LCE4ROADS PROJECT
FINAL REPORT

INTRODUCTION

This report is a summary of the LCE4ROADS Project, and aims to be a document accessible to a general, non-technical, audience who may have interest in sustainability practices applied to road infrastructure projects.

The report is divided into three parts:

a) First, a final summary report of the project covering results, conclusions and socio-economic impact. The content of this report is described in section 4.1.
b) A plan for the use and dissemination of foreground that resulted from the project. The content of this report is described in section 4.1.
c) And a brief report that covers the wider societal implications of the project, including, where applicable, gender equality actions, ethical issues, efforts to involve other actors and to spread awareness. The content of this report is described in section 4.3.

GENERAL INFORMATION

4.1. Final publishable summary report

a) Executive summary.

The EU Ecolabel 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

The concept of the LCE4ROADS project arises from the necessity of a new, green, holistic and EU-harmonised certification systems integrating by a Life Cycle Engineering (LCE) approach: environmental indicators along with the economic, technical and social aspects, for the assessment of future and existing road infrastructures, as well as their construction materials such as asphalt mixtures and cement-based materials.

After 39 months of different project activities that included research and demonstration through different cases study across Europe, the main results achieved so far are:

1) a methodology for the assessment of the sustainability performance of road projects, 2)
2) a software tool that incorporates the methodology and facilitates the evaluation of road projects according to LCE4ROADS principles,
3) a compendium of guidelines, that include recommendation for greener, safer and cost-effective products, a handbook for the tool and the LCE4ROADS Guide to certification. All these guides can be used as training material for professionals interested in LCE4ROADS and customers that require services associated with LCE4ROADS.
4) The certification system itself.

LCE4ROADS has defined criteria and recommendations for including greener, cost-effective and safer technologies in the different stages of a road project life cycle (planning/design,

construction and operation/maintenance). Furthermore it has become a strong supporter and motivator to relevant stakeholders and industry players for including sustainability principles in road projects.

Also, the drafting and publication of a CEN Workshop Agreement (CWA) as a key step toward standardization was set up. After the assessment of the standardization environment made early 2015, AENOR presented to CEN a Business Plan for the activation of a project based on the indicators established in LCE4ROADS. This resulted in the publication of the CEN document CWA 17089:2016 *Indicators for the sustainability assessment of roads* in November 2016. This document is available through CEN members.

The LCE4ROADS project will contribute to the implementation of European policies and strategies, boosting the integration of transport in sustainable development promoting technologies and materials that reduce pollutant emissions and the use of natural and financial resources.

b) Summary description of the project context and the main objectives.

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The concept of the LCE4ROADS project arises from the necessity of a new, green, holistic and EU-harmonized certification systems that integrates a Life Cycle Engineering (LCE) approach: environmental indicators along with economic, technical and social ones framework the assessment of the sustainable performance of existing and future road infrastructures as well as their construction materials such as asphalt mixtures and cement-based ones.

The LCE4ROADS methodology, together with a guide for road certification and a multi-criteria software tool that facilitates its use and implementation, looks after to provide criteria and recommendations for including greener, cost-effective and safer technologies in their road construction, maintenance and renewal projects and support and motivate relevant stakeholders and industry along the whole process.

In order to achieve the expected results a complete work plan has been performed. This plan that will move 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 of a software tool that thanks to the direct involvement of CEN in the project, will motivate future EU-harmonized certification approaches for roads that would grant the implementation of the LCE4ROADS results.

The work plan followed was structured in 8 WPs. In the following, the key work devoted to research and demo activities will be described in summarized and comprehensive manner.

WP 1: SETTING THE SCENE: Labelling approaches and Key Performance Indicators.

The main purpose of this WP was the establishment of the baseline for the LCE4ROADS methodology development (including the definition of KPIs) for greener, cost-effective, safer and resilient to climate change road products and infrastructure.

This objective was reached through the following activities:

- Extensive literature review dealing with existing labelling approaches through Europe related to road infrastructures and products, existing regulations, standards and constraints for the implementation of labelling schemes to road products and infrastructures throughout EU;
- Definition and selection of relevant KPIs for road infrastructures to cover environmental, technical, social and economic aspects at various road stages such as design, construction, maintenance and rehabilitation (thus the whole LCE approach); asphalt mixes and asphalt concrete mixes are considered in the KPIs selection;
- Benchmarking theoretical exercise on a reduced set of case studies to assess the proposed and selected indicators;
- Definition of implementation strategies for the outcomes of the project to minimize the main blocking factors identified for the advanced EU Eco label.

WP 2: ECOLABELLING METHODOLOGY FOR ROAD PRODUCTS AND INFRASTRUCTURES

There are many initiatives in the market that look after providing insights on the sustainability performance of roads, but most of them lack of a real holistic view of sustainability as the focus is, by default, put on the environmental implications of road projects. Systems like Greenroads (US), Envision (US), Invest (US), Ceequal (UK), CO2 Performance Ladder (The Netherlands) have gained a wide industry acceptance; however, a complete evaluation of sustainability has not been implemented yet because some of the current approaches do not cover all life cycle phases or all sustainability pillars (environment, social and economic). Therefore, the LCE4ROADS methodology was built taking into account the limits that other methodologies analyzed have.

In this view, this WP aimed at developing the LCE4ROADS certification system and its associated methodology. The definition of an advanced, harmonized and holistic EU sustainability certification system for road infrastructures, that cover all the sustainability domains and new challenges identified in WP1 (greener, safer, cost-effective and resilient to climate change), responds to a clear gap in the industry. This methodology, thus, was at the base of the LCE4ROADS guidelines for road infrastructures and the associated software tool that were developed in subsequent WPs.

The specific objectives of WP2 were the following:

- To finally set the LCE4ROADS methodology, including the list of KPI's that assess the road sustainable performance on the environmental, economic, social and technical domains.
- To provide a first a first version of the procedure that must be followed for being awarded with the LCE4ROADS Certificate will be proposed.

The LCE4ROADS methodology integrates a Life Cycle Engineering (LCE) approach: it includes all the sustainability pillars - Environmental, Economic and Social -, plus a Technical domain. The methodology also was developed flexible enough in order to make it applicable in different countries, with specific technical requirements and ad hoc LCA methods; flexible enough to make possible to assess the sustainable performance of the road in all road life cycle stages (from design, to construction and maintenance). The methodology took also into consideration current EN and ISO standards such as the one for Sustainability in Construction (EN15804), for LCA/LCC analysis (ISO 14040-44 and ISO15686) and previous developments from other research projects like MIRAVEC, EVITA, COST354 among others. Other key aspects at European level like

the adaptation and resilience to Climate Change were considered to create this new certification system.

The assessment of the sustainability performance of the road through the LCE4ROADS methodology target three different stages of a road life cycle: planning/design, construction and maintenance/operation. This is linked to the three stages where the LCE4ROADS 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. In order to refine the methodology, the certification system, methodology and key performance indicators were presented to key sectorial stakeholders such as:

- National and Regional Road Authorities in six EU countries (France, The Netherlands, Spain, Germany, Sweden, Poland) and Turkey (The Turkish Ministry of Transport 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.

Thanks to the stakeholder's feedback, the scope of the certification system and the applicability of the methodology was improved and released for validation to the associated work packages.

WP 3: ASSESSMENT AGAINST THE ECOLABEL METHODOLOGY OF ROAD PRODUCTS AND INFRASTRUCTURES

The main objective in WP3 was to elaborate a comprehensive assessment of the most widely implemented road products and infrastructures against the LCE4ROADS methodology which was developed in the other WP's. This included construction, maintenance, rehabilitation and operation of a road project, different types of pavements (asphalt and cement concrete), materials and their applications. Different road construction products like bitumen, aggregates, additives and cement, but also recycled materials like RAP were evaluated. A strong focus was on the energy use of asphalt mixing plants and on the warm-mix-technology (WMA). Case studies to illustrate the implementation of the LCE4ROADS methodology in road construction projects were also included. Suggestions for greener, safer and cost effective road products and infrastructures were given.

WP 4: DEVELOPMENT OF THE ECOLABEL SOFTWARE TOOL.

The main objective of WP4 was to develop and implement an innovative and user-friendly software tool based on the LCE4ROADS methodology and the Key Performance Indicators (KPI) selected. In this vein, the tool considers the integration of the certification methodology developed for road pavements on the basis of process modelling and simulation application, aiming the evaluation of the overall sustainability performance of the main stages of a road life cycle, that is, design, construction and operation. The tool also aims at facilitating the use and implementation of the LCE4ROADS methodology as it eases the evaluation of road projects in terms of sustainability performance. The tool also provides recommendations and ideas for improving the sustainable performance of the road which means that it can support the decision making of relevant stakeholders and groups of interest.

WP 5: VALIDATION OF THE ECOLABEL METODOLOGY AND THE ASSOCIATED SOFTWARE.

WP5 look after validating the methodology and associated software tool by cross-checking it with data from real cases provided by National Road Administrations. The process followed the analysis of different road projects, evaluate their sustainability performance according to LCE4ROADS and provide the recommendations the software may suggest to improve the road performance in terms of innovation, green profile, cost-effectiveness and long-term behavior.

More specifically, this objectives have been achieved through the

- The selection of real road project cases that allow obtaining reliable data for the necessary evaluation and comparison of different road projects while covering the widest European area as possible and properly validate the LCE4ROADS methodology and associated software tool.
- The evaluation of real road construction and maintenance projects analyzed and evaluated by using the defined LCE4ROADS methodology and associated software tool
- The analysis of the main green, cost-effective, technical, social and economic recommendations and suggestions provided by the LCE4ROADS software tool.

WP 6: ECOLABEL GUIDE AND IMPLEMENTATION STRATEGIES.

The purpose of WP6 was to develop the LCE4ROADS guides that explain and support the i) the implementation of the certification system; ii) the procedure that must be followed for achieving the LCE4ROADS certificate and iii) the most suitable implementation strategies in terms of market uptake including smart and green public procurement

The LCE4ROADS Guides aim at facilitating the utilization of the LCE4ROADS methodology and associated software tool among the potential applicants. The implementation strategies show how the different stakeholders interact in the infrastructures sector and how LCE4ROADS may strength the bond between stakeholders incentivizing sustainability approaches in the whole road life cycle and how potential blocking factors should be manage in order to minimize their effect and use them as opportunities for further deploy LCE4ROADS results.

Strong efforts have been placed on demonstrating how LCE4ROADS can be used as lever for future efforts in incentivizing Smart and Green Public Procurement practices at across Europe.

c) Description of the main S & T results/foregrounds.

WP 1: SETTING THE SCENE: Labelling approaches and Key Performance Indicators.

First of all, an extensive review of the state-of-the-art related to road performances, labelling or certification methods and related indicators as well as regulations, standards and constraints, was realized by the partners. Fourteen sustainability rating systems, fifteen software and online tools, fifteen EU projects and eight national projects which have been considered as labelling approaches or their support (in the case of the tools), were analyzed. Additionally, the regulatory aspects related to four major domains (technical, environmental, social and economic) of sustainable development were checked.

Then, the LCE4ROADS methodology was developed. The consortium decided that a certification was best convenient than a label. Although in a first proposal, the certification system would have cover all phases of infrastructure life cycle as a whole (planning, design, construction,

operation, maintenance, End of Life) the consortium decide to make it applicable only to Planning/Design, Construction and Operation/Maintenance, as End of Life could be considered also the beginning of a new project. Two levels of LCE analysis were covered in the methodology: road products and road infrastructure as a composition of road products and processes needed to transform group of road products into road infrastructure. The design phase was considered only once the itinerary is chosen, and both preliminary certification and final certification are provided. The certification concerns both new and existing projects. An initial set of Key Performances Indicators with a definition of their limits, was proposed for each domain.

A benchmarking based on a reduced set of projects (France, The Netherlands, Spain) was performed to check the applicability of the assessment method in the four domains and associated KPIs. Thus, the list of KPIs has been completed as regards KPIs applicability and needs.

In the last part of the work, a preliminary study on the implementation strategies and market analysis was executed. The objective was to define how supporting a wide deployment around EU and neighboring countries of the LCE4ROADS methodology (voluntary/mandatory certification, incremental implementation routes, business models to apply, etc.). In the meantime, input gained from stakeholders meetings (e.g. EU and national workshops), and work done in other Work Packages were taken into account.

WP 2: ECOLABELLING METHODOLOGY FOR ROAD PRODUCTS AND INFRASTRUCTURES

Along this task, the LCE4ROADS methodology has been defined. The baseline for the LCE4ROADS methodology was set under WP1, where Key Performance Indicators were recognized and selected in order to correctly represent all sustainability aspects (environmental, economic, social and technical) that should be covered by the EU harmonized certification system for roads infrastructure.

To develop the methodology the following activities were performed:

- Development of an **initial methodology** based on the boundary conditions set in the DoW.
- **Consensus building**: discuss baseline methodology with consortium and NRA's of countries involved in the LCE4ROADS consortium.
- **Assessment of the most relevant certification systems** in order to have a reference to be able to create the most appropriate one for LCEROADS project. This part was built upon the outcomes from WP1.
- Development of a refined **LCE4ROADS methodology** based on:
    - Conclusions analysis of the most relevant certification systems.
    - Feedback of consortium and NRA's.

The *consensus building* was achieved thanks to the following actions:

- Interviews/workshops set up by project partners with NRAs from the countries involved in the LCE4ROADS consortium.
- Interaction/involvement with The European Committee for Standardization CEN and "Project Liaison" with CEN/TC 350: "Sustainability of construction works".
- Workshop with EC representatives from DG research, DG environment, DG move and the JRC.

Considering the feedback received after the national and European workshops as well as the work done in WP2, an explicative chart has been created to make the methodology concept more clear and visual.

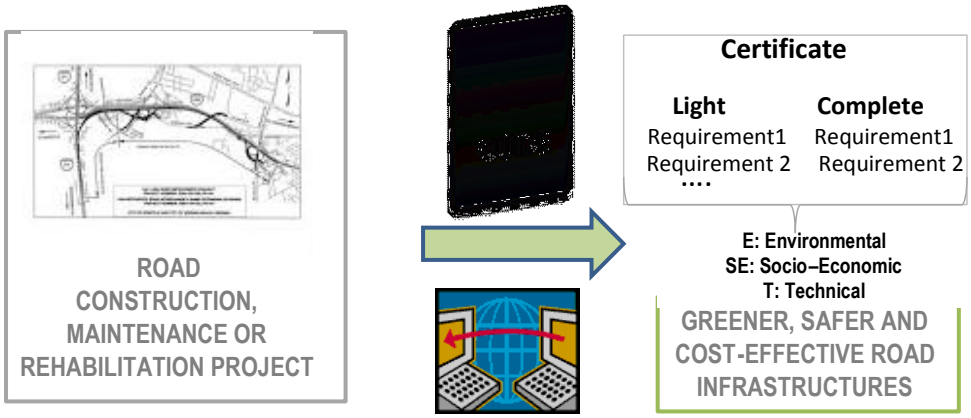

Figure 1. Refined concept of the methodology.

It must be noted that the list of KPI has passed through a long process of continuous refinement. New inputs from stakeholders and experience gained from partners during the execution of the different project tasks, generated a long debate inside the consortium that resulted in a more comprehensive list of indicators, especially in the technical and social domains. Specifically on these two domains, the indicators finally proposed were required to show relevant information related to the performance of the road at the same time they have a broad acceptance among stakeholders.

For each indicator there are two levels of achievement that corresponds to the two types of certificate that can be awarded with LCE4ROADS.

Table 1 – List of Key Performance Indicators included in the LCE4ROADS Methodology.

Domain	Key Performance Indicators		List of requirements for certificate	
			Light	*Complete*
Environmental	Material	1.Materials consumption	X	X
		2.Recycled materials used	X	X
		3.Materials suspected to be recycled	X	X
		4.Energy demand (use of renewable energy sources/non renewable energy sources	X	X
		5. Waste (Hazardous waste/non-hazardous waste/ radioactive waste)	X	X
	Environmental Impact	6.Global Warming Potential	X	X
		7.Photochemical Ozone Creation Potential	voluntary	X
		8.Ozone Depletion Potential	voluntary	X
		9.Acidification Potential	voluntary	X
		10.Eutrophication Potential	voluntary	X
		11.Abiotic Depletion Potential	voluntary	X

		12.Abiotic Depletion – fossil fuel	voluntary	X
		13.Human Toxicity	voluntary	voluntary
		14.Ecotoxicity	voluntary	voluntary
Economic	**Agency Cost**	15.Initial cost	X	X
		16.Maintenance cost	X	X
		17.Salvage value	voluntary	X
Social	**Comfort**	18.Comfort Index	X	X
	Safety	19.Safety audits & safety inspections	X	X
	Noise	20. Amount of noise reduction realized by the pavement surface in dB.	voluntary	X
Technical	**Structural**	21.Resilient modulus values from FWD	voluntary	voluntary
		22.Evenness	X	X
		23.Skid resistance/Macrotexture	voluntary	voluntary
		24.Rut depth	X	X
		25.Resilience to climate change	voluntary	voluntary

In addition, along this WP a preliminary description of the procedure to award infrastructure projects with the LCE4ROADS certificate was proposed. This preliminary procedure allowed to perform the full development of the most suitable awarding procedure developed in WP6. As the table below show, the relation between the methodology, project exploitation and implementation strategy (also part of WP6) are key for defining a sound procedure for awarding a road project using LCE4ROADS.

Previous and current work	Link to the awarding procedure	
The LCE4ROADS methodology (i.e. D2.1)	The methodology describes the scope of the certificate and the way indicators (KPI's) are calculated	Basis for the preliminary and final awarding procedure
Preliminary exploitation plan (D7.8)	The exploitation plan also describes the organisational structure and thus indicates which organisations are involved in the awarding procedure	
Market implementation strategy (D1.5 and D6.2)	This plan describes the context of the market for implementation (e.g. type of certification, procurement, etc.) and provides additional input for developing the awarding procedure	

The awarding procedure has been initially divided in 2 main phases: eligibility criteria and technical assessment.

Eligibility criteria stand for those who can apply for a LCE4ROADS certificate. In this senses, all stakeholders involved in the entire life of the road from the design and planning to end of life stages can apply for a LCE4ROADS Certificate, which can be grouped in four profiles:

- *Engineering and design companies or consultancies*: these actors are involved at the very beginning of the life of any road.

- *Infrastructure developers*: these stakeholders are construction companies or concessioners involved immediately after the design phase and completing their work according to the agreed design plan.
- *Infrastructure owners*: involved in the maintenance and operational phases and even in the end-of-life
- *Materials suppliers*: since LCE4ROADS will focus only on pavement, these stakeholders mean to companies involved in the concrete or asphalt sectors.

Stakeholders can apply for the awarding procedure to obtain the certificate at three moments: planning and design (CS1), construction (CS2), and operation (CS3).

The technical assessment occurs once the stakeholder applies for the LCE4ROADS certificate. This assessment is done with the methodology according to the specification each indicator has on its specific domain (environmental, economic, social and technical).

It is important to highlight that LCE4ROADS does not provide weights and scores for each one of the indicators the methodology provides. This is a reasonable approach as roads across the different EU countries vary considerably and the needs from National Road Authorities (NRAs) change depending on many factors that have a mostly country specific reason. Therefore, the Project Consortium recommended that weighting of indicators should be responsibility of NRAs, as LCE4ROADS looks after assessing the sustainable performance of road projects not making any comparison between roads in terms of which of them have better sustainable performance. In this sense, NRAs should indicate the criteria that must drive the evaluation of the project under their responsibility and which domain (environmental, technical, social or economic) or indicator should during this process.

WP 3: ASSESSMENT AGAINST THE ECOLABEL METHODOLOGY OF ROAD PRODUCTS AND INFRASTRUCTURES.

There is a considerable number of innovative technologies that may enhance the sustainability side of road projects. Not only technical requirement have to be considered but also the benefits or impacts those technologies have in the environmental, social and economic domain. In order to properly assess them, the LCE4Roads methodology was used and the results were reported accordingly.

To give an example, in recent years new techniques, additives and mixing processes were developed for asphalt, which allow paving and mixing at lower temperatures than usual while maintaining the workability of the mixture. Theoretically, a reduction of mixing and paving temperature should lead to a reduction of the heat and energy demands, however, there are still some open questions about the field performance of the new so-called “warm mix asphalts”. Furthermore, the large amounts of energy required to manufacture some WMA additives have to been taken into account due to their potentially high contribution to the overall LCA analysis. While all industry efforts have been in the field of temperature reduction, results show, that a reduction of aggregate moisture content or proper isolation of the asphalt plant component leads to big gains in terms of fuel and energy saving. Fuel choice is another area which can help to achieve better emissions.

Environmental impacts of asphalt and concrete material and pavements can be quantified with the existing methods, tools and databases. However, results differ greatly depending on the data source and sometimes it is very difficult to find reliable data. Small differences in the source data can lead to big differences in the end result of the environmental indicators. Therefore, when, for example, a future user such as a procurer must ensure that the data from the bids which will

take part in the tender process were calculated according to the same method and using the same data source. Reliability of the data source is also of utmost importance should the end user perform the calculations by her/himself. Unfortunately, since the data range is so spread out, it was impossible to establish an “average” or “default” value for the environmental KPIs. Future research should try to create reliable environmental data for asphalt mixtures. In this respect, the calculations and databases included in the LCE4ROADS tool are a promising step.

The technical performance of asphalt and cement concrete solutions for pavements along their service life were analyzed and assessed by using the technical key performance indicators defined within LCE4ROADS project. This was comfort (roughness and rutting), skid resistance, noise and resilience to climate change. The evaluation has been done in a qualitative way, by comparing the performance of different solutions. In some cases, as noise level, a reference value has been established to compare the rest of solutions against it. The analysis included a description of the behavior of traditional solutions along time, and, for this reason, failure mechanisms of every solution have been described. This description will be useful to define maintenance plan of both, traditional and innovative solutions, which will permit assessing them against LCE4ROAD methodology. Finally, it must be pointed out that climate has been included in this analysis. Climate is a factor that determines the long term behavior of pavements. Roads across Europe are exposed to different climate conditions. For this reason, the analysis has divided Europe into different climate regions that must be accounted when designing roads.

Case studies were evaluated in order to generate feedback for the KPI development process. They also helped in formulating advices about the scope, system boundaries, certification stages, and provided input for the database in the software tool of the LCE4ROADS methodology.

It is worth mentioning that there are indicators that have been discussed poorly in the assessments, specifically the social ones. The main reason is that social indicators have a higher impact in the Certification Stages CS2 (Construction) and CS3 (Operation), while in CS1 (Design) they are very difficult to assess. As long as more experience is gained with the implementation of the technologies, better assessments will be done on this domain. Nevertheless, a review of the social indicators is recommended, in order to include, for instance, impact on workers. Many of the technologies shown in this document (warm mix asphalt, epoxy binders, and others) produces odours and nuisances that might have a negative impact on workers, so this should be included as a social indicator in future assessments.

Another aspect that is worth discussing is the cost-effectiveness analysis. While working on the assessments, it became evident that for a real cost-effective analysis it is necessary to have real and specific project information such as initial costs and cost along its service life, which also must be linked with the long term performance of the road with whichever technology is used in its construction. Only by matching costs and performance it will be possible to perform the analysis which for almost all the technologies proposed is almost impossible. Nevertheless, a short term analysis could be possible as long as some technology performance data is available.

In practice it often worth considering the application of more than one technology at the same time. The combination might lead to more economically and environmentally viable solutions. Nevertheless, the outcomes of the assessment will provide relevant insights on how the proposed solutions described herein may foster the development of more sustainable road infrastructures.

For a look forward after the conclusion of the LCE4ROADS project, a roadmap was developed towards the expansion of the LCE4ROADS methodology to any kind of road infrastructure. The

roadmap illustrated what activities are aimed for in the future (i.e. after the LCE4ROADS project), what these activities can contribute, and what is required to execute these activities. All activities helped to improve the LCE4ROADS methodology and its application in the infrastructure sector. In detail the roadmap suggested to extend the lifecycle phases by including the 'use stage'.

WP 4: DEVELOPMENT OF THE ECOLABEL SOFTWARE TOOL.

WP4 has developed and implemented an innovative multicriteria software tool that integrates the LCE4ROADS methodology for road products and infrastructures. This tool allows the evaluation of the global performance of a road project according to the Key Performance Indicators (KPIs) defined along WP2 and WP3. Figure 2 shows a schematic drawing that describes the required information and the main steps which should be followed in order to obtain the LCE4ROADS certificate.

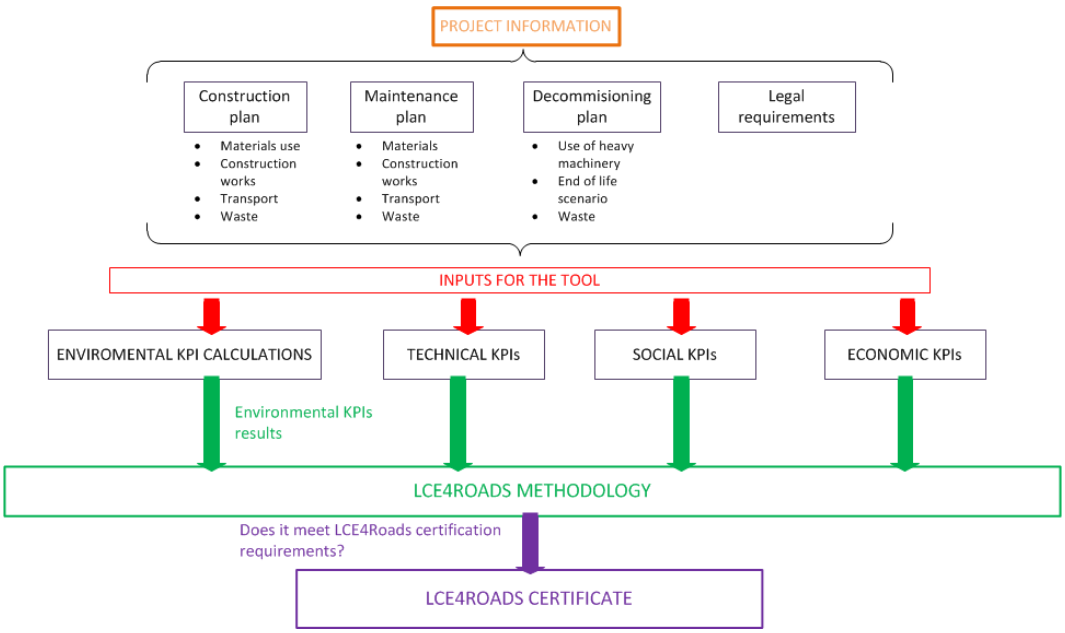

Figure 2 Overview of evaluation process of a road using LCE4ROADS methodology and tool.

To this end, the tool is able to model and calculate the impact of the materials and activities involved in all phases of a road life cycle (planning/design, construction, maintenance/operation) under a holistic multidomain perspective, providing results and recommendations that may enhance the sustainability performance of a road according to LCE4ROADS.

In this sense, an intensive work, summarized in the following activities, has been done:

- In-house development of a full comprehensive database of materials, processes for road construction, maintenance and disposal stages and other relevant information, such as technical and social country-specific legal requirements.
- In-house development of the tool algorithm to model and calculate the impact of roads and its components following the multicriteria holistic approach established.
- Development of the software core tool and integration of the individual components (database, algorithms…).
- Design and implementation of an attractive and use friendly interface
- Development of easy-to-work functionalities for improving the management of the multicriteria software tool

Figure 3 shows a brief overview along the main parts of the LCE4ROADS tool, highlighting some of the most relevant functionalities. As can be seen, besides the expected functionalities regarding the data processing based on the user inputs and the database and algorithms implemented, the software tool provide not only the final certificate but also a variety of functionalities to obtain the results, by means of tables and graphs that can be seen directly on the software interface or exported as excel or .pdf files. Some examples of them are depicted in Figure 4.

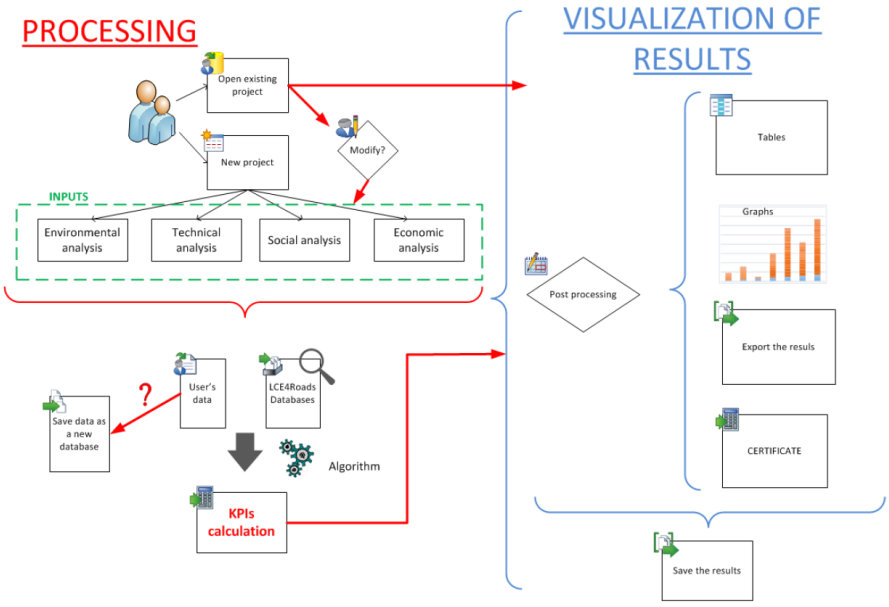

Figure 3 Overview of main LCE4ROADS software modules

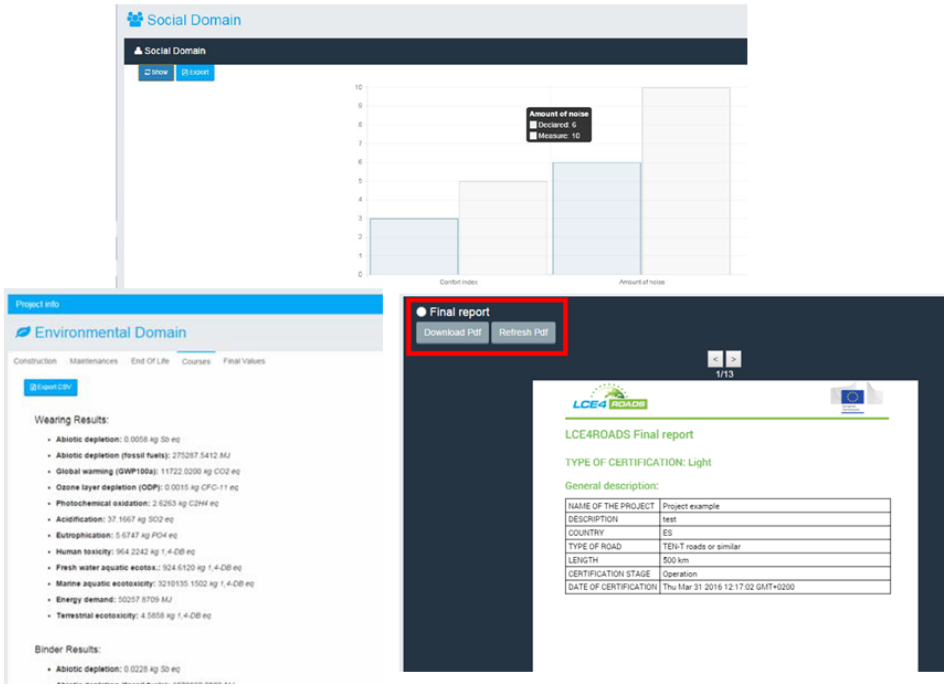

Figure 4 Examples of some results visualization functionalities: tables, graphs and certificate

Focusing on the final certificate, it contains the following sections:

- A general description of the project indicating also the type of certification selected (light/complete) according to the LCE4Roads methodology.
- Results of the road project assessment, including the evaluation of the LCE4ROADS KPIs for the four domains, namely, environmental, technical, social and economic. Additionally, the software tool also indicates if a given KPI is mandatory or voluntary, depending on the selection of light or complete certificate made by the user.
- Apart from the assessment required to obtain the LCE4ROADS certification, the final certificate also includes a section with further information that can be really useful for the tool user. For instance:
  - Recommendations to improve (reduce) the environmental impact of the project, displaying a list of potentially greener and more sustainable materials.
  - Observations about the technical and social performance, comparing the declared or measured values, depending on the certification stage selected, with legal values. In addition, the tool also warms the user if a deviation between measured and declared values was detected.
  - The evaluation of the Net Present Value of the project in case it could be required to determine the cost-effectiveness of the project.
- Finally, several tables with the environmental results disaggregated by LCA stage (construction, use phase and end of life) are also included to allow a more comprehensive analysis of the results obtained.

Although the tool has been created as desktop installation software, the interface of the tool is based on html format, to ensure a friendly and up-to-now look. Consequently, the interface is attractive, modern and user friendly following some user experience analysis in using other software tools and platforms. The tool can be installed in Windows 7 or newer and has been developed using standard open source projects.

Figure 5 shows the appearance of the main menu where the user can find four options:

- *Settings*: To see the database items and configure the database content adding new items
- *New project*: To create a new project, proceed with the evaluation and obtain the certificate
- *Load*: To load a previously saved project
- *Open recent projects*: To view a list showing the latest projects to give easy and quick access to previously saved projects

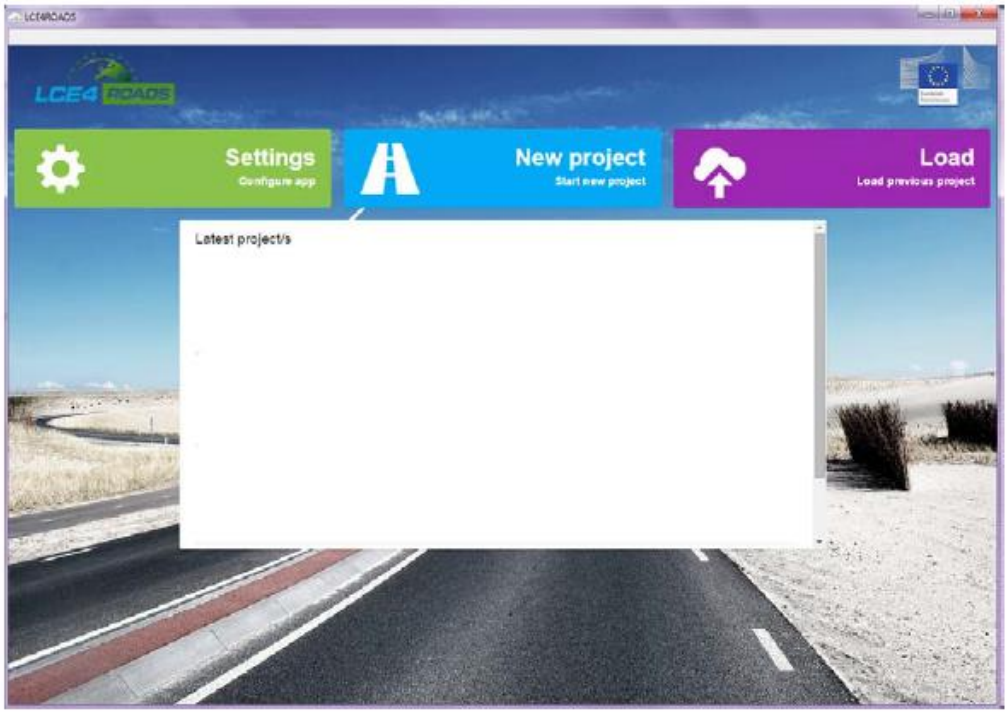

Figure 5 Home screen of the tool

Additionally, Figure 6 shows the structure of the main screen for a project evaluation. This screen is divided in three main sections:

- *Navigation menu* (in red), which allows the user to move quickly among the different domains and road stages. In addition, this section also includes a picture of the project (if it exists).
- *Project input definition* (in green), where the user can introduce all the inputs required to complete the evaluation and the project general information. This screen has available a scroll bar on the right side to facilitate the movement along the sections.
- *Tool bar* (in purple), including quick access to the following functionalities: Hidden the navigation menu, Generate the .pdf certificate, Info button which makes a quick overview alongside the definition screen and Save results button.

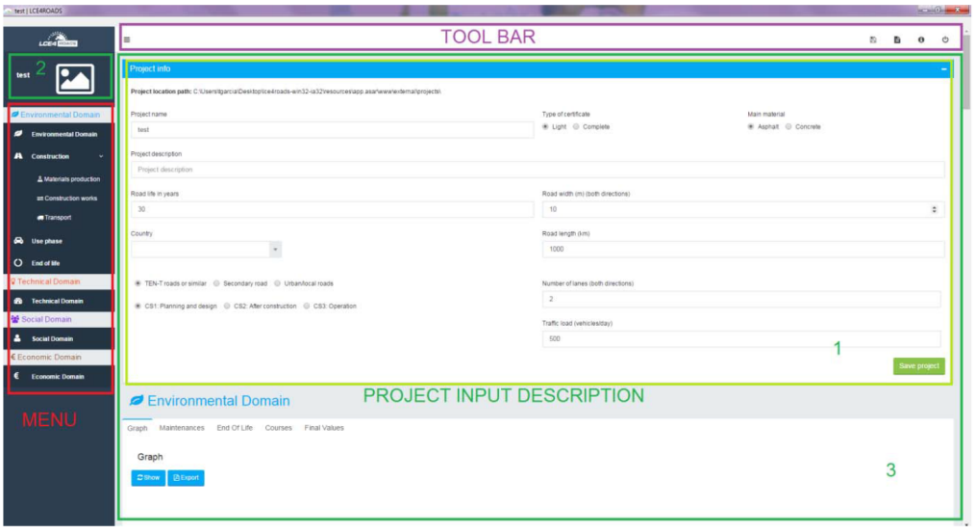

Figure 6 Project definition main screen

As was mentioned before, the software core is mainly integrated by two important components, the algorithms and the database. Both are ad-hoc developments for the purposes of project and the expected impacts sough along of its development.

The software is fed by a full comprehensive in-house developed database of materials, processes for road construction, maintenance and disposal stages, and other relevant information, such as technical and social country-specific legal requirements. Figure 7 shows the database main screen included in the software. This database was developed also as part of the project, being one of the most relevant results obtained. As general figures, it can be mentioned that the LCE4ROADS database includes:

- More than 100 different materials used alongside the European Union.
- 20 types of road construction machinery.
- 16 types of conveyance, including different types of trucks, train and ships.
- More than 100 typical dosages/mixtures for asphalt and cement roads used in different countries of the European Union and Turkey (currently on the road to EU membership).
- Different types of energy use: electricity and heat production by different fuels. When possible, this data is country specific.
- Electricity country mix for European Union countries and Turkey.
- Legal limits for technical and social indicators.

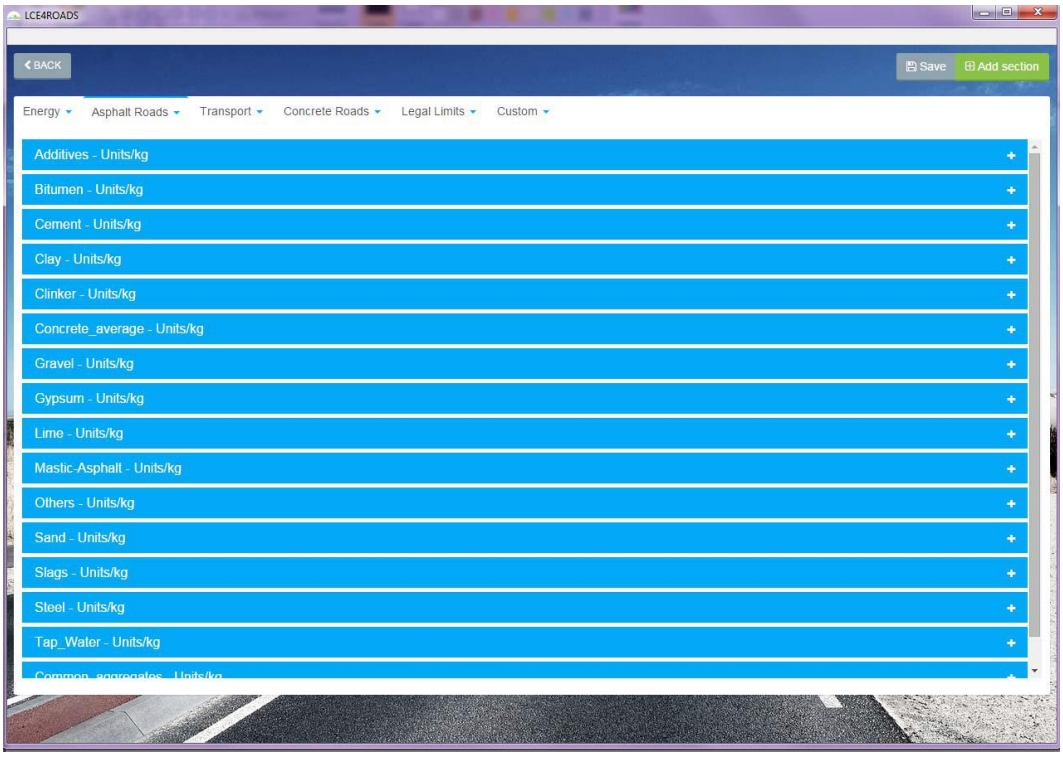

Figure 7 Database main screen

In addition, a custom section (see Figure 6), where the user can also create new elements into the database by completing all the required fields and assuming the entire responsibility on the reliability and accuracy of the data, has been implemented. The information inserted by the users into the tool, combined with this in-house database and the implemented algorithms created specifically for the software development based on the LCE4ROADS methodology, will

enable them to determine the status of their respective projects to obtain the LCE4Roads certification.

The tool aims to boost and facilitate the implementation of the LCE4ROADS methodology in all EU State Members and other countries, supporting decision making of relevant stakeholders and groups of interest in TEN-T (Trans-European Transport Networks) roads and motorway projects.

Apart from public bodies and policy makers who may award the certification, the tool may also be used by road contractors and operators or consultancy and engineering companies in order to evaluate and compare different road projects, by selecting the most proper combination of materials, activities and scenarios according to their particular requirements. The tool creates a certificate with the KPIs values applying the LCE4ROADS methodology. However, the procurer would be the one responsible for taking the final decision about giving or not the certification, which may be supported by additional criteria (such as scoring, limits, or penalties or bonus depending on the KPIs).

a 'Handbook for the use of the tool' has been developed (see D4.2 of the LCE4Roads project). The main goal of the document is to describe the main aspects regarding the LCE4ROADS tool being an easy to use and clear handbook for its use, including a quick overview of most relevant functionalities of the tool, the database management, edition and updating, a description of the procedure to carry out a project creation and evaluation, how the results can be obtained and the final certificate generation.

WP 5: VALIDATION OF THE ECOLABEL METODOLOGY AND THE ASSOCIATED SOFTWARE.

After a comprehensive and complete list of projects selected within WP5, including those selected in WP1 and first case study in WP3, these projects have been analyzed based on LCE4ROADS methodology and cross-checked with the virtual output provided by the software tool. Miscalculations and defects have been identified and solved, and consequently it was possible to ensure that a fully-demonstrated and proven methodology and software tool can be delivered to the market.

KGM, INVESTEKO and NAPE selected three asphalt pavement road projects, and additionally, IECA selected a concrete pavement road project. Since it is aimed to select both asphalt and cement-based real road cases as well as to include both traditional and eco innovative applications, KGM collected data from both traditional and WMA applied sections while other partners collected data from traditional projects.

In accordance with the LCE4ROADS methodology and KPIs list, required data for the selected road cases were collected. As a result, not only data about materials, courses, transport and costs during construction but also data about pavement characteristics (IRI, skid resistance, noise, surface texture) after road construction were collected.

The validation of the LCE4ROADS methodology is described according to ISO standards on LCA. A framework for the goal and scope definition is provided, together with an example of life cycle inventory analysis (LCI), life cycle impact assessment (LCIA) and life cycle interpretation. The validation of the LCE4ROADS software tool was also performed. The analysis of functionality and user friendliness of the tool was carried out. With the feedback given, new versions of the tool were developed and the process of re-evaluation continued up to the practically the end of the project.

The sensitivity of the LCE4ROADS methodology was also subjected to analysis, covering aspects related with changes of the final environmental impact caused by selection of data for LCE4ROADS database. Different data sets were compared and some discrepancies among them were detected. Partners focused on these data, which had the biggest influence on the final environmental impact, therefore aggregates, bitumen and cement were analyzed more deeply comparing with other materials form the database. A deeper inside view on energy sources (and energy mixes) was done, as it also influenced much the final results.

In order to check the proper functioning of tool algorithms, partners carried out analysis of simple case studies for asphalt and cement pavements. Errors and miscalculations detected were reported to the tools development partner, which used this information for further improvements of the tool.

The results from the different case study analysis were reported accordingly. It can be concluded that, the LCE4ROADS methodology defined under WP2 and the LCE4ROADS software tool developed under WP4 and were validated successfully in the WP5.

WP 6: ECOLABEL GUIDE AND IMPLEMENTATION STRATEGIES.

WP6 represented the latest phase of the project as it aimed at development the LCE4ROADS guidelines for the implementation of the new road certification system and set the framework for the most suitable strategies to facilitate the business deployment of LCE4ROADS including how the project outcomes could contribute to the new EU Public Procurement Directive and other innovative initiatives such as the Green Public Procurement Criteria for pavements developed by the Joint Research Centre.

The guidelines set the framework for the deployment of the LCE4ROADS the road certification system during the planning and design, construction and operation phases after assessing performance of environmental, social, economic and technical indicators in future and existing road infrastructures, as well as their construction materials such as asphalt mixtures and cement-based materials. They offer a description of the final list of KPIs, including the measurement methods (i.e. data requirement, performance calculation), level of achievements (i.e. light and complete certificate) and as well evaluation criteria and documentation to be presented during the tendering processes by those parties interested to receive the certificate.

The reliability of the LCE4ROADS methodology relies on the completion of various initial tests for asphalt and concrete materials in small scales. Outcomes of these tests have been used by the consortium to optimize the Guidelines and the associated software (i.e. functioning, requirements, layout) together with the results of its validation in three real projects in Turkey, Poland and Spain.

The implementation plan was developed to identify barriers and opportunities for LCE4ROADS certification system. There are several key issues in the implementation strategy: First, the practices and interests in sustainability assessment are drivers across Europe, but a simultaneous implementation of LCE4ROADS is therefore unlikely to happen so an incremental approach is preferred (focusing on certain countries first). This does require an EU-wide platform to coordinate activities and to safeguard harmonization. Secondly, broad use of LCE4ROADS will require pilot projects in each country to increase interest and gain experience, and to further validate the value of LCE4ROADS. Thirdly, adding a LCE4ROADS certificate including sustainability assessment will generate additional costs in infrastructure projects. Such additional cost may be minimal, especially considering the value gained through improving the

sustainability of road infrastructures. Nonetheless, actors and policy makers will need to decide if the benefits are worth the investment.

In conclusion, the implementation plan of LCE4ROADS described eight activity groups:

- **EU-wide LCE4ROADS platform/committee;** these activities are aimed at preparing the European wide implementation process, and to coordinate and harmonize European initiatives and developments related to LCE4ROADS.
- **Sector & market analyses**; activities aimed at further understanding the infrastructure sector in each country and determine the opportunities for LCE4ROADS. These activities are follow-up activities of the analyses performed within the LCE4ROADS project.
- **Stake- & shareholder engagement;** activities aimed at engaging with interested parties for certification related activities (certification owner, software, certification bodies, etc.) and to seek out actors to endorse and commit to LCE4ROADS (road authorities, contractors, etc.).
- **Pilot projects LCE4ROADS**; an important step in the implementation of LCE4ROADS is to stimulate use of the LCE4ROADS methodology. It is foreseen that several pilot projects will be carried out in each country as a stepping stone to wider use of the methodology and certificate.
- **Certification organization development;** activities to develop an organization that owns, maintains and further develops the LCE4ROADS methodology and certification system.
- **LCE4ROADS methodology development;** the methodology is to be further developed (and the development needs to be tailored to stakeholder requirements.
- **Standardization;** these activities required to align LCE4ROADS to relevant standards and to incorporate LCE4ROADS into standards.
- **Financing**; these activities are aimed at getting the required financial resources necessary for the activities in the other activity groups. These activities are aimed at supporting the successful implementation of LCE4ROADS in the EU and neighboring countries.

d) Provide a description of the potential impact *(including the socio-economic impact and the wider societal implications of the project so far)* and the main dissemination activities and the exploitation of results.

Impacts on industry, as a whole.

From an industry perspective, LCE4ROADS aim for enhancing the application of sustainability concepts along the life cycle of any road project. The involvement of stakeholders in the proposition and evaluation of better designed roads through the measurement of the different impacts on the key performance indicators the LCE4ROADS methodology has proposed may result in:

i) better defined projects;
ii) with well identified impacts on the environment and society;
iii) and financially sound aiming an optimum use of economic resources.

Once the project has been assessed, stakeholders can go through the impacts shown on each indicators and therefore propose or require solutions that addresses specific impacts according to needs and gaps identified on a case by case basis.

From planner/designers to operators, LCE4ROADS is a powerful mean that facilitates the implementation of added-value engineering solutions (greener, safer and cost-effective) that satisfy the mobility and communication needs from user, but at the same time it provides insights on how specific issues that may from a road project affect society and the environment can be solved and properly managed through ad-hoc solutions. The sustainable performance of an original project and the one with improved and innovative solutions can be compared and assess which one of the two better perform in each one of the sustainability domains, provided that the technical performance is fully ensured.

The software tool, in addition, is a wonderful facilitator for using and implementing LCE4ROADS as methodology for assessing the sustainability performance of roads. Since LCE4ROADS can be considered a simplified Life Cycle Assessment that includes the economic, social and technical aspects that affect a road project, a sustainable assessment can be done quickly in due time depending on the schedules managed by stakeholders.

It is very important to highlight that, the LCE4ROADS methodology is supported by the CWA 17089 *Indicators for the sustainability performance of roads*, which has been developed in the European Committee for Standardization (CEN) and published in December 2016, as a CEN Workshop Agreement (a type of European standardization deliverable) as part of the LCE4ROADS Project. This document is based on the results of the project and the comments received from CEN national mirror committees (33 European countries), and agreed on consensus by 20 organization representing sector stakeholders that participated in the CEN Workshop physical and online meetings. Although, the list of indicators in CWA 17089 has some variations respect to the list in the LCE4ROADS methodology, it is worth mentioning that the CWA provides a solid and widely accepted reference for assessing roads from a sustainable perspective and therefore provides the industry with a “close-to-be” standard of practice.

<u>Environmental impacts.</u>

Taking into account the possibility for comparing two different approaches for a same project and evaluate the sustainability performance for the both of them, it is clear that the use of LCE4ROADS may provide direct and positive impacts in the environment. To show an example, the CO_2 emissions from two different versions can be easily estimated with LCE4ROADS, therefore a direct comparison on the benefits on this indicator an innovative solution has can be easily assessed. Ideally, innovative designs/solutions that reduce a 5% of CO_2 emission can provide significant impact on the environment and might be evidenced thanks to the LCE4ROADS methodology.

Nevertheless, in civil engineering project “the best solution” is just the result of a long list of trade-offs between many of the performance indicators on the environmental, economic, social and technical domains. In this sense, the proposed “suggestions for greener, safer and cost effective roads” list a long number of technologies indicating the expected impacts on each one of the domains addressed in LCE4ROADS and the trade-offs that may be faced when implementing them in a real road project. Therefore, the proposed 5% reduction of CO_2 emissions can be possible be achieved through the use of LCE4ROADS evaluated suggestions and measured and certified by LCE4ROADS methodology.

In addition, LCE4ROADS foster a resource efficient approach to road projects. Even if current country specific standards foster the use of recycled materials in road construction, the use of LCE4ROADS definitely will strength this approach by facilitating the assessment of the impacts in other performance indicators and therefore the positive side effects on the rest of the list of indicators contained in the methodology.

Potentially, LCE4ROADS will scale up by integrating the "use-phase" into the sustainability assessment. In spite of its inherent uncertainties, the "use-phase" is critical as greater impacts have been observed during this phase of the road life-cycle. The possibility that LCE4ROADS provides in making a multi-domain assessment of road projects and facilitating the incorporation of innovations in materials, processes and many others may increase the performance of the road by making users to travel more efficiently, that is requiring a 7% less energy for travel for heavy vehicles as stated by different research studies.

Socio-economic impacts

The list of LCE4ROADS indicators shows different areas where a road project can have considerable impact, but independently of the specific domain the indicators belong to, the can have a broader and significant impact in both the social and economic areas.

At first, the use of LCE4ROADS can give communities with relevant information regarding the areas affected by any road project and the implications it may have from an environmental, social, economic and technical perspective. Nevertheless, the technical aspects are often left aside and in hands of experts, but the concepts underneath the other domains, independently of their technical nature, can be understood by practically all stakeholders involved. The main advantage of LCE4ROADS in this sense is that in can provide measures of impact based on data and hypothesis widely accepted and therefore have enough information on all the implications a project have.

This for instance can result in showing to communities how resources are better managed, reducing their associated environmental impact. Similarly, in the different stages LCE4ROADS address for certification, communities can be engaged in order to provide insight on local needs and issues in order to provide better road projects with considerable higher impact.

Since its inception, LCE4ROADS has being understood as a catalyst for implementing greener, safer, innovative and cost-effective approaches to road design, construction and management. Concentrating all sustainability domains in a single evaluation system result in a powerful tool for communicating the use of economic resources to community and how they are used for improving associated impacts of road projects such as the CO_2 emissions and user safety. During the financial crisis started in the late 2000's, especially in Europe, the concern on where public fund have been allocated has raised considerably. In this sense, LCE4ROADS will facilitate the understanding of road project not only as allocation of resources into an asset, but also as an allocation of money on well design and sustainable projects that strength communities, are safer for user and have well identified and minimized impacts on the environment.

Furthermore, LCE4ROADS is a catalyst for new business opportunities. On the one hand, as the business model proposed for exploitation indeed aims at creating a new professional roles that indeed will perform the full sustainability assessment of road projects. On the other, the need for greener and cost-effective technologies for road infrastructures, independently of being used during construction or during operations, may accelerate current research initiatives towards implementable result and require further investments for scaling up technologies and further commercialize them.

This opportunities are in line with the European Energy Plan 2020. The combined effects of incentives energy savings and the possibility to generate opportunities that may improve Europe`s industrial competitiveness, will have the potential for creating up to 2 million jobs and reduce annual greenhouse gas emissions by 740 million tons.

Main dissemination activities

A number of dissemination tools have been developed for the project, including (but not restricted to):

- **Face to face** communication to the stakeholders by the partners.
- **Project website** at www.lce4roads.eu: The project website served as the most versatile communication tool, because it both provides information to a worldwide audience as well as a platform for the project team. It has been regularly updated with an overview of the activities, progress and outcomes of the project.
  The website's structure aimed to provide both easily accessible information for external visitors and special information in more detail, for registered users. It has been active since the beginning of the project and updated towards the end of the project with the results as they evolve and details of the final conference.
  A specific component of the site was reserved to the project beneficiaries to be used as an efficient communication channel between them (e.g. exchange of documents).
- **Project logo, flyer and posters:** A coherent visual identity has been developed for the project, including graphics, templates, styles and guidelines which can be used by partners when presenting their work in electronic and print material.
- **E-newsletter:** The project consortium has published a regular e-newsletter which is accessible through the public part of the website and sent by email to all identified stakeholders. These newsletters have reported the news of the project. LCE4ROADS partners have contributed to setting up a stakeholder list of 1663 people who received the newsletter.
- **Social media** – a LinkedIn group has been set up at https://www.linkedin.com/grp/home?gid=8126039, which in December 2016 had 74 members.
- **Publications**: Articles on the project have appeared in several editions of the FEHRL Infrastructure Research Magazine (FIRM). The ERF newsletter also presented articles during key phases of the project lifetime.
- **Workshops and conferences:** Project partners have participated in a number of events, conferences and workshops where the project has been disseminated through presentations and/or promotional materials both at European and international venues.

Exploitation strategy

There are four main results from the LCE4ROADS project, which are:

The first and most important one is the methodology itself, as the whole list of indicators allows performing a sound assessment of the sustainable performance of a road. Moreover, the other results are strongly linked to the LCE4ROADS methodology, as they all have it as underlying element. Without the methodology, any product or service identified as potential outcome of the project become valueless. It is very important to highlight that, the methodology is supported by the CWA 17089 *Indicators for the sustainability performance of roads*, which has been developed in the European **Committee** for Standardization (CEN) and published in December 2016, as a CEN Workshop Agreement (a type of European standardization deliverable).

The second exploitable result is the certification system, which provides confidence in the declared result ensuring a common approach of the methodology in Europe, based on the

criteria defined in the consortium. It comprises the whole process of collecting data from a project, evaluate the project according to the methodology and issue a certificate which attest that the sustainable performance of the road project have been properly assessed.

The third exploitable result is the software tool which allows the evaluation of the global performance of a road project according to the Key Performance Indicators (KPIs) indicated in the methodology. The tool is able to model and calculate the impact of the materials and activities involved in all phases of a road life cycle (design, construction, maintenance and final disposal) under a holistic multi-domain perspective (environmental, economic, social and technical) and provides results and recommendations to obtain the LCE4ROADS certification.

The fourth exploitable result is a compendium of guidelines, that can be used as training material for professionals interested in LCE4ROADS and customers that require services associated with LCE4ROADS. These guides are the following:

- Suggestions for greener, safer and cost effective road products and infrastructure (Deliverable 3.4, *LCE4ROADS suggestions for greener, safer and cost-effective road products and infrastructure*).
- Handbook for the use of the tool (Deliverable 4.2, *Handbook for the use of the tool*).
- Guide for the LCE4ROADS certificate for road infrastructure (Deliverable 6.4, *Procedure to be awarded with the LCE4ROADS certificate*).

Basic for any exploitation strategy is the assignation of Intellectual Property rights (IPR) on the project results, because the share of ownership on each result will frame the positioning each partner will assume during exploitation. A very small survey was circulated among partners asking for their claims on IPR on each of the project results. The survey resulted in the claims shown in Table 2. 10 partners have IPR claims on the project results and 3 partners have declared they will not claim any IPR.

Table 2 – LCE4ROADS Project partners IPR claims.

	Methodology	***Software tool***	***Certification***	***Guidelines***
ACCIONA	x	x	x	x
BAST		NO IPR		
CIRCE	x	x		x
CHALMERS		NO IPR		
ERF	x		x	x
FEHRL		NO IPR		
IECA	x	x	x	x
IFSTTAR	x	x	x	x
TNO	x		x	x
KGM	x	x	x	x
AENOR			x	
INVESTEKO	x	x		
NAPE	x	x		

Declarations made do not bind any partner to each one of the project results. In fact, further discussion is needed especially in respect to the ownership share each partner has on every project result. Discussions were left aside until the project formally ends, mainly because according to the project Consortium Agreement (CA) *The joint owners shall, within a six (6) month period as from the date of the generation of such Foreground, establish a written separate joint ownership agreement regarding the allocation of ownership and terms of exercising,*

protecting, the division of related costs and exploiting such jointly owned Foreground on a case by case basis.

In the beginning of 2016, a questionnaire was distributed to all LCE4ROADS partners in order to better understand their perception on how the project outcomes should be exploited, including the most suitable business model for doing so. Four business models were proposed, which are the following:

- Consulting company.
- Non-for-profit organization.
- Software company.
- LCE4ROADS Franchise.

From all of them, the "LCE4ROADS franchise" seemed to be the most attractive one, probably because this business model allows reaching bigger geographic areas, reduces infrastructure costs and risks are distributed between the owner and the franchise holder. Moreover, it creates a virtuous circle between the owner and the franchise holder, as the first provides technical support and updated know how and the second provides industry inputs to the owner for better defined new products and offering coming from LCE4ROADS.

e) Provide the public website address *(if applicable)*, as well as relevant contact details.

Web site: www.lce4roads.eu

Table 3 LCE4ROADS Project relevant contact details

Participant	Contact person	Email
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