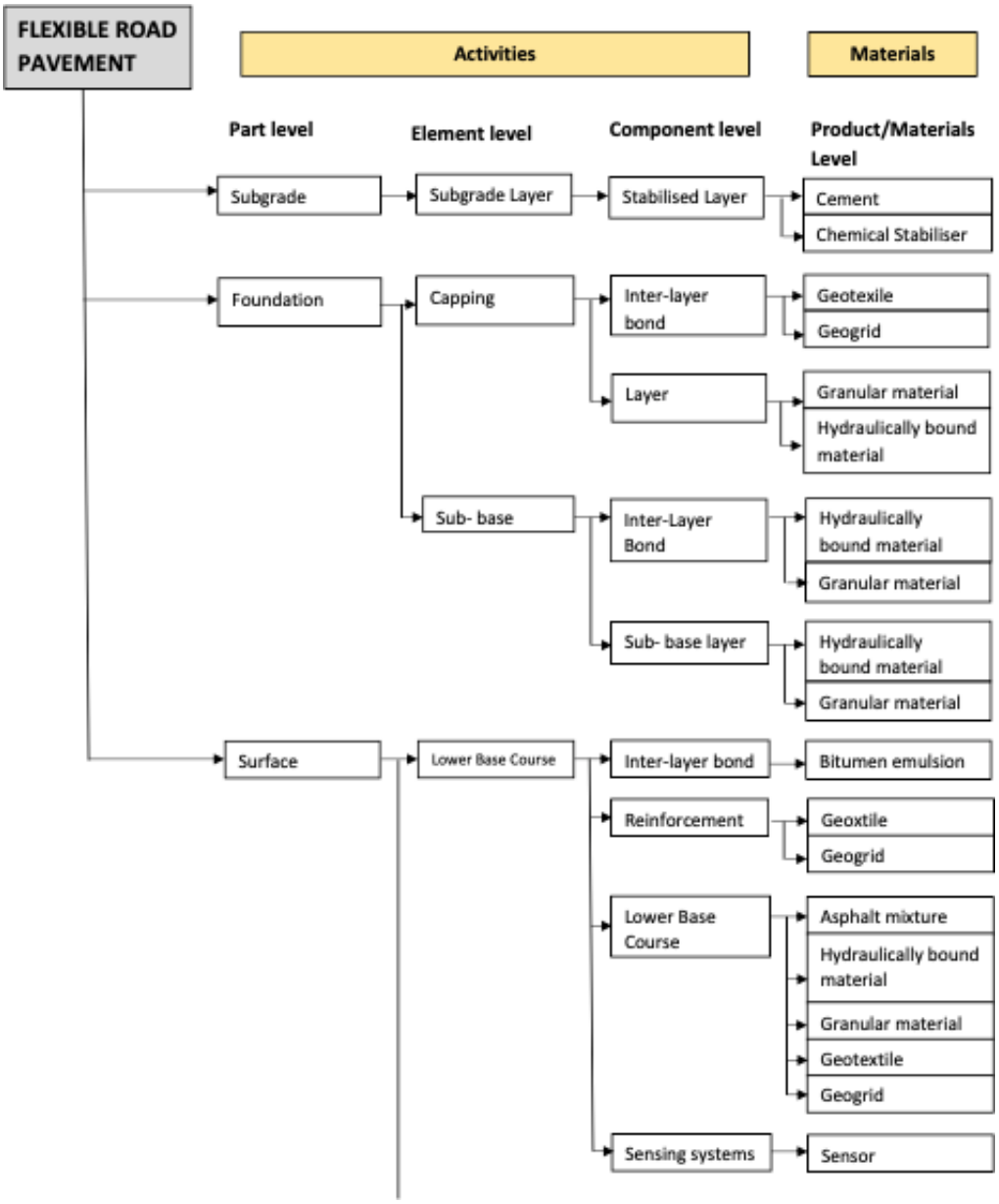
1.1.1 Road Pavement model (adapted from EN 15978:2011)

PavementLCM framework for Sustainability Assessment is focused on pavements for motorways which are typically managed by National Road Authorities (NRAs) in Europe. In order to tailor the SA exercise within this context, flexible road pavement was at first modelled according to the example proposed for “buildings“ within EN 15978:2011 and shown in Figure 1. The purpose of the flexible road pavement model is to explode the different levels of aggregation of a road pavement so enable the quantification of the mass and energy flows in each different SA exercise. This quantification should be organised in a structured way. To facilitate the quantification, the road pavement model is separated into:

- its constituent parts (all road pavement elements, road pavement components, road pavement products, road pavement materials);
- related processes such as transport, construction, maintenance, repair, replacement, end-of-life processes;
- operational use (energy, water), if any

The choice of the level of details depends on the goal and scope of the assessment and of the availability of data at the time the assessment is carried out (planning, design, procurement, construction, asset management, etc.).

Furthermore, the information - whether it is detailed or aggregated - can be either generic, averaged or specific.



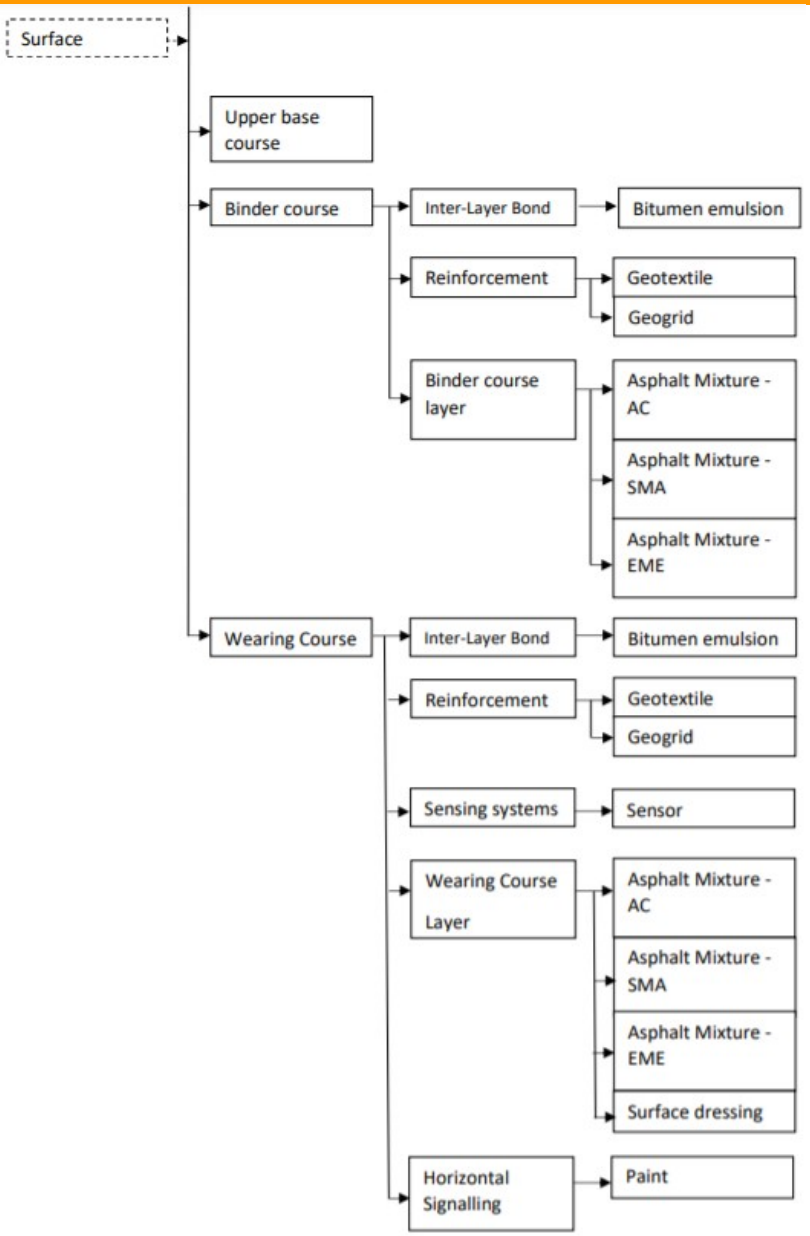


Figure 1 - Example of Flexible Road pavement model using differnet level of aggregation

1.1.2 Scope of SA

The aim of PavementLCM Sustainability Assessment Framework is to provide recommendations and guide NRAs to setup the SA of two systems within the road pavement model: ***pavement materials/products*** and ***pavement activities***.

Pavement materials/products, are those entities that must be used to build, repair, replace and maintain road pavement and its components. The SA exercise for these products should be responsibility of material producers (i.e. asphalt manufacturer) and focuses on the "product/materials level of the model"

1.1.2.1 Manufactures: must perform the SA of each material and/or products supplied to Contractors and/or NRAs for the construction of a new road pavement and/or themaintenance of existing road pavements

Pavement activities, are those activities that must be carried out to build, repair, replace and maintain the functional and technical requirements of road pavement and its components. The SA exercises for these activities should be responsibility of paving contractors and road owners and it focuses on either Part, Element or Component level of the model". In particular:

- Contractors: must perform the SA of the contracted activities, such as the construction of a new road pavement and/or the replacement of the road pavement component/element (i.e. wearing course)
- Road owners (i.e. NRAs): must support their decision-making process by performing the SA of selected maintenance strategies and/or projects to be procured or awarded related to the whole flexible road pavement related or at a Part level of the model. Furthermore, NRAs might want to evaluate innovative technologies related to material manufacturing and/or installations of road pavement components.

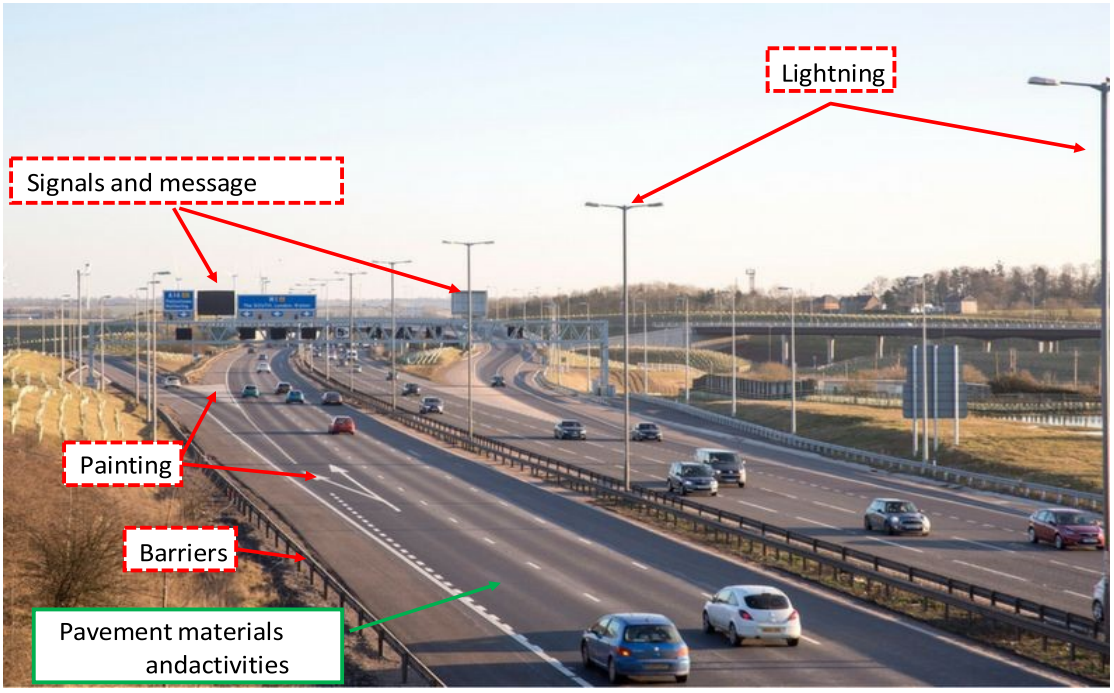


Figure 2 - Scope of PavementLCM SA Framework. The element in green continous line (pavementmaterials and activities) are inside PavementLCM SA Framework, while the elements in red dashedline are outside PavementLCM SA Framework

In order to facilitate the implementation within NRAs, the suggested SA exercises focus on the road pavement only and a number of items of a pavement are not taken into account (Figure 2), such as:

- Unbound subbase or base layers
- Painting
- Signals and message boards
- Lighting

- Barriers
- Drainage structures

1.2 Objects of Assessment and functional units

As defined earlier, the PavementLCM Sustainability Assessment Framework provides recommendations and guide NRAs to setup the SA of two systems: ***pavement materials*** and ***pavement activities***.

It is important to highlight the importance of this differentiation since (Figure 2):

1. The stakeholders involved in the SA of pavement materials and activities are different. While material designers and manufactures are interested in the SA of materials to declare the sustainability performance of their products, the SA of activities is interesting for Contractors to provide reliable information on performance of road components to road owners and NRAs to help their decision-making process
2. The life cycle of each system is different.
3. Different indicators are needed to perform the SA of each system.

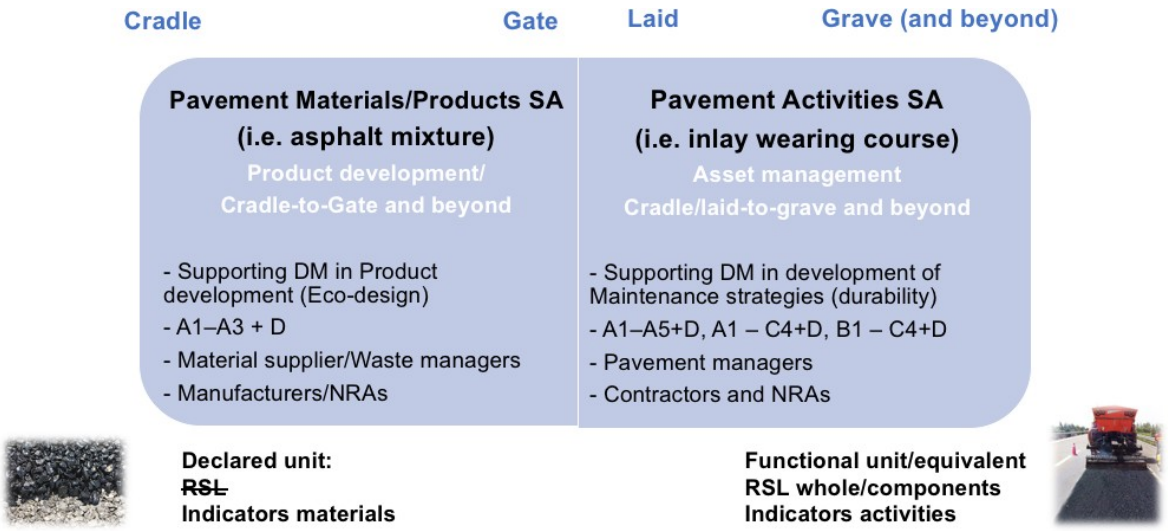


Figure 3 - Pavement materials/products vs Pavement activities

Considering these two systems, the object of assessment in a SA using a life cycle approach (EN 15643-5) is defined by:

a) A description of the object.
b) System boundaries: They determine the processes that are taken into account for the object of the assessment. They are composed of four different stages: product/construction, use, end of life and benefits beyond the system life cycle (waste, reuse, recycle, ..)
c) Analysis period (if applicable): It's the chosen reference study period
d) Instead the functional equivalent or functional/declared unit, as suggested in EN 15643-5, is defined as:

- The functional unit defines the way in which the identified functions or performance characteristics of the product are quantified. The primary purpose of the functional unit is to provide a reference by which material flows (input and output data) and any other information are normalized to produce data expressed on a common basis.

- The declared unit is used instead of the functional unit when the precise function of the product or scenarios is not stated or is unknown.

- The functional equivalent is a representation of the required technical characteristics and functionalities of the pavement. the major functional requirements shall be described together with intended use and the relevant specific technical requirements. This description allows the functional equivalency of different options and building types to be determined and forms the basis for transparent and unbiased comparison.

  Furthermore, according to FHWA Pavement Life Cycle Framework, it is useful to define the **physical boundary** too (if applicable). The physical boundaries of the functional unit define the portions of the pavement structure to be considered part of the pavement system at the location(s) included in the study. The dimensions permit the determination of volumes, masses, surface areas and other quantities needed to perform the SA. If the goal of the LCA does not include the complete pavement system, then the system boundaries can be adjusted.

- Module D is now mandatory in Environmental Product Declarations (EPD R 2019): since efficiently recycled building materials are crucial for circular Construction. Hence, important changes to European environmental certification now recognise the contribution an infinitely recyclable material like asphalt mixtures can make to the circular economy and will help specifiers to select the most sustainable materials. The new EPD standard (EN 15804:2019) provides core product category rules (PCR) for environmental declarations for any construction product and construction service. It describes which stages of the product's life cycle are considered in the EPD. It is now mandatory to cover the end of life (EoL) stage and to report the additional benefits and burdens resulting from EoL reuse or recycling. This standard uses a modular approach of product life cycle stages: production (Module A), in use (Module B), end-of-life stage (Module C) and end-of-life recycling (Module D). In the new standard the mandatory Module D provides an overview of the recycling performance and benefits for the full product life cycle. Hence, it is a key element in supporting an environmentally-sound circular economy in the building sector. With regards to asphalt the following are the recommendations that can be provided at NRAs for the suggested SA exercises:

  - Asphalt recycling saves significant resources but also huge amounts of energy. With the current focus on resource efficiency and circular economy, the proper consideration of recycling aspects within Environmental Product Declaration (EPD) is essential. It can be recommended that basically asphalt can be recycled in three applications (Dutch PCR 2020):

    - The foundation or basement layer. This application had almost no (environmental) advantage as it replaces just rocks or other stone-waste

material. The unique properties of bitumen do not have a very specific function in this application when compared to the other stone-waste materials, so bonus in D is negligible

- The lower asphalt layers. Technically this is the least challenging recycling route. Therefore, in the Netherlands around 50% of the lower asphalt layers on average consist of recycled material. As D can only be calculated for the recycled primary materials (EN 15804) – the bonus is not 100%

- The top layer. Technically recycling is challenging, as the stone size and the bitumen grade for this application are strictly determined. In Holland top-layers of asphalt used to be 100% primary material – so the bonus in D can be higher . However, in all layers it is important to take into account the loss of quality and technical performance (e.g. granulates rounding off, bitumen erosion, granulate sizes after milling).

- Furthermore, during the development of the t Dutch PCR 2020, it was recommended to consider the following issues/suggestions to be included in Module D:

  <u>For the material/product manufacturer</u>

  - Use 'Standardized' asphalt recipes to allow for good quality recycling
  - Consider limitations whenever additives/admixtures/pigments/alternative binders/etc. are added (to extend the lifetime for example). In fact this seems to make the asphalt difficult/impossible to recycle; it then can only be used as basement material and no or less benefits in Module D should be accounted for
  - Keep track of your material flows: create a system where you can track which materials are laid in which layers and on which location, and where you track the composition of your asphalt granulate when it is stockpiled.

  <u>For the road owner</u>

  - Allow for the most optimal recycling route of removed asphalt granulate; to facilitate that asphalt is recycled in a similar application (top layer in top layer)
  - Encourage the tracking of pavement materials: to achieve optimal recyclability, it is crucial to know what materials you have "in stock" (i.e. in the existing road layers) and log where they go after removal
  - Prevent that the cheapest option is to use the asphalt as foundation material (as the unique properties of bitumen are not needed for this application)? if needed, make sure that recycling of asphalt-in-asphalt is financially advantageous
  - Do not ask for asphalt types that are difficult to recycle (for example, red epoxy based asphalt that is in Holland often used for bike lanes cause complications for the recycling route, but that can be replaced by a red colored bitumen asphalt)

1.2.1 Pavement Materials/Products

Pavement materials and products, are those used to build, repair, replace and maintain road pavement and its components. The SA exercise for these entities should be the responsibility of material producers (i.e. asphalt manufacturer) although it could also be used by NRAs to evaluate the sustainability of innovative pavement materials and products (A1-A3 and D)

SA exercise for Manufacturers (pavement materials/products)

The following objects of assessment are included in this system:

1.2.1.1 Asphalt mixtures
1.2.1.2 Concrete
1.2.1.3 Prefabricated concrete slabs
1.2.1.4 Emulsion
1.2.1.5 Steel
1.2.1.6 Fabrics
1.2.1.7 Other items

a) The description of the material/products under evaluation should be included in the definition of the object of assessment
b) The system boundaries are as shown in Figure 4. These materials do not have a functionality assigned, and therefore their life cycle includes only the product stage, or in other words “cradle-to-gate” analysis.
c) Analysis period: Not applicable (since only the product stage is included)
d) Declared unit: 1 metric ton (tonne) of manufactured material (according to NAPA 2017, EATA 2017, The International EPD System 2017, The Norwegian EPD Foundation 2017)
e) Output: The asphalt manufacturer should proceed with this exercise to provide Contractors and NRAs with EPDs of the material supplied, together with information about economic and social indicators

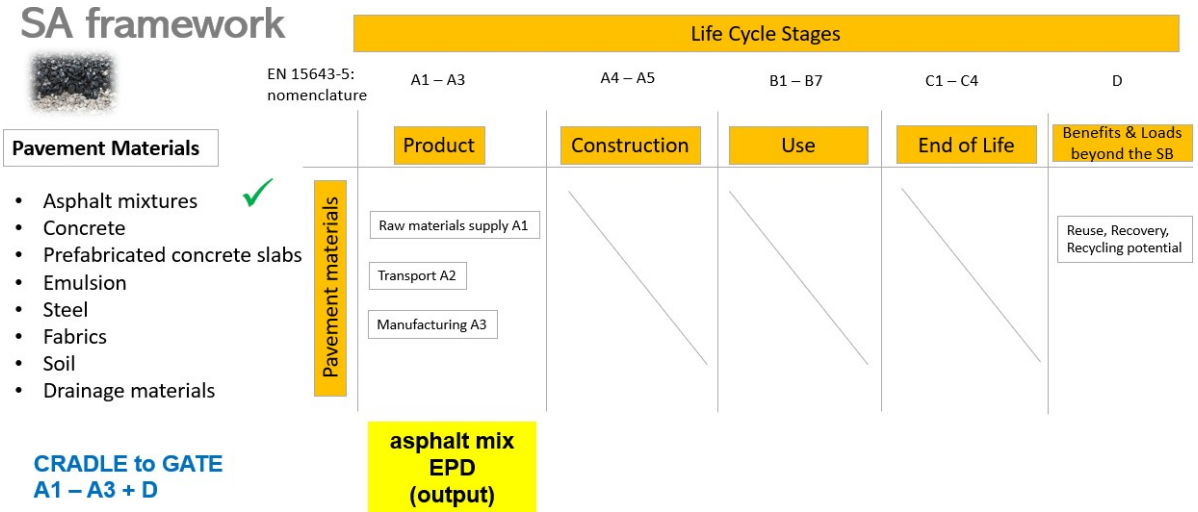


Figure 4 - System boundaries and life cycle stages for SA of pavement materials for Materials/Products manufacturers

The following lifecycle stages should be in the system:

- Raw matrial supply (A1), primary data and/or derived from raw material supplier EPDs
- Transport to manufacturing plant (A2), if present
- Product manufacturing (A3)

  Recycling strategies (D) for pavement materials to be included. *(see section 7.2 for advices on module D)*

SA exercise for NRAs and Manufacturers (Innovation in pavement materials/products)

Manufacturers could be asked by NRAs to provide support in performing a comparative analysis of the sustainability of innovative paving materials and technologies and/or solutions (A1 – A3 and D).

For this solution, the SA exercise is basically equivalent to the one already described for Pavement materials/products

1.2.2 Pavement Activities

Those activities that must be carried out to build, repair, replace and maintain the functional and technical requirements of road pavement and its components. The SA exercise for these products should be the responsibility of paving contractors and road owners. On this regards, the framework introduces SA exercises for pavement activities dedicated to Contractors and different ones dedicated to road owners.

SA exercise for Contractors (road pavement components)

Paving contractors must perform the SA of the contracted activities, such as the construction of a new road pavement and/or the maintainance, repair and replacement of existing road pavement components (i.e. wearing course).

Contractors should estimate the reference service life of each installed pavement component within the specific contracted activities. Furthermore, according to the details of the procured activities, the contractors should perform SA also to provide information on functional and technical requirements

The following objects of assessment are included in this system and are valid for both new construction and/or repair, mainteinance and replacement:

- Wearing course
- Binder course
- Base course
- Other if physical boundaries are changed (i.e. subgrade)

a) The description of the contracted activity under evaluation should be included in the definition of the object of assessment
b) Estimated/Reference Service Life: durability of each road pavement component and/or contracted activities
c) Analysis period: equal to the Reference Service Life of the object of the assessment (contracted activities/road pavement components)
d) Functional Equivalent/ Functional unit: the exact volume (or weight) of the pavement components to be contracted and/or built as required at project level. Furthermore, the functional equivalent should specify any other relevant technical and functional

requirements (e.g. regulatory framework and client's specific requirements) and reference/estimated service life (according to The International EPD System 2017, The Norwegian EPD Foundation 2017, The international EPD System 2018)

e) Inputs: The asphalt contractor should receive information from material manufacturer (i.e. materials EPDs)

f) Output: the SA exercise should be carried out to provide NRAs with vital information (i.e. EPDs for the contracted activity) to allow them to implement life cycle management practices

g) The system boundaries are as shown below. This is a cradle-to-grave assessment that includes a use phase limited to a period equal to the estimated/reference service life of the road component(s) included in the contracted activities, as well as suggested end-of-life strategies

The following lifecycle stages should be in the system:

- Product (A1 – A3), derived from material manufactures' EPDs
- Construction (A4-A5): Transport to site (A4) and Installation of pavement components (A5)
- Use (B1-B7): Use of the installed pavement components limited to the reference service life of the pavement components and including pavement-user/environment interaction (B1) maintenance of specific technical and functional requirements (B2) and Repair (B3).
  Refurbishment, Operational Energy Use and Operational Water use, (B5, B6, B7) of the road pavement components, might be considered for special pavement able to harvest energy and/or use operational water to guarantee a certain functional requirement
- End-of-life (C1-C4): the end of life of each pavement component is equal to the activities linked to its replacement. In other words the B4 is for this case the C1 – C4
- Benefits and Loads beyond the System Boundaries (D): Recycling strategies for pavement components to be included. *(see section 7.2 for advices on module D)*

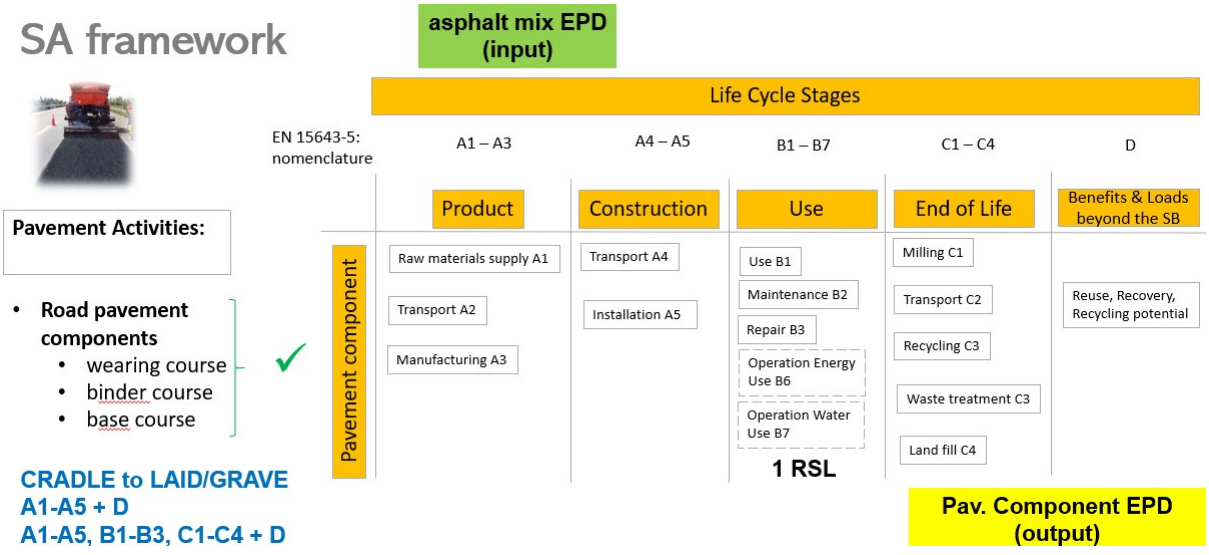


Figure 5 - System boundaries and life cycle stages for SA of pavement activities for Contractors

SA exercise for NRAs and Contractors (Innovation in installation of pavement components)

Contractors could have the need, or could be asked by NRAs, to performing a comparative analysis of the sustainability of innovative pavement installation techniques and technologies (A1 – A5 and D).

In this case NRAs can perform SA of pavement activities with the aim of selecting the most sustainable technology with a cradle-to-laid approach that doesn't need information on durability of infrastructure component, use stage and end-of-life, however it must include the information linked to the Module D

The following objects of assessment are included in this system and are valid for both new construction and/or repair, mainteinance and replacement:

- Wearing course
- Binder course
- Base course
- Other if physical boundaries are changed (i.e. subgrade)

a) The description of the contracted activity under evaluation should be included in the definition of the object of assessment
b) Functional unit: the exact volume (or weight) of the pavement components to be contracted and/or built as required at project-level.
c) Inputs: The asphalt contractor should receive information from material manufacturer (i.e. materials EPDs)
d) Output: the SA exercise should be carried out to provide NRAs with innovative sustainable solutions including both materials and paving operations
e) The system boundaries are as shown above. This is a cradle-to-laid assessment that doesn't includes a use phase and end-of-life strategies

The following lifecycle stages should be in the system:

- Product (A1 – A3), derived from material manufactures' EPDs
- Transport to site (A4)
- Installation of pavement components (A5)
- Recycling strategies (D) for pavement components to be included. *(see section 7.2 for advices on module D)*

SA for road owners/NRAs (flexible road pavement)

Road owners (i.e. NRAs): must support their decision-making process by performing the SA of selected maintainance strategies ad/or new construction of road pavement related projects to be procured or awarded. Hence, this system includes any activity related to the construction, use and end of life of pavements such as:

- Project-level "New construction"
- Project-level "Asset Management" divided in:
    - Regular operations (also periodic or routine maintenance): involves all activities that are of a repetitive nature and are executed in short-term intervals (< 1 year). The activities are often small in terms of resource demand and aim at retaining the condition of road assets rather than bringing them to an increased performance level. Typical regular maintenance activities include cutting grass, cleaning drainages, and small pavement repairs. Winter

maintenance and emergency repairs will be also classified as regular maintenance. Winter maintenance involves activities like snow ploughing and road salting and can form a larger part of a NRAs maintenance tasks depending on the climatological region. Emergency repairs can include pothole patching, lighting repair or flushing of blocked drainage systems (Hartmann, Aijo, & Roehrich, 2015). According to EN phases is the B2R Maintenance and B3R Repair.

- Rehabilitation operations (also variable maintenance): is carried out in longer, nonrepetitive intervals (>1year), involves a larger amount of work, and aims at enhancing the service life of a road asset or improving its performance. It is often based on a long-term planning taking the deterioration behaviour of the assets into account. Typical rehabilitation activities include pavement resurfacing and bridge joint replacing (Hartmann et al., 2015), in other words the substitution of pavement components at the end of their service life. According to EN phases this is the B4R Replacement, however in the PavementLCM Framework for pavement component this represents the C1 – C4 phases for each pavement component.

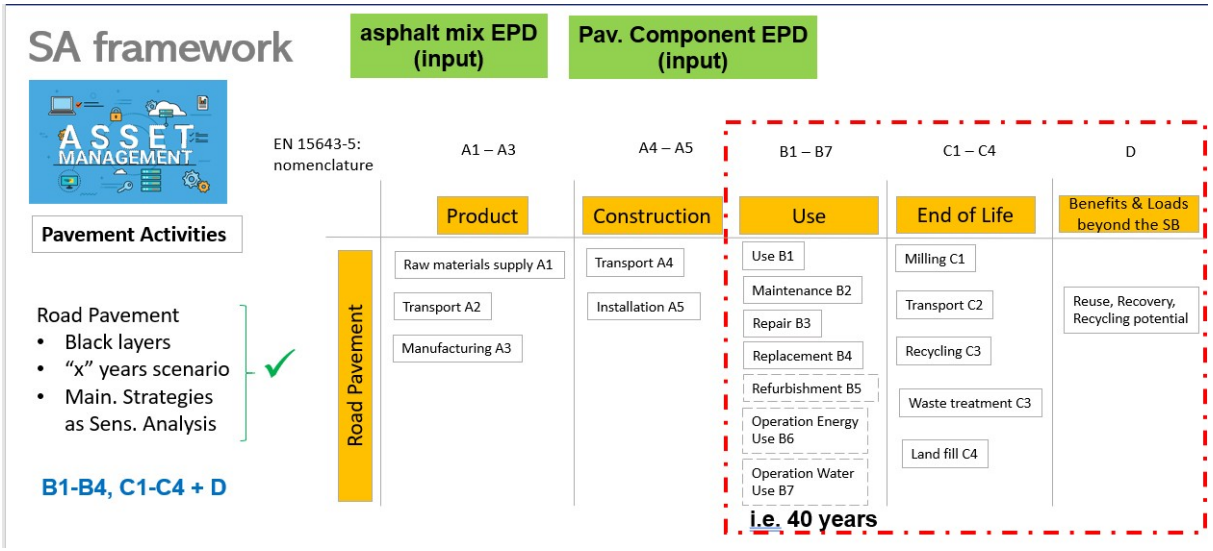


Figure 6 - System boundaries and life cycle stages of SA of pavement activities for NRAs (Life Cycle Management)

The following objects of the assessment are included in this system and are valid for both new construction and/or repair, mainteinance and replacement:

a) The description of the activity under evaluation should be included in the definition of the object of assessment
b) Analysis period: the timeframe necessary for the specific project to include at least one major rehabilitation activity/replacement of the road surface (according to the model). This is usually 40 years
c) Functional equivalent/ Functional unit: the exact volume (or weight) of the road pavement to be contracted and/or built as required at project-level or 1 m2 of surfaced pavement, as recommended by PCRs, together with a clear description of the physical boundaries in order to account for the total volume of paved materials.. Furthermore, the functional equivalent should specify any other relevant technical and functional requirements (e.g. regulatory framework and client's specific requirements) and reference/estimated service life (according to The International EPD System 2017, The Norwegian EPD Foundation 2017, The international EPD System 2018).

d) Inputs: Together with primary data, road owners should request EPDs, with also information about economic, social, technical and functional indicators, to both materials manufacturer and contractors
e) Outputs: Comparative analysis of project solutions to assess which is the most sustainable option
f) The system boundaries are as shown in Figure 6. The life cycle includes product, construction, use and end of life stages + benefits and load beyond the system boundary. If all the stages are considered, the analysis is "cradle-to-grave + D".
Physical boundaries: It is recommended to perform the analysis by considering the road pavement as the surface layer: wearing course, the binder course and the base course

The following lifecycle stages should be in the system:

- Product (A1 – A3), derived from material manufactures'EPDs + data on economic and social indicators
- Construction (A4-A5):
  - Transport to site (A4), derived from contractors'EPDs + data on economic,social and technical and functional indicators
  - Installation of pavement components (A5) derived from contractors'EPDs + data on economic, social and technical and functional indicators
- Use (B1-B7):
  - Use of the installed pavement components over the analysis period (B1)
  - Maintenance, Repair and Replacement (B2, B3, B4) of the road pavement components
  - Refurbishment, Operational Energy Use and Operational Water use, (B5, B6, B7) of the road pavement components, might be considered for special pavement able to harvest energy and/or use operational water to guarantee a certain functional requirement
- End-of-life (C1 – C4) activities:
  - if road pavement physical boundaries are limited to surface, then the activities linked to the replacement of whole road pavement surface represents the end-of-life
  - if physical boundaries are extended to subgrade end-of-life might not exist or it can be considered only if the pavement changes functionality (C1 – C4)
- Benefits and Loads beyond the System Boundaries (D): Recycling strategies (D) for road pavement to be included. *(see section 7.2 foradvices on module D)*

1.3 Indicators for pavement materials and pavement activities

As required in 15643-5, the sustainability of civil engineering works have to be measured through quantifiable indicators. In this regard, in Chapter 2 of this deliverable, the indicators available in EN15804 (only environmental), EDGAR, CWA17089 and SUP&R ITN were presented.

The sets of indicators in those efforts were considered as the base to establish the final sets of indicators, within PavementLCM this list was reviewed and number of indicators reduced according to priorities recognised by NRAs. This process was carried out by conducting interviews with NRAs (Chapter 3) and finalised in the 1st CEDR PavementLCM workshop for Sustainability Assessment, where the set of indicators was approved (Chapter 4 – D2.1a).

Due to the the availability of new studies (JRC Technical Report 2018) and standards (i.e. EN 15804:2011+A2:2019), the set of indicators was update as reported below.

The philosophy behind the selection of indicators has been as following:

- To reduce the number of indicators to help introducing SA in NRAs, based on the initial sets of indicators defined in EN15804 (only environmental), EDGAR, CWA17089 and SUP&R ITN which considered the most critical sustainability issues concerning pavement materials and activities.
- To use the most relevant indicators for NRAs to be able to assess their priorities for more sustainable pavement materials and activities.
- To consider indicators for the three pillars of sustainability and technical and functional requirements, as required in EN15643‑5.
- To select indicators that can be calculated using available tools.
- Furthermore, according to EN 15804 and JRC Technical Report published in 2018, there some core environmental indicators which have a main role in environmental assessment due to their potential burdens. Also EN 15804 does the same.
- The indicators, including sub-indicators, can be calculated separately and the decision making can be performed by considering the values of the indicators independently or by using Multi-Criteria Decision-Making techniques as detailed in D5.1

In this regard, the indicators selected are shown in table 9 including the object of assessment for which they can be calculated and their description. This list of indicators has been updates within the course of the project by considering

- Feedback from workshops
- Review of advisory board members
- New standards and new studies on sustainability assessment

Table 1.. Indicators for the Sustainability Assessment of pavement materials and activities

SA Indicator	Related to	Object of assessment	Description
Global Warming Potential (GWP total)	Environment	Pavement materials/ products 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) The GWP total is the sum of three different calculations: - Global Warming Potential·Fossil fuels (GWP- Fossil fuels) - Global Warming Potentia - Biogenic (GWP-biogenic) - Global Warming Potential- Land use and land use change (GWP-luluc)

Energy use	Environment	Pavement Materials// products and activities	Includes a quantification of the energy required during the life cycle of 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	Environment	Pavement materials// products 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
Acidification potential	Environment	Pavement materials// products and activities	Includes a quantification of all acidifying compounds that causes a reduction in system's acid neutralising capacity. Generally, it is caused by air emissions of NH_3, NO2 and SO_X.
Eutrophication potential	Environment	Pavement materials// products and activities	It measures the enrichement of the environment with nutrient salts. Three indicators have to be calculated: - Eutrophication potential, fraction of nutrients reaching freshwater end compartment (EP-freshwater) - Eutrophication potential, fraction of nutrients reaching marine end compartment (EP-marine) - Eutrophication potential, Accumulated Exceedance (EP-terrestrial)
Natural resources consumption *This is a macro indicator given by the following indicators* - *Water (user) deprivation potential, deprivation-weighted water consumption (WDP)* - *Potential soil quality index (SQP)* - *Abiotic depletion potential for non fossil resources (ADP-minerals&metals)* - *Abiotic depletion for fossil resources potential (ADP-fossil)*	Environment	Pavement materials/ products and activities	Includes a quantification of the consumption of natural resources linked to the activities. Each impact indicator can be expressed in the following way and is linked with a specific impact category: - WDP in m3 world eq. deprived for **Water use** - SQP is dimensionless for **Land use** - ADP - minerals&metals in ksSb eq. for **Depletion of abiotic Resources (minerals and metals)** - ADP-fossil – MJ, for **Depletion of abiotic Resources use (Fossil fuels)**

Air pollution *This is a macro indicator given by the following indicators:* *- Potential incidence of disease due to PM emissions (PM) (mandatory)* *-Formation potential of trophospheric ozone (POCP) (optional)*	Environment	Pavement materials/ products and activities	Assessing pollution potential on the basis of air pollution (non-CO_2 emissions), evaluating particulate matter and photochemical oxidation potentials. Each impact indicator can be expressed in the following way and is linked with a specific impact category: - PM is measured in kg $PM_{2.5}$ equivalent and used for **Particulate matter** - POCP is measured in kg Ethene equiv and used for **Photochemical ozone formation.**
Cost *This indicator differs for materials and activities:* -Cost -Net Present Value/ Whole life cycle cost	Economy	Pavement materials/ products Pavement activities	All costs related to the object of assessment during the product stage. - 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	Technical and functional requirements	Pavement activities	The type of pavement used has an impact on the tyre/road noise level on a given road. This indicator is expressed as reduction of tyre/pavement noise level in dB compared to the reference pavement
Durability	Technical and functional requirements	Pavement activities	Reference Service Life of pavement components. Estimated as suggested in WP4 of PavementLCM
Optional indicators	Technical and functional requirements	Pavement activities	This indicator is left customisable from each road authority on the basis of local priorities. (i.e. skid resistance, permeability, etc..)

According to the studies proposed by the JRC and the EN15804:2012+A2:2019, the selected methodology is the EF Life Cycle Impact Assessment method, which provide its own list of indicators and characterization factors (CF), except for Energy Use and Secondary Materials Consumption proposed in CWA17089.

2. Conclusions and Recommendations

This deliverable aims at providing the PavementLCM Sustainability Assessment Framework for pavement materials and activities for NRAs.

Knowledge transfer activities

- 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 alsoappreciated 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).
    - 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 necessarily assessed by asphalt contractors and/or road owners, at least by means of mean value and standard deviation obtained by gathering expert opinion

PavementLCM Sustainaibility Assessment Framework

- PavementLCM SA Framework has been developed to provide recommendations and guide NRAs, as well as asphalt manufacturers and asphalt contractors, to perform the SA of two systems: **pavement materials/products** and **pavement activities**. In this regard, it aims at contrubiting filling the current gap in EU standards defining indications fort he calculation methodology of each exercise

- **Pavement materials/products**, are those entities that must be used to build, repair, replace and maintain road pavement and its components. The SA exercise for these products should be responsibility of material producers (i.e. asphalt manufacturer) and focuses on the “product/materials level of the model“
- **Pavement activities**, are those activities that must be carried out to build, repair, replace and maintain the functional and technical requirements of road pavement and its components. The SA exercises for these activities should be responsibility of paving contractors and road owners and it focuses on either Part, Element or Component level of the model“. In particular:
    - Paving contractors: must perform the SA of the contracted activities, such as

  - the construction of a new road pavement and/or the replacement of the road pavement component/element (i.e. wearing course)
  - Road owners (i.e. NRAs): must support their decision-making process by performing the SA of selected maintenance strategies and/or projects to be procured or awarded related to the whole flexible road pavement related or at a Part level of the model. Furthermore, NRAs might want to evaluate innovative technologies related to material manufacturing and/or road pavement installations

- Furthermore, in accordance to the standard EN 15643-5, PavementLCM SA Framework covers the assessment of the three pillars of sustainability (environmental, economic and social) as well as functional and technical requirements. For this, a set of indicators is proposed for the SA of pavement materials and pavement activities.
- PavementLCM exercise consists of seven steps that are explained and support with tools and resources within the PavementLCM Guidelines (D5.1).

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