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Life cycle engineering for roads (LCE4ROADS), the new sustainability certification system for roads from the LCE4ROADS FP7 project

Rocio Fernandez Flores a, Carlos Martin-Portugues Montoliu a,.*, Edith Guedella Bustamante a

*aAcciona Infraestructuras, Avenida de Europa 18, Alcobendas28108, Madrid, Spain

Abstract

There are many initiatives in the market capable to assess some aspects of sustainability for roads (mainly environmental). For instance, in America it should be noted the Greenroads, Envision and Invest certification systems. In Europe, it must be highlighted some sustainability assessment systems such as Ceequal in UK as well as rating and awards scheme for civil engineering or many tools to evaluate CO2 and Carbon Footprint, for example, the Dutch CO2 Performance Ladder. However, a complete evaluation of sustainability has not been implemented yet as a consequence of that some approaches do not cover all life cycle phases or all sustainability pillars. What is more, there is a lack of regulation in terms of a framework for sustainability assessment of civil constructions, for instance, CENTC 350 is still under development In addition, there are regional peculiarities which are not always considered in the evaluation systems and sometimes there are some stakeholders refusing the idea of road comparison. The EC by means of the Joint Research Centre (DG-JRC) is developing the Green Public Procurement Criteria (GPP) for design, construction and maintenance of roads, as useful method for the pre-selection criteria for contractors and for ensuring compliance of performance.

This paper summarizes the new sustainability certification system for roads named “LCE4ROADS”, under development as part of the FP7 project: “Life Cycle Engineering approach to develop a novel EU-harmonized sustainability certification system for cost-effective, safer and greener road infrastructures”.

LCE4ROADS will integrate by a Life Cycle Engineering (LCE) approach, all the aspects of sustainability (Environmental, Economic, Social, Technical) to asses roads projects and works (both new construction and rehabilitation/maintenance) with the final goal of creating a holistic and EU-harmonized methodology to increase the sustainability roads.

* Corresponding author:
E-mail address: carlos.martinportugues.montoliu@acciona.com
The certification system developed is based on current EN and ISO standards for sustainability in construction (EN15804) and LCA and LCC (ISO 14040-44 and ISO15686) and considers previous developments from other research projects like MIRAVEC, EVITA, COST 354 among others. Key aspects at European level like the adaptation and resilience to Climate Change and the implementation of freight corridors (the so called TEN-T: Trans European Transport Network) will be considered in this new certification system. With the goal of refining the certification system and the parameters and key performance indicators to be considered, it should be mentioned that LCE4ROADS has been already presented to different key stakeholders such as:

- National and Regional Road Authorities in six EU countries (France, The Netherlands, Spain, Germany, Sweden, Poland) and in Turkey (The Turkish Ministry of Transport (KGM) is partner of the FP7 Project).
- The European Commission (DG Research, DG Environment, DG JRC, and DG Move-Transport)
- Sectorial Platforms and Associations like the European Committee for Standardization (CEN), The European Road Federation (ERF), the Spanish Construction Technology Platform (mirror of the European ECTP) among others.

The US Federal Highway Administration (FHWA) is also interested in this topic and is working closely to the FP7 project team (the EC selected the project to collaborate with the most important transport research center in America).

The feedback received for future implementation from the key stakeholders has been taken into consideration to modify the scope of the certification system, the phases covered and the certification moments. This system, together with a guide for application and a multi-criteria software tool to be developed could be really useful for future procurement and GPP processes in Europe.

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1. Introduction

The concept of the LCE4ROADS sustainability certification system arises from the necessity of a holistic and EU-harmonized certification system that includes the three pillars of sustainability (environmental, economic and social), and all the phases of the road lifespan, from planning to design & construction, operation (use), maintenance and end of life.

The integration of all these aspects and phases was carried out in this research following a Life Cycle Engineering (LCE) approach, which includes the assessment of environmental impacts in conjunction with the economic ones under consideration of technical boundary conditions.

This will be useful for the assessment of the sustainability of future and existing road infrastructures:

- Future because following the developed certification system it will be feasible to assess road projects from the very beginning.
- Existing because in an aged road network like the European, maintenance and rehabilitation projects will be more than necessary in the very short term, and it will be again feasible to assess their sustainability at an early stage.

This paper summarizes the methodology developed to create this new certification system (which will be refined and improved as part of the FP7 LCE4ROADS “Life Cycle Engineering approach to develop a novel EU-harmonized sustainability certification system for cost-effective, safer and greener road infrastructures” project development: www.lce4roads.eu), the collaborations and links created and the main results achieved so far: definitive methodology, first version of the multi-criteria software tool, the standardization activities and roadmap towards the extension of the project.

It should be mentioned that one of the topics under discussion in the project is the introduction of the operation phase (also known as use phase) in the assessment carried out. This task is under development and is linked to the American National Sustainable Pavement Consortium (NSPC) where Virginia Tech, the Federal Highway Administration and the Virginia Department of Transportation are collaborating with the project coordinator ACCIONA Infraestructuras, and the LCE4ROADS partners: BASt (The German Federal Highway Research Institute), TNO (Netherlands Organisation for Applied Scientific Research) and IFSTTAR (French Institute of Science and Technology for Transport Development and Networks).
1.1. Environmental labelling approaches

Environmental labelling approaches are currently used tools to enhance the evaluation of environmental performance. These approaches can be classified, according to different ISO Standards as:

- Environmental Labels Type I:
  The EU Ecolabel is an environmental Label Type I (third party organizations establish criteria for judging the environmental-friendliness of products and grants a Type I environmental label to them based on said criteria) identifies products and services that contribute to sustainability because they have demonstrated a reduced environmental impact throughout their life cycle. There are already more than 17,000 EU Ecolabelled products on the market, but there are no references for road products and infrastructures.

- Environmental Labels Type II:
  Environmental labels Type II are self-declared environmental labels (often a single attribute, sometimes a company’s own environmental logo). There are already a huge number of self-declared labels of several products on the market, but there are no references for road products and infrastructures.

- Environmental Labels Type III:
  The Environmental Product Declaration (EPD®) is a Label Type III and it is a registered trademark. An environmental declaration is defined, in ISO 14025, as quantified environmental data for a product with preset categories of parameters based on the ISO 14040 series of standards, but not excluding additional environmental information. Environmental Product Declarations (EPD®) add several new market dimensions to inform about environmental performance of products and services.

  EPDs are based on principles inherent in the ISO standard for Ecolabel Type III environmental declarations (ISO 14025) giving them a wide-spread international acceptance.

  The EPD methodology, including a structured and well-defined procedure is based on LCA for mapping all relevant environmental aspects of goods and services in a life-cycle perspective.

  EPD® has been created for several infrastructures such as railways, tunnel or bridges but there is little information regarding EPD of roads. Acciona Infraestructuras was the first construction company in creating an EPD of a road, in particular de N-340 regional road in Spain.

  EPDs have become a trend for being an excellent way to communicate transparently the environmental impacts assessed through LCA. EPDs are also useful in GPP not only to obtain environmental information on the products but also as verification on environmental requirements in the tendering documents. However, there is still a gap due to the fact that EPDs only assess and communicate the environmental performance, not including neither social nor
economic aspects. This is one of the reasons why sustainability certification systems arise to an excellent idea to cope with those uncover aspects.

![Image](http://www.environdec.com/en/Detail/?Epd=9342)

**Fig. 1. First EPD of a Road: N-340 road in sector E-40, Elche, Alicante (Spain).**

1.2. Sustainability certification methodologies for roads

The experience has shown that these approaches such as labelling and certification initiatives stimulate industry, strengthen innovation and creativeness while using mechanisms for cost-effective results, promoting smart procurement, and move regulations and methodologies from national to international standards (international harmonization).

Procurers of buildings generally wish to lower costs and decisions in all stages of the facility’s life (acquisition, operation, maintenance, replacement and disposal), for that well-known reason, they often follow the International Standard ISO 15686-5: Buildings and constructed assets -Service-life planning -Part 5: Life-cycle costing.

The European Committee for Standardization (CEN) by means of its Technical Committee TC-350, has developed two environmental life cycle assessment methods: EN 15804 for building products and EN 15978 for buildings. All European member states shall comply with these European methods when using LCA for buildings.

There is an implemented framework for labelling and certification applied to buildings and there are both local and harmonised approaches. The European BREEAM and DG 2002/91/EC9: “Performance of buildings”, together with LEED in the US could be considered as recognized measures of sustainability performance.

Similar approaches for road infrastructures are trying to find a similar status in the market, for instance, the GREENROADS, INVEST and ENVISION rating systems in the US, the environmental labelling approach EPD© (Environmental Product Declaration for road based on Life Cycle Analysis (LCA)), the French methodology: ROUTE-DURABLE for “sustainable roads”, the Dutch Environmental LCA tool: DuboCalc and the CO₂ Performance ladder system or CEEQUAL assessment, rating and awards scheme for civil engineering mainly in UK. Some of these systems will be considered by the EC to establish the selection criteria on the competency of the construction/ maintenance/rehabilitation contractors as part of the future directive on Green Public Procurement Criteria for design, construction and maintenance of roads, under development by the Joint Research Centre of the European Commission. Again as this is concentrated in environmental impacts, not all the sustainability pillars will be equally considered. Additionally, there are no regulations or standards about the certification of sustainability. The most advanced pillars in terms of regulation are the economic and mainly the environmental.

1.3. Life cycle engineering for roads

As it was mentioned Life Cycle Engineering or Lifetime engineering includes the assessment of environmental impacts in conjunction with the economic ones under consideration of technical boundary conditions. In particular Lifetime engineering is an innovative idea and a concretization of this idea for solving the dilemma that currently exists between infrastructures as very long-term products and their short-term approach to design, management and maintenance planning [Sarja, (1997)].
The main elements of lifetime engineering are:
- Lifetime investment planning and decision making,
- Integrated lifetime design,
- Integrated lifetime management and maintenance planning,
- Modernization, reuse, recycling and disposal,
- Integrated lifetime environmental impact assessment and minimization.

Although LCE is not a fully recognized science and in many cases it is not even known, the fact is that several of its elements have already been applied for road construction and management systems (Gáspár, 2008), among others:

- Whole life (life cycle) costing for planning and design of road projects, including end-of-life strategies like deposit, recycling or reuse of demolished material.
- Pavement performance models for the forecasting of future behavior of various road pavement types as a function of time or traffic passed.
- The user costs (vehicle operating costs, time delay costs and accident costs) in normally considered in terms of national economy.
- Analysis of road and traffic effects such as air pollution, noise and vibration.
- Pavement recycling methodologies are more frequent in roads construction and maintenance.
- Innovative technologies and with reduced impact on the environment are promoted by policy makers and public bodies via fiscal benefits, innovative tendering processes among others.

These are some of the reasons why the team developing the LCE4ROADS sustainability certification system considered that a LCE approach could be suitable for roads and could make feasible the future implementation in the roads procurement and management systems.

2. The LCE4ROADS concept

The LCE4ROADS sustainability certification system is based on flexible methodology tailor made for road pavements that intends to cover their whole life cycle, all the sustainability pillars and capable to include the required versatility to be EU-harmonized (leaving room for regional peculiarities).

Applicability:
- The methodology will be suitable for construction and rehabilitation/maintenance projects (future and existing roads respectively) and pavement focused (including asphalt and concrete pavements, granular bases, stabilized soils and earthworks).
Bridges, tunnels and other road elements are excluded in this first phase of the certification system. In the future it could be adapted to develop aligned sustainability certification systems such as LCE4BRIDGES, LCE4TUNNELS and even LCE4RAILS.
- Suitable for the whole Europe and Turkey, considering regional peculiarities and regulations, and focused on the TEN-T: Trans European Transport Network, although it could be adapted to any kind of road.

- Phases to be considered: The methodology assesses the sustainability of a road projects over its lifetime.
  - All life cycle stages are considered (design and planning, construction, operation, maintenance and end of life). LCE4ROADS follows the CEN/TC 350 standards (EN15804), which define the life cycle of buildings, and in the future also define construction works including civil engineering works.

- Certification stages:
  - There will be three stages when the certificate can be awarded: During the planning and design stage (1), after construction (2), to validate that all what was defined in the project has been fulfilled and during the operation phase (3) to check the real performance.

Levels of achievement
- LCE4ROADS certification system will comprise two levels of achievement: light and complete. The certification methodology will be based on a set of criteria for achieving a light (basic), covering a minimum range of requirements, or a complete (optimum), while covering the whole range of requirements.
  In order to establish the light and complete criteria per each KPI, the GPP requirements and criteria drafted by the JRC from the European Commission, previous European research projects like SUNRA, MIRAVEC, EVITA, COST354, ROSANNE, TYROSAFE and the American INVEST and ENVISION rating systems have been taken as a reference.

Criteria: The certification system implies the three pillars of sustainability (environmental, economic and social) and technical criteria that are crucial for road infrastructures
- The environmental criteria considered are: the materials to be used, the environmental impact associated to the infrastructure as a whole (following EN 15804 and including all the construction processes, the planned maintenance and rehabilitation and a separate module for the use phase).
- The economic domain is based on the ISO 15686-5 including agency cost (Initial cost, Maintenance cost and Salvage value).
- The social aspect covered includes criteria for comfort, safety (EU harmonized safety audit and safety inspection (Directive 2008/96EC) applied to the TEN-T: Trans European Transport Network) and noise.

Technical aspects will also be considered as supporting parameters to be fulfilled according to national standards. Limit legal values for technical parameters or maintenance scheme, structure, and mechanical characteristics will be defined per country when they exist. With the aim of going a step forward, resilience to climate chance aspects will definitively be considered also as technical parameter in terms of the percentage of budget associated to climate resilience mitigation and adaptation measures (described to make feasible the assessment by the road authority).
Usefulness:

LCE4ROADS methodology will be a cutting edge methodology extremely valuable for:

- Contractors, engineering companies who will be motivated for implementing more sustainable technologies, materials or processes.
- NRAs who will have a proven methodology to enhance sustainability in roads through GPP, PPI or others.
- Certification bodies who will be able to generate market niches thanks to the proposed sustainability certification system for roads.

Considering the key stakeholders, LCE4ROADS has been already presented to the following audience with the idea of getting feedback from them in terms of usefulness of the methodology and its main concepts.

- National and Regional Road Authorities in six EU countries (France, The Netherlands, Spain, Germany, Sweden, Poland) and in Turkey (The Turkish Ministry of Transport (KGM) is partner of the FP7 Project).
- The European Commission (DG Research, DG Environment, DG JRC, and DG Move-Transport)
- Sectorial Platforms and Associations like the European Committee for Standardization (CEN), The European Road Federation (ERF), the Spanish Construction Technology Platform (mirror of the European ECTP) among others.

Following the comments and suggestions received from them, the initial conceptual methodology was refined to end up on the methodology presented in this paper. The methodology will be presented again to the same stakeholders together with the software tool in order to analyze potential deployment and implementation routes.

In those terms, the collaboration between all stakeholders becomes essential for being able to obtain the certificate. The cooperation network between stakeholders is shown in Figure 5.
• Supporting tools:
  - A complete guide for users will be developed and there is a software tool tailor made programmed to support the certification and the procurement process.

![Home screen of the tool](image1)
![Main navigation screen](image2)

Fig. 6 a) Home screen of the tool; b) Main navigation screen

3. The use-phase and the collaboration with the FHWA

The aim of this collaboration is fostering the exchange of knowledge between both sides of the Atlantic, finding synergies which improve the current trends in terms of enhancing sustainability in pavements. The collaboration is focused specifically on the consideration of the use phase in the road’s life cycle. FHWA together with the University of Virginia support the consortium with their experience and simulation models of the use phase of pavements (considering fuel consumption of the vehicles according to the surface characteristic of the road, etc.). Several papers provided by the Americans with crucial information have been carefully analyzed [Bryce, (2011)], [Bryce, (2012)], [Bryce, (2013)], [Bryce, (2014)], [Santos, (2014)]. From Europe’s side, some LCE4ROADS consortium members have been also sharing their know-how about use phase models from MIRIAM and ROSANNE FP7 Projects [Haider, (2011)], [Sandberg, (2012)], Hammarström, (2012)] as well as their expertise in issues for American’s interests such as the obtaining of EPDs or PCRs for roads products and processes as well as the usefulness and benefits of the application of the European Policies in terms of Green Public Procurement for road infrastructures (http://ec.europa.eu/environment/ecolabel/ecolabel-and-green-public-procurement.html). For the future, new common actions and objectives were established to keep on encouraging the collaboration.

4. LCE4ROADS in the standardization system

In order to have a future common framework for sustainability assessment of roads, standardization should be involved providing experience and knowledge to the project. The project strategy in terms of standardization consists of developing a Consortium Working Agreement (CWA) which despite of being less transparent compared to the already running CEN initiatives (parties/ countries cannot join after the CWA agreement, and the voting is based on the majority), it is considered the best and the most effective option for this project. The “level” of the document is clearly lower than EN, TS, or TR, and thus the consensus needed is also lower. Anyway stakeholders from the relevant TC are invited to participate. Anyway the level of consensus and applicability of the indicators using a CWA track will be higher than outside the standardization system. This CWA has similar intentions as two CEN initiatives that are already running (TC 350 Working group 6 for infrastructure and TC 277 for road materials). In addition ISO 21930 is under development. The participation of the standardization system in the outcome of the project is also positive for CEN, as a way to disseminate CEN/TC 350 indicators and methodologies in future road assessment methods. As CWA shall be compliant with in-force EN standards, the indicators of the project will be in line with CEN methodologies. The project could also help to spread these indicators in US via the collaboration established with them. The market players that will benefit from the outcome of this CEN Workshop are: road public administrations, environmental public administrations, road materials manufacturers, construction companies, sustainability professionals, construction research organizations and road users.
5. Roadmap towards the extension of the LCE4ROADS

The Figure 7 provides an overall view of the roadmap for the extension of the LCE4ROADS. The summation below specifies important steps and milestones. The latter are listed in chronological order.

Fig. 7. Overall roadmap.

**MS 1:** Inclusion of all type of road on the certification scope.
**MS 2:** Definition of the use phase: interest, consequences on certification.
**MS 3:** Inclusion of the use phase on the certification.
**MS 4:** Inclusion of every additional element of the road: drainage system, barriers...
**MS 5:** Consensus building for weighting and scoring.
**MS 6:** Inclusion of every road infrastructure as tunnels and bridges on the certification. Analysis to extend the methodology to other transport infrastructure (e.g. Railways)
**MS 7:** Consensus building for the most widely set of KPI.
**MS 8:** Weighting guide.
**MS 9:** Consensus building for standardization.
**MS 10:** Beta version of uniform calculation method and way to collect data.

Currently, the project is running on month 25 (October 2015) and it will end in M36 (October 2016). The long term is up to 5 years. The short term is up until about 1-2 years and medium term is something between 2 and 4 years. However, this roadmap is just a first attempt. Therefore, these time indications are just suggestions and they could change.

6. Conclusions

The concept of the LCE4ROADS sustainability certification system arises from the necessity of a holistic and EU-harmonized certification system that includes the three pillars of sustainability (environmental, economic and social), and all the phases of the road lifespan, from planning to design & construction, operation (use), maintenance and end of life.

This paper summarizes the methodology developed to create this new certification system (which will be refined and improved as part of the FP7 LCE4ROADS “Life Cycle Engineering approach to develop a novel EU-harmonized sustainability certification system for cost-effective, safer and greener road infrastructures” project development: www.lce4roads.eu). The proposed methodology will support the harmonization process of the European sustainability certification systems for roads as a result of a flexible method useful for contractors, NRAs, certification bodies, among others, hence filling the existing gap in the current trends in terms of sustainability pillars, phases and regional peculiarities.

The main aspects of the methodology were carefully described such as the applicability, the phases to be considered, the certification stages, the levels of achievement, the criteria, the usefulness and the supporting tool.
Furthermore, the standardization process as well as the roadmap towards the extension of the LCE4ROADS was clearly presented. In addition, the collaboration with the NSPC from the United States highlighted by pointing out the key benefits of achieving common goals such as the inclusion of the use phase in the LCE4ROADS methodology or the obtaining.

In the near future and until October 2016 when the Project will end, the LCE4ROADS consortium will go along with the pertinent tasks keeping on developing the final software tool taking into account the results of the validation of several case studies. Finally, a guide will be created as a supporting material for the user to make possible the road sustainability assessment.

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