ERA-NET Road - Energy

Sustainability and Energy Efficient Management of Roads

Final Report

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Foreword

The ERA-NET Road programme Sustainability and Energy Efficient Management of Roads was initiated and cross-border funded by the National Road Authorities of Germany, Denmark, Ireland, Netherlands, Norway, Sweden and United Kingdom. The overall aim of the programme was to improve the common understanding and performance of sustainable development. The whole life cycle of sustainability and energy efficiency should be considered and decision-making tools should be developed with practical application to all stages of road planning, design, construction and maintenance.

The Programme Executive Board (PEB) was chaired by Sweden and FFG in Austria was the programme manager.

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Published reports and results from the projects can be found at the ENR Energy website: http://www.eranetroad.org/

Executive summary

In 2011 the 4th call of the trans-national joint research programme ERA-NET Road (ENR) was initiated, consisting of the subjects Mobility, Design and Energy. This report is a summary of the results within the Energy subject.

The overall aim of ERA-NET Road Energy – Sustainability and Energy Efficient Management of Roads – was to improve the common understanding and performance of sustainable development. The whole life cycle of sustainability and energy efficiency should be considered and decision-making tools should be developed with practical application to all stages of road planning, design, construction and maintenance. To achieve this, three sub targets were formed:

- Develop a common understanding of sustainability and development of a rating system
- Provide an energy-efficient road infrastructure (construction, maintenance and operation)
- Determine the most important road infrastructure characteristics which influence vehicle energy use

Four projects, carried out between 2011 and 2014, were funded by the research programme:

SUNRA (Sustainability — National Road Administrations) had the objectives of providing a common definition of sustainable development within the context of European road authorities and a common system of measurement of sustainability performance at NRA level through the development of a metric or metrics. SUNRA also aimed at providing a framework for a road-project level rating system that enables interventions at the appropriate project stage and for different project types. Furthermore, the project should suggest intervention routes through procurement and Life Cycle Cost (LCC). The definition of sustainable development, along with the metric(s) and rating system should be tested with a selection of NRAs. The main outcome was a planning tool consisting of three interlinked frameworks for the identification, assessment and follow-up of sustainability of NRAs and road projects.

CEREAL (CO_2 Emission Reduction in Road Lifecycles) aimed to develop a decision tool for NRAs and contractors that can calculate the most important contributions of CO_2 emission with focus on pavement maintenance and rehabilitation of in-service roads.

An inventory and evaluation was performed of existing tools that calculate CO_2 emissions of road construction and pavement maintenance. Potential user groups in public and private organisations in Europe were identified and a list of requirements of a new tool applicable in European countries was defined. A decision support tool was developed on the basis of the requirements. The tool can be used to identify low CO_2 emission solutions in road constructions and maintenance.

LICCER (Life Cycle Considerations in EIA of Road Infrastructure) aimed to develop a model for assessment of life cycle energy and greenhouse gas (GHG) emissions of road infrastructure to be used in the early stage decisions of the transport planning process. The main outcome of the project was a model to calculate energy use and GHG emission pertaining to infrastructure construction and traffic using the road located in alternative road corridors. The input data include type and length of the road alternatives: topography; number, length and type of tunnels and bridges; infrastructure elements; traffic (categories) using the road; road-maintenance; and infrastructure decommission.

MIRAVEC (Modelling Infrastructure Influence on Road Vehicle Energy Consumption) had the aim of providing recommendations for road infrastructure design and operation leading to reduced energy use and associated reduced CO_2 emissions from road transport. Effects and properties connected to road-vehicle energy use and the relevant mechanism or connection were described. The sensitivity of fuel use due to a change in the variables was evaluated and a calculation tool based on simplified models was developed. The tool can be used to evaluate the potential savings in vehicle energy use achievable by NRAs actions. The current role of road vehicle energy use and CO_2 emissions in existing systems and opportunities for improvement was studied. Five recommended steps were defined for how to implement an increase in the effectiveness of road vehicle energy use in pavement and asset management systems.

All four projects developed software tools that can be used by NRAs as decision support and/or monitoring tools. The tools are flexible and easy to use. They can be used at different stages of the project planning and they are applicable to both construction and maintenance.

Conclusions emerging from the four projects include that there is a great demand for practical tools that can assist decision makers when it comes to energy use, GHG emissions and other aspects of sustainability in the planning of roads. As the quality of the output is dependent on the quality of the input, calibrated models and reliable metrics should be used wherever possible and quality assurance (preferably by third party) of any data introduced into the tool databases is strongly recommended.

To gain a more consolidated ground for integration into the road-planning process, some of the models will need additional R&D to be fully applicable for practical use in NRAs. Further improvement to the models could be based on R&D involving case studies. Future efforts to tune the four tools could be a means of reaching a higher degree of combined utility of the tools.

In order for these models to be used in NRA decision support systems, great effort should be placed on implementing them. This will require good arguments as well as authorization and support from the senior management of the organisation. It is also important to have access to reliable data and updated models. There is a need for developing a plan for maintaining, updating and improving the software tools.

Recommendations for future activities

A plan for implementing and using the models within the NRA should be developed. A stable organisational platform must be provided to accommodate the models. Responsible bodies must be agreed and funding secured for this to happen. A careful planning of implementation is crucial to ensure the models are accepted within the NRA and its supplier organisations. One strategy could be for the NRA to use two or more of the tools in parallel. Harmonising specific data between the tools would create synergies that could be explored. In this way the NRA would become acquainted with the tools, pros and cons would be identified and handled, and then the tools could be introduced to contractors.

A close cooperation with suppliers/contractors and other stakeholders is recommended to ensure successful implementation of the models. Procurement is a key intervention point for promoting sustainability in road management. Contractors are responsive to requirements in procurement. Tight contractual language is needed to ensure performance.

Another strategy could be to use the tools in a number of case studies in several countries. When planning the implementation of the models in different European countries, careful consideration of the different national settings, legislation and planning practices is strongly recommended.

The need for development activities to improve the tools has already been identified. The NRAs will need to take a leading role here, for instance by securing good institutional conditions for further development of the models to facilitate adaptation to changes in organisational structures, priorities, internal and external demands, etc. Close collaboration between the NRA and its suppliers/contractors and other stakeholders will probably make the improvement activities more efficient and practice oriented.

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1 Introduction

ERA-NET Road – Coordination and Implementation of Road Research in Europe – was a coordination action funded by the 7th Framework Programme of the European Commission. The partners in ERA-NET Road (ENR) were the United Kingdom, Finland, the Netherlands, Sweden, Germany, Norway, Switzerland, Austria, Poland, Slovenia and Denmark (www.road-era.net). The 4th call of the joint research programme was initiated in 2011 and comprised the three subjects Mobility, Design and Energy. This report describes and summarises the main results achieved under the subject Energy.

The overall aim of ENR Energy – Sustainability and Energy Efficient Management of Roads -- was to improve the common understanding and performance of sustainable development in the context of the road authorities. A whole-life consideration of sustainability and energy efficiency was to be considered and decision-making tools with practical application to all stages of road planning, design, construction and maintenance should be developed. The funding national road administrations (NRA) in this joint research project were those in Germany, Denmark, Ireland, Norway, Sweden and the United Kingdom.

The programme was based on three objectives:

A. Develop a common understanding of sustainability and develop a rating system
B. Provide an energy-efficient road infrastructure including construction, maintenance and operation
C. Determine the most important road infrastructure characteristics which influence vehicle energy use

Within the framework of ENR Energy, four research projects were initiated with 19 partners from 10 different countries:

- SUNRA – Sustainability - National Road Administrations
- CEREAL – CO_2 Emission REduction in roAd Lifecycles
- LICCER – Life Cycle Considerations in EIA of Road Infrastructure
- MIRAVEC – Modelling Infrastructure influence of RoAd Vehicle Energy Consumption

Information about the projects can be found at the ENR Energy website:
http://www.eranetroad.org/

A final conference, organised by the Swedish Transport Administration, was held on 12-13 February 2014 in Stockholm. During the conference, the results and overall conclusions of the funded projects were presented. During the conference, there was also an opportunity to participate in group discussions about implementation in general and implementation of the specific projects. A description of the projects, the final reports and deliverables and presentation from the conference can be downloaded from the ERA-NET Road website http://www.eranetroad.org/.

The aim of the present report is to summarise the four projects and their main results as well as to provide recommendations based on the project results and the discussions during the final conference.

2 Project descriptions

2.1 SUNRA – Sustainability—National Road Administrations

Project facts

Duration:	1 October 2011 – 31 December 2013
Budget:	380,000 €
Coordinator:	Clare Harmer, Transport Research Laboratory (TRL), Great Britain
Partners:	TRL
	CH2M HILL, Ireland
	Swedish National Road and Transport Research Institute (VTI), Sweden
	Technical University of Denmark (DTU), Denmark
	TNO Automotive Safety Solutions, the Netherlands

Background and objectives

The background of the SUNRA project was stated as follows in the project application:

"*The National Road Authorities (NRA)s within Europe continuously develop their delivery of road networks. This improvement has been underpinned by significant research in the optimisation of road planning, design, construction and maintenance, which has enhanced the understanding of the social, environmental and economic dimensions of managing a road network. These three types of dimensions are the pillars of sustainability and are addressed at different levels across European countries, through sustainable development plans and strategies. Whilst there is common understanding in some aspects of sustainability there is not a common understanding of sustainability as a whole and thus how to benchmark and improve overall performance.*

The Sustainable Development Strategy for the European Union (EU SDS) sets out a framework for the long-term vision of the EU and highlights certain development priorities. The 2009 review of the strategy reinforces the need to have a balanced approach to sustainable development to meet the global financial, social and environmental challenges. The development plan sets out a vision for Europe in delivering sustainable development but not in the specific context of building and managing a road network. For NRAs to effectively contribute to this long-term vision there must be an understanding, and a clear process identified, of how sustainable development is applicable to all stages of road planning, design, construction and maintenance."

SUNRA had the following objectives:

- Provide a common definition of sustainable development within the context of European road authorities
- Provide a common system of measurement of sustainability performance at NRA level

through the development of a metric or metrics

- Provide a framework for a road-project level rating system that enables interventions at the appropriate project stage and for different project types
- Provide suggested intervention routes through procurement and Life Cycle Cost (LCC)
- Test the definition, metric(s) and rating system with a number of NRAs
- Disseminate the results

Methodology

As a basis for the work, a comprehensive international literature review was undertaken to identify key observations concerning sustainable development, sustainability and road transport, and sustainability and road management. The review also identified both existing and recommended metrics for measuring the sustainability performance of NRAs. To identify opinions on how to design a framework for defining sustainability and how to introduce and apply the sustainability framework in NRAs, SUNRA arranged a seminar in which some 20 representatives of road administrations, governmental organisations, research organisations and consultants participated. A survey of NRAs was also undertaken to better understand current practice with regards to sustainability.

SUNRA produced three interconnected frameworks to help NRAs initially consider incorporating sustainability into their activities or to assist NRAs improve their performance in applying sustainability principles. Given the differences between EU member states in terms of their visions, ambitions, priorities, stakeholder concerns and organisational structures, the frameworks produced are flexible so that they are available to most NRAs. Framework 3 was trialled with a selection of targeted users (mainly NRAs and their suppliers) to ensure that the tool was fit for purpose and consistent to use.

Outcomes

Objective	***Outcome***
Present a common way of defining sustainable development within the context of NRAs	A comprehensive literature survey resulted in an international state-of-the-art report on interpretations of "sustainability" and its application to transport infrastructure with special focus on NRAs. See Deliverable 3, Report (ref. S1)
Ditto	Based on the outcome of the SoA report, the foundation for SUNRA Framework 1 was developed. Framework 1 is intended to support NRAs in their work to define sustainability at a strategic (NRA) level. The framework, comprising 4 steps, helps NRAs define their level of ambition, commitment and their implementation approach. See Deliverable 3, Framework (ref. S2)
Identify how to measure sustainable development	Based on the literature review and workshop, 270 metrics representing the economic, social and/or environmental

at a strategic level and integrate sustainable development decision-making into key intervention points	pillars of sustainability were identified. Addressing 24 priority sustainability topics, the project developed a metric framework (Framework 2) for NRAs to measure their sustainability performance against four levels of ambition. Performance is measured at board, programme and project level. See Deliverable 4, Report and Deliverable 4, Framework (ref. S3 and S4, respectively)
Identification of the state of practice in transportation sustainability assessment	From current sustainability rating systems applicable to transportation, 15 were selected and systematically described according to system owner, certification possibility, credit system and other characteristics. See Deliverable 3.1 (ref. S5)
Overview of perceptions, current practice, interest, best practice and development needs concerning sustainability issues in road projects in a selection of NRAs and other relevant organisations in Europe	A survey was undertaken of NRAs across Europe. Based on 17 questionnaire responses (out of 22 invited), an analysis of views on various aspects of sustainability, such as current practice, ambition, use of tools and R&D needs was performed. The results fed into the development of Framework 3 (described below). See Deliverable 5 (ref. S6)
Identification of starting points for the development of a sustainability rating system framework for road projects	Through discussions with personal contacts, and a workshop with potential framework users in Sweden, expectations relating to Framework 3 were identified. Also, standpoints for framework development were discussed, targeted user groups and suitable intervention points were also identified as well as 32 candidate sustainability topics described. See Deliverable 6 (ref. S7)
Trialling a draft version of the sustainability rating system framework for road projects	National workshops were held with four NRAs (in SE, NL, IRL and UK), and some of their suppliers, to obtain feedback from a selection of potential users of Framework 3 having tested a draft version of the framework. Key suggestions on improvements were used in the further development of the tool. See Deliverable 6/7 (ref. S10)
Providing NRAs, road-construction industry and other stakeholders with a tool to assess the sustainability of individual road projects and report the sustainability development of the project over time	Using input from the trial, Framework 3 was further developed into a tool, which has the potential to be implemented in NRAs. The framework addresses 26 sustainability topics each accompanied with a variety of elements, each equipped with a scoping question to help determine whether or not to include/exclude the element. For many of the elements, a goal is suggested, accompanied with a corresponding indicator. A summary sheet shows the outcome of the achievements towards each target. See Deliverable 9 (ref. S13), preceded by Deliverables 9

	(references S8, S9 and S11)
User guide to SUNRA Framework 3	Organisational-level user guide to the SUNRA sustainability rating framework tool. See Deliverable 9 (ref. S12)
Dissemination of SUNRA results	Results of the SUNRA project to be presented at the Transport Research Arena, April 2014, Paris (ref. S14)

One early output of the SUNRA project was a comprehensive international review of the views and interpretations of “sustainability” and the application of sustainable development in the transport sector and in road administrations. Goals, responsibilities, priorities, delivery methods, approaches to sustainability issues, organisational structures and other features were found to differ greatly between NRAs. The review identified 27 categories of positive or negative impacts of road transport covering the economic, social and environmental pillars of sustainability. A further literature review looked at the metrics and measures currently being used by NRAs related to sustainability. 270 metrics representing the economic, social and/or environmental pillars of sustainability were identified, with 52 being reported by more than one country. This again indicated the wide variation in approaches being undertaken by NRAs.

A questionnaire responded to by 17 NRAs in Europe likewise revealed a wide variety of practice and approaches to sustainability and the extent of sustainability implementation in their respective organisations.

The main outputs of SUNRA are three interlinked sustainability rating frameworks (see Figure 1).

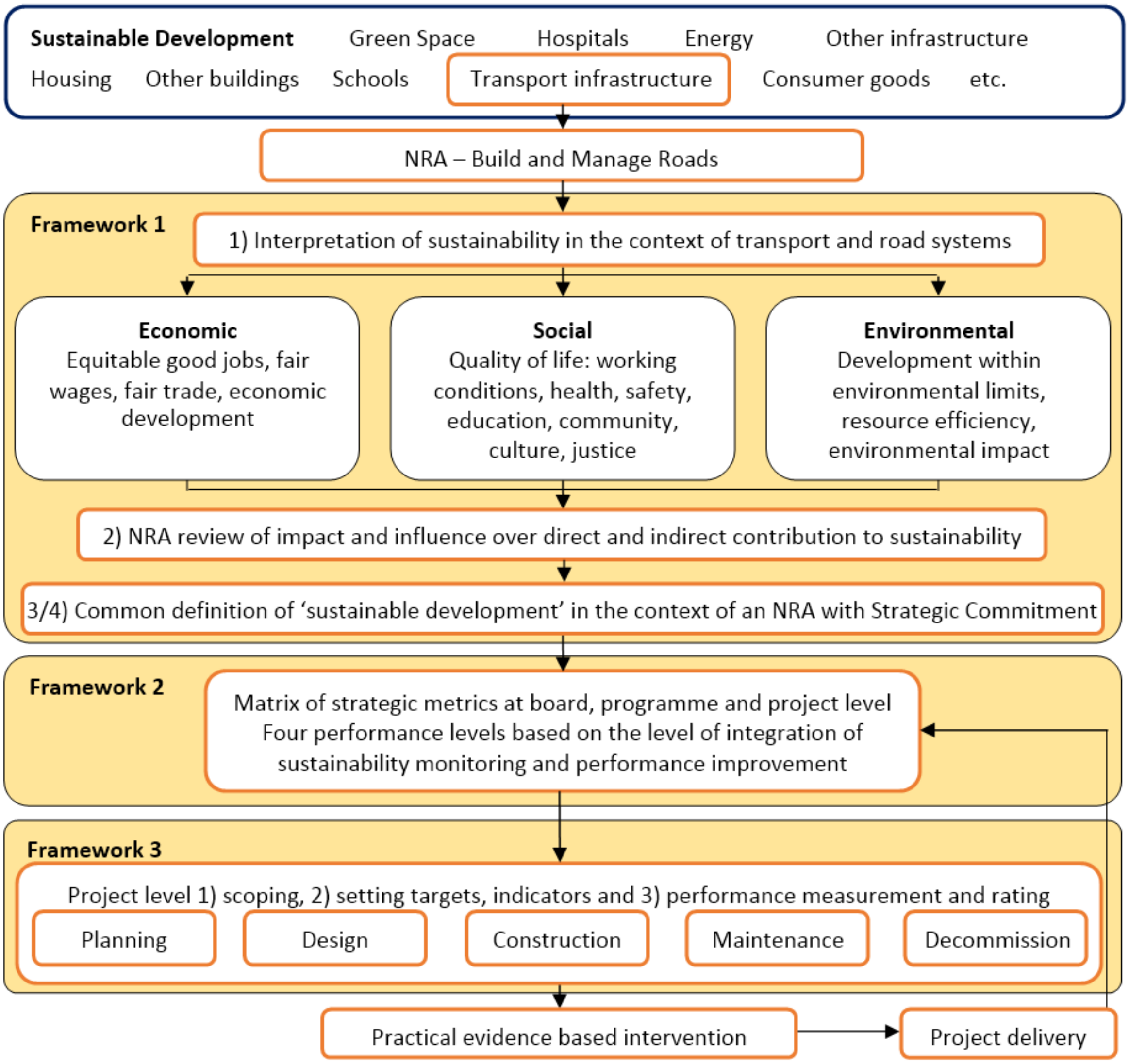

Figure 1: The three interlinked SUNRA frameworks

SUNRA Framework 1 suggests a procedure to define and measure sustainable development performance at a strategic (NRA) level. This framework addresses a wide variety of economic, social and environmental aspects of sustainability. Framework 1 helps NRAs with different organisational structures and levels of sustainability knowledge to:

(1) Consider definitions and principles of sustainability

(2) Identify and develop their responsibility for sustainable development

(3) Choose an ambition level for sustainable development and set appropriate sustainability performance targets, and

(4) Identify metrics and indicators to measure their sustainability performance against four levels of achievement.

Framework 2 provides a matrix of sustainability performance levels for managing and monitoring requirements at project, programme and board level. It is supported by example metrics at each performance and management level for 24 sustainability topics distributed between the three sustainability pillars. This framework allows NRAs to benchmark themselves against each other by allocating themselves into one of the four performance levels, with one being the lowest and four being the highest, and then work their way up the matrix as they extend their work in relation to sustainability and improve performance.

Framework 3 (Figure 2) aims to provide NRAs, the road-construction industry and other stakeholders with a tool to assess the sustainability of individual road projects, and report on the performance of the project over time. Procurement is one of the key intervention points at which the framework can be used. This Excel-based framework addresses 26 topics pertaining to the economic, social and the environmental pillars of sustainability. Depending on ambition, the user may work with all or a selection of the topics. For each topic, a variety of elements has been identified. Each element has a scoping question to help determine whether the element is relevant to the particular project. For each element, some information has been provided to allow discussions related to goal setting. In most cases a potential target has been suggested, accompanied by a metric or indicator. A summary sheet shows the number of topics and elements that are scoped in for the project and the progress being made towards achieving each target. Framework 3 can be used without prior use of Framework 1 or 2, although some consideration is likely to be needed by the NRA in terms of priorities with regards to sustainability before the framework can be properly implemented. Unlike many of the existing sustainability rating systems, the SUNRA project sustainability rating framework does not result in a score and does not require accreditation.

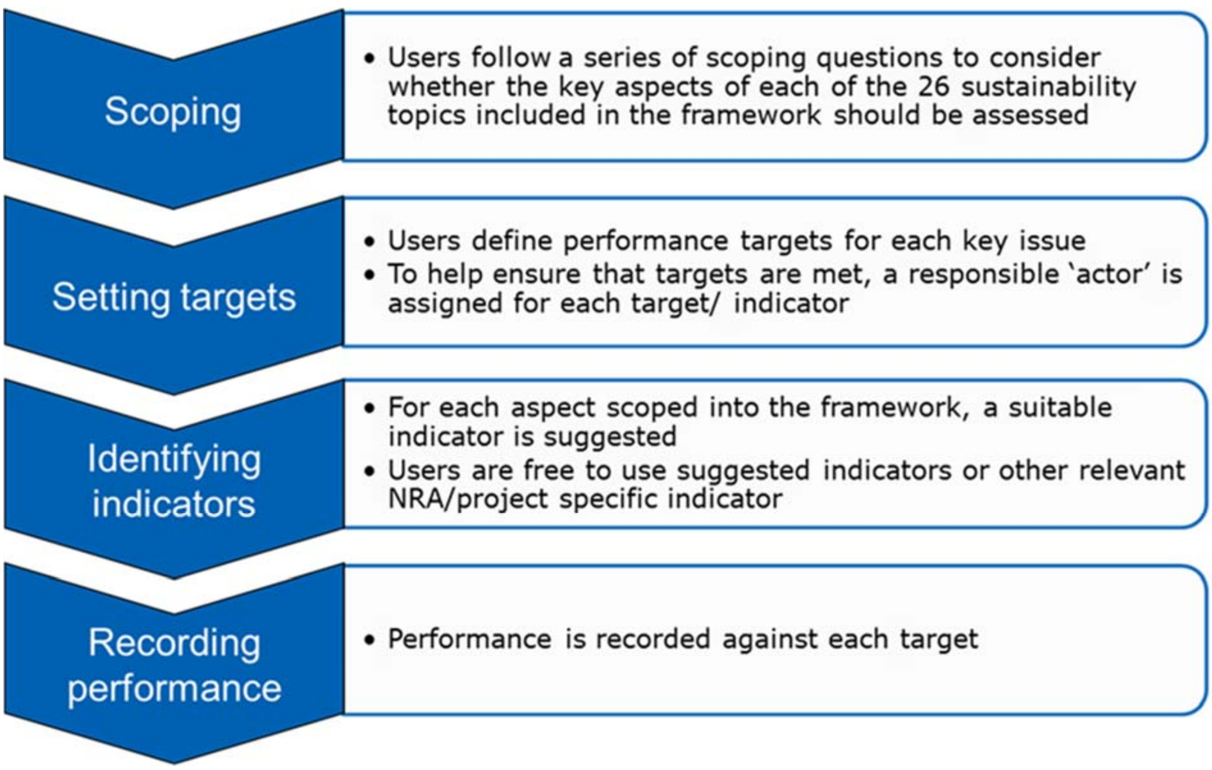

Figure 2: Working process of SUNRA Framework 3 for the sustainability assessment and follow-up of a road project.

2.2 CEREAL – CO_2 Emission Reduction in Road Lifecycles

Project facts

Duration:	1 October 2011 – 1 May 2013
Budget:	334,378 €
Coordinator:	Renilde Spriensma, DHV B.V., the Netherlands
Partners:	DHV B.V.
	Danish Road Institute, Denmark
	KOAC• NPC, the Netherlands

Background and objectives

Enhanced reductions in CO_2 emissions are vital to modern society. Some efforts are currently being made on the computation of CO_2 emissions to identify low CO_2 emission solutions in road construction, however, for most NRAs this is still an area for considerable development. Most available national models focus largely on the design stage or optimisation on the use of materials. Currently, the number of new roads constructed in Europe is generally small whereas the upgrade and maintenance of existing roads is of greater importance. In general, approximately 10% of road construction works involves the construction of new roads while 90% of works involves the maintenance and upgrades of existing roads (ref. C2). Therefore, the tool developed in the CEREAL project concentrates on the maintenance and rehabilitation of existing roads however, it will also be applicable to new roads.

The objective of CEREAL was to develop a decision making tool for NRAs and contractors, which is harmonized at a European level. The decision support is to be in the form of a software tool that can accurately calculate the most important contributions of CO_2 emission with focus on pavement maintenance and rehabilitation of existing roads. In addition, the model can be used as a guide to a CO_2-reduction strategy. The tool should be easy to use for non-experts without losing reliability and accuracy for attaining enough information to make well informed decisions. This is considered an important condition for widespread use of the tool.

Methodology

An online survey was sent to a number of organisations and companies in order to investigate the general level of experience with CO_2-related tools in road projects. To attain adequate responses, the criteria for the respondents were that they should have sufficient knowledge of the road sector, be working for a road authority, contractor or consultancy firm in Europe, and have experience with or a special interest in CO_2 calculations for road construction. Other aims of the survey were to prepare an inventory of existing tools, identify potential user groups, identify possible outcomes expected from the model and the use of specific protocols. Further goals were to verify the scope of the tool and to identify and formulate the requirements of a new model to ensure an effective and long-term use. To get more in-depth information, the online survey was complemented with interviews.

An evaluation of existing available models and data was made where the assessment was divided into background of the CO_2 calculation tool, technical and user-related aspects. Based on the outcome of the survey and the assessment of existing tools, a complementary, harmonized European model was developed. The dominant contributing aspects to CO_2 emissions were identified and included in the model.

Outcomes

Objective	***Outcome***
Inventory and evaluation of existing tools that calculate CO_2 emissions of road construction and pavement maintenance.	Of an initial list of 50 tools, 9 were assessed and evaluated. Pros and cons of each tool were listed. (ref. C3)
Identify requirements for the CEREAL tool to be applicable in European countries.	A list of characteristics of the new model was identified and listed (ref. C1, C2)
Develop a decision-support tool to help identify low CO_2 emission solutions in road construction and maintenance.	The CEREAL tool, Carbon Road Map, has been developed. A testing protocol and procedure was formed and the final version of Carbon Road Map has been tested (ref. C3)
Proper use of the tool.	Training courses, tutorial material and user guide have been developed. Two workshops have been held for interested users, in Copenhagen and in Amsterdam.

The survey performed in CEREAL resulted in 47 completed returns, 18 of which came from relevant stakeholders within NRAs. A general conclusion drawn from the survey, interviews and the assessment of available tools is that none of the existing instruments fulfilled the project needs. Most models were closed and not transparent. They require a large amount of input data and/or have a complex structure. In addition, the existing tools tend to focus more on construction rather than maintenance. It was identified at the start of the project that the maintenance of existing roads was more important than the construction of new roads. However, the available European models provided useful data on materials and components.

Based on the outcome of the survey and literature review, it was concluded that a new tool should be tailored for use on projects in North-Western Europe, which would provide robust and reliable calculations of CO_2 emissions. As a perquisite, the tool should use the best available engineering knowledge and process data but have low data input requirements. Existing databases and calculation rules from the existing models are to be used along with country specific databases. The tool should have predefined maintenance measures and scenarios that are based on present technology. The full life cycle of roads should in principle be included but the main focus would be on maintenance projects and differences in maintenance scenarios. Main road objects, such as tunnels, were to be included if sufficient information was available. Another criterion was that the tool should be open to adding or changing information about project specific data and technology.

The CEREAL model, “Carbon Road Map”, was developed with these requirements as a basis. The tool is easy to use in default mode and it is possible to adjust most defaults in the so-called expert mode. Carbon Road Map (Figure 3) is based on refined engineering calculations and makes use of existing tools and databases. It consists of six main modules:

- Start.
- Project definition – Outlining basic input to the project such as country, type of project, length, number of lanes and slip roads, project life in years and name of the project.
- Construction data – Description of the basic characteristics of the road, for example, design life, speed limits, traffic volume (AADT), share of heavy vehicles, type of road foundation, subgrade and pavement. In the “Details” mode it is possible for the user to define the prerequisites.
- Maintenance – There are predefined maintenance scenarios of treatment and for different lanes. In this section there is also a “Details” mode which allows the user flexibility to freely choose certain parameters.
- Overview
- Results – The results of the calculation shows total CO_2 emissions in tonnes of CO_2-eq for different parts of the road and for the different stages of construction and maintenance. In the Results section, one can also see the CO_2 emissions from maintenance attributable to production materials, transport offsite and use of equipment, see Figure 4.

Figure 3: Outline if the Carbon Road Map produced by the CEREAL project.

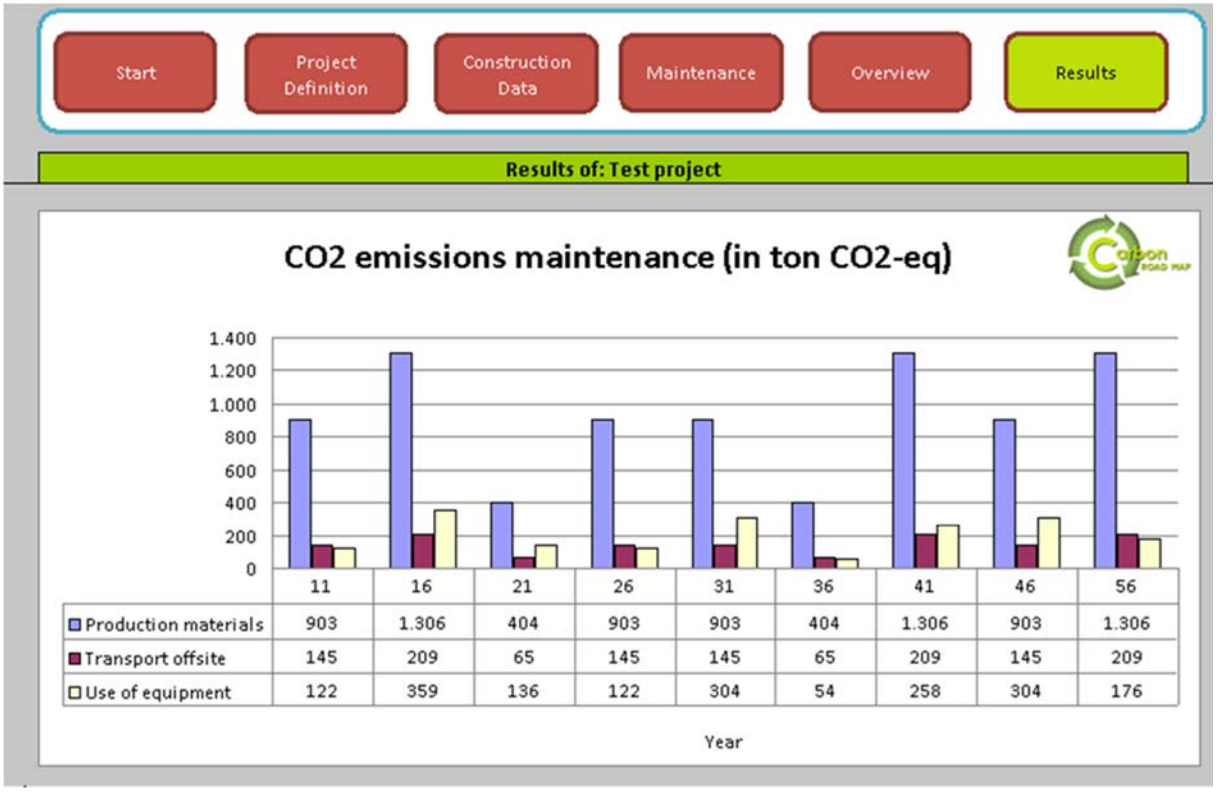

Figure 4: Example of results in Carbon Map Road.

2.3 LICCER – Life Cycle Considerations in EIA of Road Infrastructure

Project facts

Duration:	1 January 2012 – 31 December 2013
Budget:	250 000 €
Coordinator:	José Potting, Royal Institute of Technology (KTH), Sweden / Wageningen University, the Netherlands
Partners:	KTH
	Ecoloop, Sweden
	Harpa Birgisdottir Consulting, Denmark
	Norwegian University of Science and Technology (NTNU), Norway

Background and objectives

For several decades, there has been increasing interest in the possibility of including life-cycle considerations in the early stages of road planning. Life cycle analysis (LCA) is a well-established methodology for calculating environmental impacts of a product system over its entire life cycle. Performing an LCA, however, requires a detailed description of the product system. Therefore, LCA has been sparsely used at early stages of the road-planning process, i.e., at stages where the choice between alternative road corridors has not been identified and the detailed design of the new road infrastructure is not established. The LICCER project was set up to provide road planners with a tool to compare alternative road corridors. The model output may complement the Environmental Impact Assessment (EIA) process, be added to the socio-economic assessment (i.e., as part of the cost-benefit analysis), or be integrated with an overall assessment. The LICCER model developed for this project will therefore support decision-makers in selecting the most appropriate road corridor out of several alternative corridors. The environmental impacts addressed by LICCER are energy use and emission of greenhouse gases (GHG). Energy use is often a reasonably good indicator for a range of other environmental impacts, including acidification, eutrophication and photochemical ozone formation.

The aim of LICCER was to develop "*a model for assessment of life cycle energy and greenhouse gas (GHG) emissions of road infrastructure to be used in the early stage decisions of the transport planning process*" (Potting et al. 2013; Report 6/ref. L10).

Methodology

LICCER used three approaches to include LCA considerations in the road-planning process (Lundberg et al. 2013; Report 4.1/ref. L5):

- Integrated in the Environmental Assessment or EIA
- Integrated in an overall environmental assessment that documents and evaluates a wide range of impacts serving all decision perspectives
- Integrated in the socio-economic assessment, e.g. using CBA

More or less from scratch, the LICCER model was gradually developed with the aid of the following:

- a literature study (environmental statement reports from SE and NL)
- an overview of the road-planning processes in SE, NO, DK and NL
- in-depth interviews with Swedish and Dutch stakeholders (NRAs, consultants and researchers)
- information from the Norwegian and Danish NRAs, consultants and researchers
- project-team meetings
- two workshops with external participants representing NRAs and other stakeholders
- application of a preliminary version of the LICCER model to actual road projects, one in Sweden and one in Norway

The LICCER model comprises energy and GHG-emission calculations pertaining to four road-infrastructure elements:

- Production (e.g., asphalt, aggregate, steel)
- Construction (e.g., diesel and electricity used for transport of materials)
- Operation (e.g., resurfacing, lighting, ventilation)
- End of life (material removal, demolition and transport)

as well as

- Road traffic (during the service time of the road)

During the project period, there was significant information exchange between LICCER and CEREAL.

Outcomes

Objective	***Outcome***
Evaluation of the Dutch and the Swedish use of Environmental Assessments	Overview of road infrastructure planning process and the use of Environmental Assessments in the Netherlands and Sweden. See Kluts and Miliutenko (2012) (ref. L4) and Miliutenko et al. (2012) (ref. L13)
Overview of the road-planning process in NL, DK, SE and NO	Contributions to conferences; journal manuscript (in preparation). See Miliutenko et al. (2012) (ref. L18), Miliutenko et al. (2013) (ref. L14) and Miliutenko et al. (forth-coming) (ref. L15)
Input of stakeholder views on coupling LCA with the road-planning process as well as expectations on the LICCER model	Workshop 1 with stakeholders from NL, DK, SE and NO. See Lundberg & Toller (2012) (Report 1/ref. L6)
Stakeholder test of a preliminary version of the LICCER model and input of stakeholders' views on its relevance and applicability	Workshop 2 with stakeholders mainly from SE. See Potting et al. (2013) (Report 3/ref. L11)
Development of a model for assessment of life cycle energy and GHG emissions of road infrastructure to be used in early-stage decisions of the transport planning process	The LICCER model, preceded by preliminary versions. Reports pertaining the final version: Brattebø et al. (2013 a) (Report 2/ref. L1), Brattebø et al. 2013b) (=Report 4.2/ref. L2), Lundberg et al. (2013) (Report 4.1/ref. L5) and Potting et al. (2013) (Report 6/ref. L10) Reports pertaining to preliminary versions: Liljenström (2013) (ref. L7) and Van Oirschot (2013) (ref. L12)
Evaluation of the applicability and robustness of the LICCER model as tested on a Swedish road project as a case study	Input to amendment of the model. Traffic-related model output (energy use and GHG emission) was in both case studies highly dependent on assumptions on future fuels and energy mix. The change in traffic, i.e. the road-distance difference between alternatives, contributes in both case studies very much more to road-lifetime energy use and GHG emission than does infrastructure itself. Infrastructure will become more important, however, when road-distance differences between alternatives become smaller, and also when traffic gradually becomes more energy efficient and carbon neutral (as European policies target for). See Liljenström et al. (2013) (Report 5.1; ref. L8),

	Miliutenko et al. (2014) (ref. L16) and Potting et al. (2013) (Report 6/ref. L10)
Evaluation of the applicability and robustness of the LICCER model as tested on a Norwegian road project as a case study	Experience from testing the amended model on a Norwegian road project. The results pointed out the importance of: using a realistic scenario of energy efficiency and fuel mix and consumption during the service life of the infrastructure; taking service-life differences between infrastructure sections into account; and using case-specific parameters (e.g. topography) where available instead of the default ones. See Iversen (2013) (ref. L3), O'Born et al. (2013) (Report 5.2; ref. L9)

Planning processes targeted by LICCER are outlined in Figure 5.

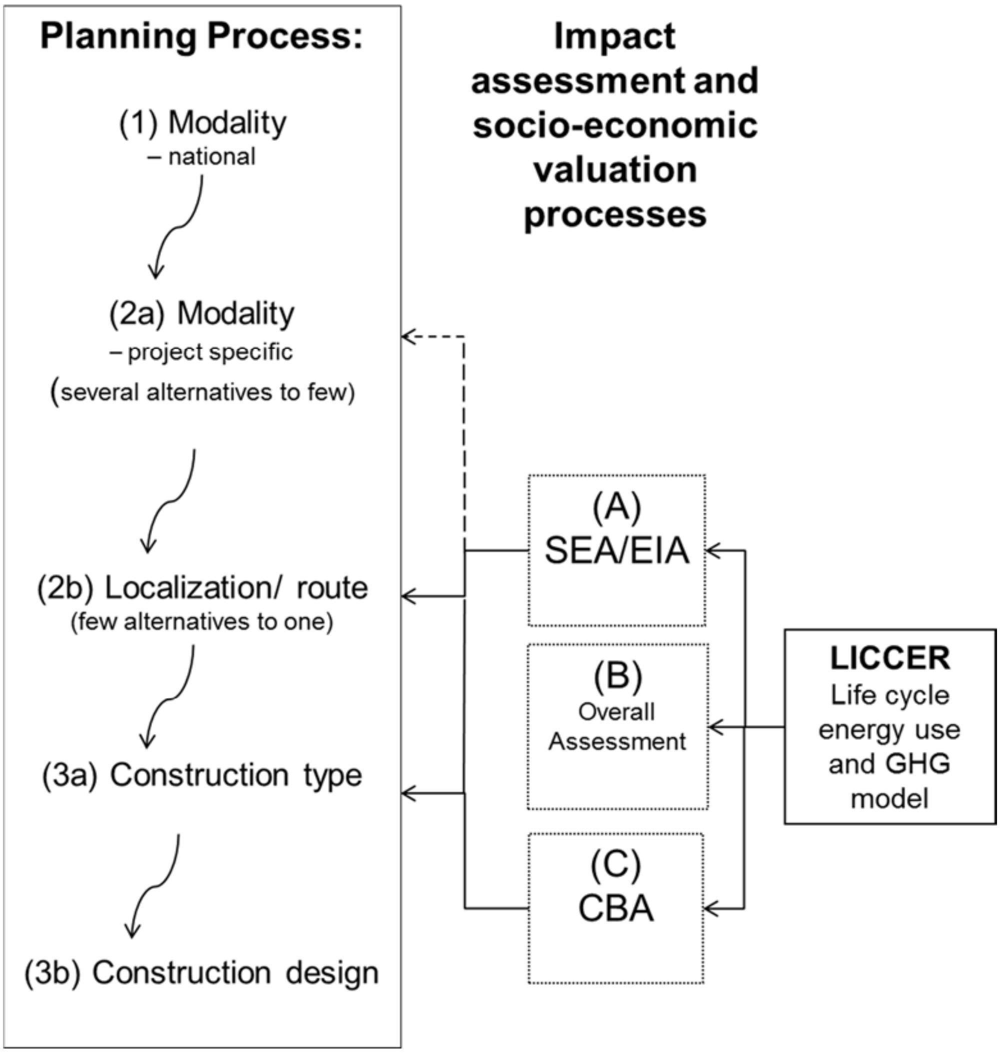

Figure 5: Suggested use (A, B and C) of the LICCER model in the transport decision and planning process

The LICCER model calculates energy use and GHG emission pertaining to infrastructure construction and traffic using the road located in alternative road corridors. The input data mainly comprise of the following:

- type and length of the road alternatives
- topography
- number, length and type of tunnels and bridges
- infrastructure elements
- traffic (categories) using the road
- road-maintenance
- infrastructure decommission

The model contains default (national) data on (material) transport distances, specific consumption of materials, electricity and fuels, and emission and energy factors for different vehicle categories. Where available, the model user can substitute default values by real-case values. This is recommended when project-specific values are easily available in early-stage planning, and particularly in cases that include large amounts of high-impact materials and heavy infrastructure. A sensitivity analysis of the Norwegian case study showed that inserting case-specific parameters for the bridges resulted in much higher energy use and GHG emission than those calculated for the default-type of bridges in the LICCER model. Also, energy use for tunnel lighting using modern and innovative technology will most probably be much lower compared to the model's default values based on present-day technique. This is especially important with regard to the long service life of a tunnel. The Norwegian case study also evidenced the importance of considering realistic forecasts of energy use of traffic and infrastructure maintenance as well as using case-specific input data as far as possible instead of the default ones.

The two case studies, where there was a considerable difference in road distance between the alternatives, gave strong further evidence of a clear dominance of traffic over infrastructure construction when energy use and GHG emission are calculated for the service life of a road. Infrastructure will become more important, however, when road-distance differences between alternatives become smaller. Present European policies, targeting for carbon neutrality and considerable energy efficiency improvement for traffic, will also increase the importance of road infrastructure. These conclusions were possible to draw thanks to the inclusion of traffic as an additional element in the model; this model extension was beyond the agreement in the LICCER project contract.

The LICCER model is constructed in Excel and is characterized by transparency and ease of use. Although equipped with default values of many parameters, substitution by case-specific input data is strongly recommended. In Figure 6 there is a schematic showing the comparison mode and in Figure 7 there is an example of some of the results calculated by LICCER. In this example, the comparison between the three road alternatives gives completely different outcomes depending on whether construction material or traffic is compared.

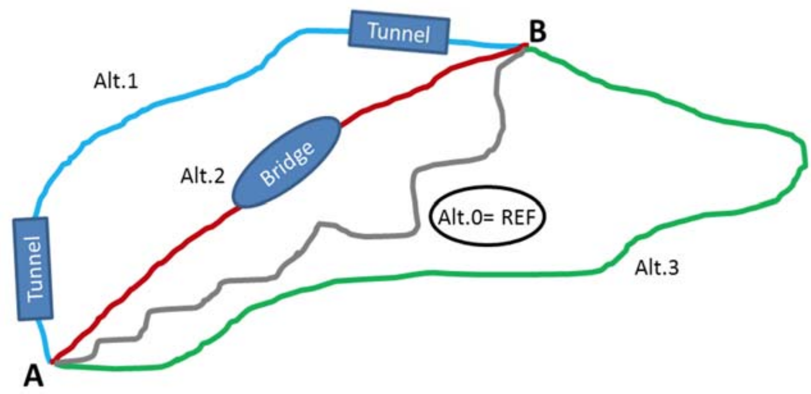

Figure 6: Schematic sketch of the comparison and adding-up mode

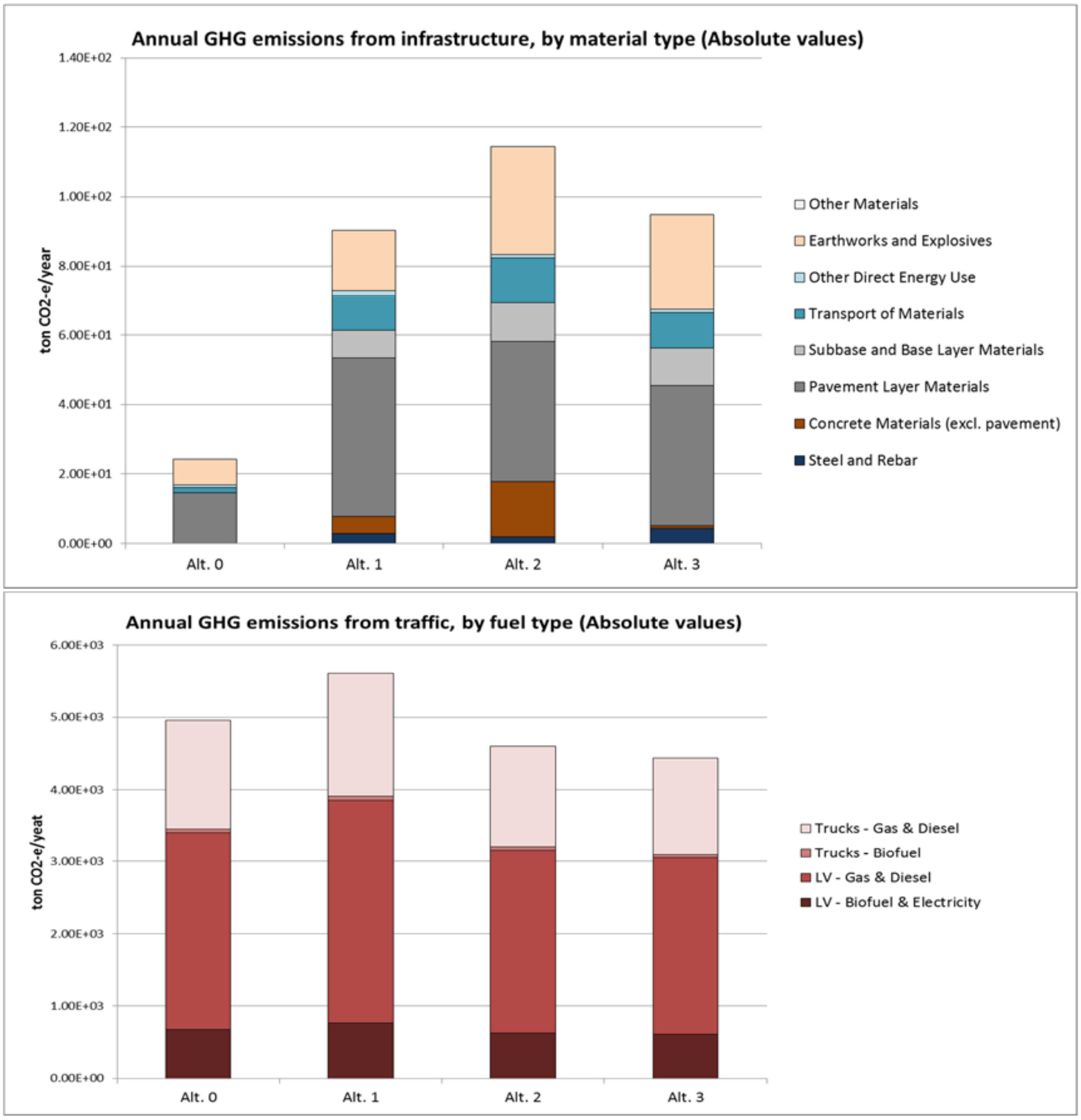

Figure 7: Illustration of a potential outcome of a comparison between three road alternatives using LICCER.

2.4 MIRAVEC – Modelling Infrastructure Influence on Road Vehicle Energy Consumption

Project facts

Duration: 1 October 2011 – 31 October 2013

Budget: 290.000 €

Coordinator: Manfred Haider, AIT Austrian Institute of Technology GmbH (AIT), Austria

Partners: AIT

Centrum Dopravniho Vyzkumu (CDV), Czech Republic

Forum of European National Highway Research Laboratories (FEHRL)

Slovenian National Building and Civil Engineering Institute (ZAG), Slovenia

Swedish National Road and Transport Research Institute (VTI), Sweden

Transport Research Laboratory (TRL), Great Britain

Background and objectives

CO_2 emissions from road transport represent an important part of the overall emissions of GHG in society. Consequently, they contribute to the on-going climate change. Therefore, it is important to engage in efforts to reduce those emissions, and all influencing factors on energy use of road vehicles have to be considered. Road infrastructure and its characteristics have an important influence on traffic fuel use. Technologies to improve these characteristics related to fuel consumption can contribute to an overall CO_2 reduction in road transport. Road infrastructure measures to achieve this will need to complement parallel efforts in the fields of low-emission vehicles, energy saving tyres and intelligent road transport systems. However, this requires both a thorough understanding of those interactions and implementation of the results in current pavement and asset management practice. The impact of different infrastructure designs needs to be well understood and modelled to give road administrations a sound basis for management decisions. In parallel, road administrations need knowledge about the limitations of available data and models.

MIRAVEC aimed at achieving a more holistic view considering a wide variety of effects. The main objective of MIRAVEC was "…*to provide recommendations for road infrastructure design and operation leading to reduced energy consumption and associated reduced CO_2 emissions from road transport*…".

As a complement to the main objective, the following aims were also defined:

- Identify the most important effects contributing to road vehicle energy use, which are due to the interaction with road infrastructure and to determine suitable infrastructure parameters that can describe those effects.
- Describe the existing modelling tools and evaluate their capabilities with respect to analysing the effects identified as being most important.

- Assess the potential for NRAs to achieve reductions in vehicle energy use, and to understand how this is influenced by the traffic flow, vehicle characteristics and infrastructure design.
- Gather knowledge into existing pavement/asset management systems and to identify associated opportunities and risks.

Methodology

The impact of road infrastructure on the energy use of road vehicles has been examined in a number of previous projects. MIRAVEC built on the existing knowledge and models to achieve a more holistic picture. Different road infrastructure variables, which can contribute to the overall road vehicle energy use, were described. The variables that can be influenced by infrastructure design were highlighted.

The most important effects which contribute to road vehicle energy use and which are due to interaction with the infrastructure and their associated variables were identified. The compilation of the effects and parameters served as a basis for an evaluation of the necessary modelling tools for the effects. A spreadsheet model was developed using Excel where the relative importance of the different factors was assessed. Using the MIRAVEC tool and case studies, the potential savings in vehicle energy use that can be achieved by NRAs by making changes to the road infrastructure were evaluated.

An on-line questionnaire was distributed to NRAs in Europe and USA to investigate the current role of road vehicle energy use and CO_2 emissions in road pavement and asset management systems. To support energy efficiency considerations in the decision-making processes of NRAs, specific recommendations on how to implement the available knowledge, or models and tools, into existing pavement/asset management systems were given.

Outcomes

Objective	***Outcome***
Inventory of road infrastructure variables influencing vehicle energy use. Identifying the most important effects contributing to vehicle energy use	For each effect or property, the relevant mechanism or connection to road vehicle energy use was described. A list of variables was developed and sorted into five groups. Of these, the most important factors were highlighted. (ref. M1)
Description and evaluation of modelling tools and projects for the effects defined as the most important	A selection of projects having studied road characteristics and the effect on energy use were described and evaluated. A table was presented of projects and the variables they include. (ref. M2)
Evaluation of the most important factors and proposal for inclusion of additional variables	Using a statistical approach, the sensitivity of fuel use due to a change in the variables was evaluated. The effects on fuel use due to changes in the variables and for different road types and vehicle types were described. Some additional variables

	that can, at a later stage, be considered were identified. (ref. M2)
Development of a method for estimating vehicle energy use due to the influence of different road characteristics	A spreadsheet calculation tool based on simplified models was developed. (ref. M3)
Evaluation of the potential savings in vehicle energy use achievable by actions taken by NRAs	Using the MIRAVEC tool, six case studies were performed and compared. (ref. M3)
Knowledge of the NRAs on existing models and possibilities for implementation. Identification of the current role of road vehicle energy use and CO_2 emissions in existing systems and of opportunities for improvement	14 countries answered a web-based questionnaire. The result shows the attitudes to the importance of traffic fuel use and also what variables are included into existing pavement/asset management system (PMS/AMS). (ref. M4)
Recommendations for implementation of road vehicle energy use in pavement and asset management systems	Five recommended steps for implementation were listed. (ref. M4)
Dissemination strategy	Presentation material, newsletter and website. (ref. M5)

A list of 24 variables in total was identified and grouped into the following five groups:

A. Effects of pavement surface characteristics (6 variables)

B. Effects of road design and layout (6)

C. Traffic properties and interaction with the traffic flow (5)

D. Vehicle and tyre characteristics including the potential effect of technological changes in this area (3)

E. Meteorological effects (4)

Of these, it was found that the NRA can most likely control effects from groups A and B, either via road planning and construction or via monitoring and maintenance. It was established that the necessary data for developing a model are more or less available. For some effects, there were indications that new or further developed variables could improve the prediction capabilities of the models. Some knowledge gaps were identified that concerned the relevance of surface defects and road strength, the influence of road infrastructure features on driving speed, the effects of ITS measures, the degree of adoption of electric vehicles and low rolling resistance tyres and the impact of precipitation on rolling resistance. Of the 24 variables, 15 were proposed for further analysis in the project (ref. M1).

A number of projects have studied the effect of road characteristics and the effect on energy use. A selection of these projects were described and analysed. Results show that there can be benefits concerning energy use in taking the energy aspect into consideration when planning a new road or choosing pavement rehabilitation measures.

For analyses of the influence of road variables on traffic fuel consumption, a microscopic model is considered the most appropriate, since it is capable of describing the input data in detail. For the development of the MIRAVEC model, it was decided that a generalized fuel use estimate generated by the VETO model should be used as input, since this was considered the most efficient solution. With this, it is possible to consider speed, vehicle type and emission concepts, sight class of rural roads with curvature and gradients and urban roads. However, there is a need to develop a routine that makes it possible to take changes in roughness and macrotexture into consideration.

A sensitivity analysis was performed using the information of the Swedish state road network (ref. M2). The results show a close to linear relationship between relative changes in the analysed road variables and the relative change in fuel use. In general, changes in the gradient lead to the largest impact, followed by macrotexture and horizontal curvature. The relative changes are larger the heavier the vehicle but the changes are also dependent on the road type. Some variables have been identified that are likely to have an effect on fuel use but there is a need for further research before they can be included. These are rolling resistance effect of rutting, speed effect of macrotexture, presence of water, moisture, snow or ice, and also road deterioration model that considers surface defects and road strength.

The MIRAVEC tool was developed as an Excel spreadsheet and brings together a number of models and studies of fuel consumption (ref. M3). The tool is expected to be used mainly in the road planning phase, to assess either construction or maintenance alternatives and schemes. The input data needed are divided into two main categories: global data and local data.

The global data concern:

- Traffic breakdown – The distribution of traffic by vehicle sub-classes and Euro class.
- Traffic flow distribution – Makes it possible for the user to define peak/off-peak hours of the day.
- Default values – This page consists of predefined default values that will be used in case any of the cells in the local data sheets is left blank. The users have the possibility to enter their own default values specific for their country. In this sheet it is possible to enter values for uncertainty that are used to calculate expected error in the output.

Local data are defined for the route to be studied and data can be entered for shorter sections of the route that are of homogenous nature:

- Road layout – Carriageway width, number of lanes, presence of a junction.
- Speed limits – Defined for each of the vehicle classes.
- Pavement characteristics – Details about gradient, curvature, road roughness macrotexture and rut depth.
- Traffic volume – Annual average daily traffic (AADT).

- Traffic speed for all flow groups – Shows the average speeds and idle time calculated by the speed model for each flow group.

The model calculates traffic fuel use and CO_2 emissions as an overall value for a specified route and on a graph format over the length of the route. Furthermore, it is possible for the user to compare two scenarios to investigate the effects of changes to the route on fuel consumption.

The MIRAVEC model has been used to perform six case studies to evaluate the capacity for NRAs to provide energy reducing infrastructure (ref. M3). Data for specific lengths for various road types and from different countries were used. The findings are that the effectiveness of intervention depends on the condition and traffic levels on site. It will therefore be necessary to investigate schemes on a case-to-case basis.

The on-line questionnaire was answered by 14 countries in Europe (ref. M4). In general, the countries agree with the statements that reducing CO_2 emissions from transports is important and urgent where vehicle energy use is an important factor for an overall reduction. In addition, improvements of road infrastructure is seen as an important contributing factor to an overall reduction of CO_2 emissions. Eleven countries have a PMS/AMS system developed in-house and Figure 8 shows how common it is that different properties are considered (ref. M4). As shown, traffic volume, surface texture and longitudinal evenness are monitored by all 14 respondents. However, only six of them have environment-related methods/models in use. Also, monitoring energy use within the existing PMS/AMS is not common today.

The answers also revealed that the most expected way of using new models would be for prognosis of the evolution of CO_2 emission over time, based on different budget levels for the different maintenance treatments/measures modelled. Even though monitoring energy use of traffic is considered important, the respondents foresee some difficulties with introducing new parameters and rule sets for vehicle fuel use into the existing system, e.g. acceptance, funding and technical perspectives such as measuring and modelling.

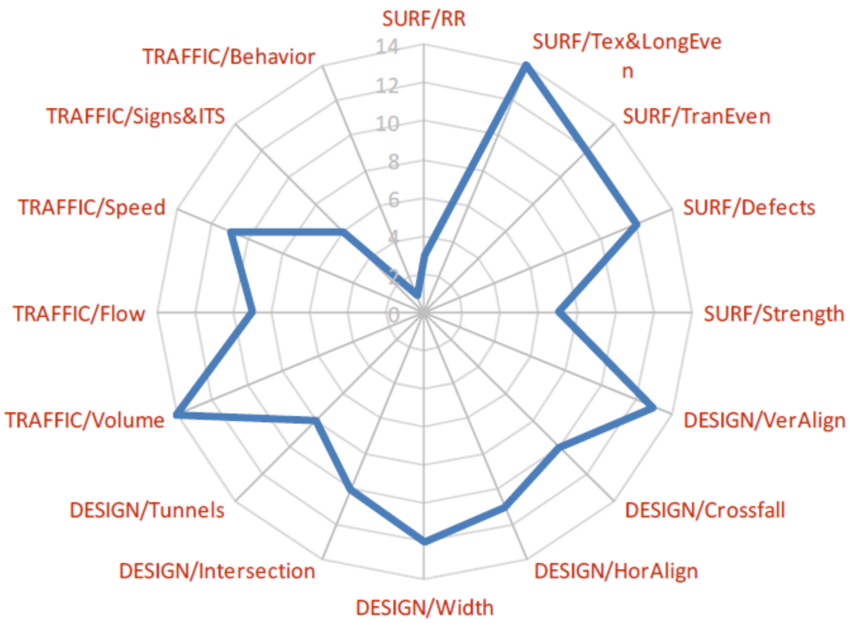

Figure 8: Properties considered in Pavement Management Systems (ref. M4)

The following steps are recommended for how to implement vehicle energy use and CO_2 emissions in PMS/AMS:

1. Prepare clear policy goals and rules through, e.g., road agency or central government
2. Perform theoretical studies concerning appropriate vehicle/pavement models, deterioration models and optimization models
3. Perform and evaluate practical studies; good experience in different EU countries is important; verify models; set adequate form for proper input data
4. Prepare implementation process
5. Start using vehicle energy use/CO_2 emissions as performance indicator

3 Final Conference

An international conference, organised by the Swedish Transport Administration in cooperation with ERA-NET Road, was held on 12-13 February 2014 in Stockholm. The aim of the conference, “Sustainability and Energy Efficient Management of Roads”, was to present the four ERA-NET Road Energy projects SUNRA, CEREAL, LICCER and MIRAVEC and their main results to road authorities and their contractors, entrepreneurs and consultants in the construction sector, researchers, stakeholders and others interested in sustainable and energy-efficient road management. The conference was attended by 82 participants.

3.1 Open session

The programme of the open session (found at http://www.trafikverket.se/eranet/) included:

Åsa Lindgren, Swedish Transport Administration: **Welcome and introduction**

Jon Krokeborg, Norwegian Public Roads Administration: **Presentation of ERA-NET Road**

Lars Nilsson, Swedish Transport Administration; Bjarne Schmidt, Danish Road Directorate; Vincent O’Malley, National Road Administration, Ireland; Jan van der Zwan, Rijkswaterstaat, the Netherlands; Bob Hamel, Norwegian Public Roads Administration and Dean Kerwick-Chrisp, Highways Agency, UK: **Strategies and goals—Presentations from national road and transport administrations**

Clare Harmer, Transport Research Laboratory, UK and Chris Sowerby, CH2MHill: **SUNRA: Experiences and expectations**

José Potting, KTH and Helge Brattebø, Norwegian University of Science and Technology: **LICCER: Experiences and expectations**

Manfred Haider, Austrian Institute of Technology and Emma Benbow, TRL: **MIRAVEC: Experiences and expectations**

Michael Ruben Anker Larsen, Danish Road Directorate: **CEREAL: Experiences and expectations**

Steve Phillips, Conference of European Directors of Roads: **The way forward on sustainability and energy issues**

Tomas Kåberger, Chalmers University of Technology/Japan Renewable Energy Foundation: **Worldview in the eyes of others**

Representatives of NRAs: **Panel discussion**

Lars Nilsson: **Closing remarks**

Krokeborg presented the organisation, mission and goals of ERA-NET Road. He explained the idea behind ERA-NET Road's guiding terms: "Trust. Understand. Commit". The overall aim of ERA-NET Road's programme "Sustainability and Energy Efficient Management of Roads" is to improve the common understanding and performance of sustainable development, and further to i) develop a common understanding of sustainability and development of a rating system; ii) provide an energy efficient road infrastructure (construction, maintenance and operation); and iii) determine the most important road infrastructure characteristics which influence vehicle energy consumption.
He also presented the network organisation CEDR, its goal and its procedures for coordination, management and dissemination.

The representatives of the national road administrations presented the main missions, strategies and goals of their organisations, especially concerning energy efficiency and carbon dioxide emissions. Though differing in the emphasis on various parts of their priorities, the road administrations were found to share a common view of the importance of giving high priority to sustainable development of the road transport system and energy efficiency of road management and road traffic. Among issues highlighted were the carbon footprint of the transport sector, a life-cycle approach, a fossil-free transport sector, sustainability consideration in the planning process, and the need for a range of actions and a holistic view to reach the goals.

Representatives of **SUNRA, CEREAL, LICCER** and **MIRAVEC** then presented results from their projects. All of the projects have developed software tools that can be used by the NRAs as decision support and/or monitoring tools. The common denominator of the tools is that they are flexible and easy to use. Also, they can be used at different stages of project planning and are applicable to both construction and maintenance.

LICCER is most likely relevant to use during early planning stages, e.g. to support the choice of one road route out of a few alternative routes. CEREAL is most applicable at later planning stages where the type of road is set and decisions on the type of pavement or maintenance are to be taken. MIRAVEC would also be appropriate for use in the late planning stages and decisions regarding maintenance strategies that will affect the road characteristics. SUNRA takes a holistic approach, providing three frameworks to assess the sustainability not only of individual road projects but also the sustainability of the NRA as an organisation playing a key role in sustainable development.

The different projects relate to each other in various ways. Figure 9 shows one way of considering this. LICCER, CEREAL and MIRAVEC are focused on energy and GHG emissions, however for different parts of the road infrastructure. LICCER and CEREAL would benefit from sharing data on pavement, as could MIRAVEC. LICCER and MIRAVEC have a common focus on traffic energy and road design. SUNRA takes a more holistic point of view, treating the environmental, economic and social pillars of sustainability by addressing relevant aspects of each of a range of sustainability topics. In a way, therefore, the other three projects can be seen as supplementary to or supporting SUNRA by providing energy and CO_2 information.

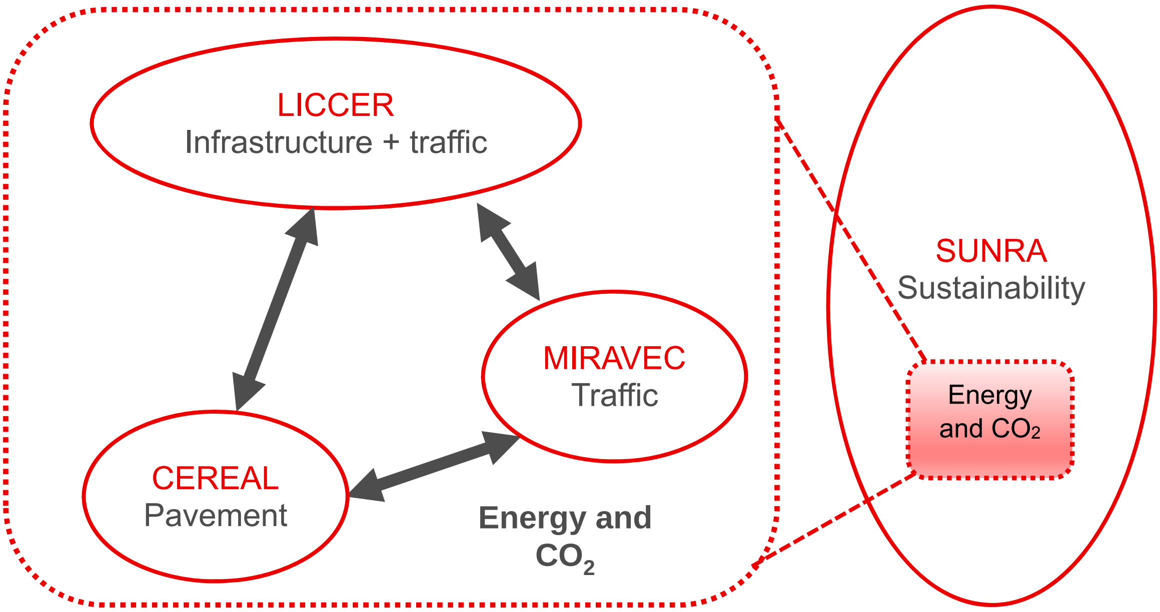

Figure 9: Relationships between the four ERA-NET Road Energy projects

Harmer and **Sowerby** presented the main outputs of the SUNRA project; demonstrating the usefulness of the three SUNRA frameworks in identifying sustainability considerations at the NRA level; choosing strategic sustainability metrics at the organisational, programme and project levels; and assessing the sustainability of individual road projects.

Potting and **Brattebø** presented the ability of the LICCER model to calculate GHG emissions and energy use associated with alternative road routes. The ease with which the model can be used to support planners in choosing a road route out of a few alternative routes was presented using its application to a Norwegian and a Swedish case study. The model could be further developed by integration with regulatory assessment tools and extension with other environmental impacts and cost-benefit analysis.

Haider and **Benbow** presented how the Excel-based MIRAVEC spreadsheet tool can be used to calculate the influence of traffic, vehicle characteristics, road routing and road design on the energy use and fuel consumption of the traffic. For instance, the tool helps the decision maker explore the effect of alternative road alignments, road layout, design and pavement. Use of the model is linked to existing traffic/energy/infrastructure models, e.g. VETO.

Anker Larsen presented the main results of CEREAL. Based on a questionnaire on knowledge and desired characteristics of an easy-to-use CO_2-related model applicable to road infrastructure and traffic, CEREAL developed a model called Carbon Road Map. This model involves the use of existing models and (national) databases and requires little input of data to complement the default data already present in Carbon Road Map. Where available, case-specific data can be substituted for the default data, however. Carbon Road Map focuses the maintenance phase of the road and contains pre-defined settings of maintenance practices and scenarios.

Participating via video link, **Steve Phillips** described the mission and work of CEDR and the main challenges European road directors are faced with: i) decreasing state of maintenance, ii) multi-modal transport solutions, iii) climate change and iv) strategic choices and implementation of ITS. Concerning energy use for road operation and maintenance, CEDR has identified the following main issues: selecting and adopting the most appropriate energy reduction technologies available; the need to reduce energy use to meet internationally agreed targets while maintaining safety; and providing resilience against increasing energy costs.

Tomas Kåberger took a world-wide perspective in his presentation of current trends and reasonably foreseeable scenarios concerning global energy use. He especially emphasized the dramatically increasing role of China as GHG emitter and user of energy for, e.g., transportation. Large investments in wind energy are currently being made in many countries, notably China but also USA. Solar energy is attracting growing interest in, e.g., Germany. Solar and wind energy installations can often be co-located with road infrastructure. Another evident trend is a growing demand for electric vehicles since fossil-fuel dependence is increasingly considered unsustainable. Further, he pointed to the importance of finding novel solutions to bring the energy demand for transportation down to a level which complies with international GHG agreements and the absolute need of adapting transportation to the demands of a sustainable development.

In the **Panel discussion**, a range of issues were covered, including:

- The great job performed by the four ERA-NET Road Energy projects must now be followed up by the implementation of the tools by the NRAs.
- CEDR needs to be involved in the implementation process.
- Application of each of the four tools to a specific case will not necessarily give the same result.
- SUNRA will most probably be implemented by the Highway Agency in England shortly and also in Ireland and Sweden.
- Potential users of these tools are encouraged to try use them and should not feel discouraged by technical details in the tools.
- Starting to use the tools within NRAs will create discussion on sustainability.
- The introduction of novel tools or procedures in road planning is largely hampered by unwillingness to divert from the traditional planning process.
- Implementation generally is a great problem in NRAs; setting a budget for the implementation of these practical and effective tools however seems to be a good investment.
- Ownership, maintaining and up-dating of the tools is crucial for them to become successfully used.
- Acceptance of the tools must be created by the NRAs and their contractors.
- The results of these projects have to be presented in “Director-General’s language” in order to gain entrance to the NRA.
- At least in some countries, the NRA is not allowed to prescribe the use of a specific tool.

- Practical tools are needed in procurement but what aspects to include in the procurement is up to the procurer.
- To be used in various European countries, the tools will have to be translated and adapted to national settings.
- The current trend of NRAs cutting down their R&D budgets and becoming increasingly concentrated on practical issues poses a threat to innovative thinking and the implementation of innovations.
- Often being governed by a 3-4-year term of office of the government, or having merely a 1-year budget perspective, many NRAs see solving today's problems as their first priority. Instead, they should be aware of their role in shaping our common future.
- The NRA is steered by the government prescribing the tasks of the NRA, which poses restrictions on the NRA having too long a perspective.

In his closing remarks, **Nilsson** presented some personal reflections that included:

- Four great novel tools have been presented.
- Now a window of opportunity has been opened - to start discussing the future instead of continuing cutting budgets.
- New ideas and solutions are entering the stage. We are now leaving technical specifications behind and are gradually introducing functional specifications in procurement.
- Innovation must become a winning concept in such a conservative sector as the road sector.
- NRA thinking is handicapped by a rigid apprehension of "a road".
- We will see many new technologies approaching: electric roads, automotive driving, etc. When we stop talking about ITS as such, we can begin discussing for what we can use it.
- Sustainability is still not as self-evident as it ought to be.
- The inclusion of social sustainability aspects in SUNRA is a step forward.
- An infrastructure perspective, a traffic perspective and a transport perspective are not always the same thing.
- CEDR is a proper forum for discussions on the future.

3.2 Group discussions

According to their interests, the participants were divided into five discussion groups focusing on SUNRA, CEREAL, LICCER, MIRAVEC and General considerations, respectively. Views expressed during the discussions included the following:

- There is a demand for practical tools that the NRAs can apply for planning and follow-up of road projects and it is valuable to have models that complement each other. However, it can be questioned if it is positive to get a common European solution, since some tools are more applicable in some countries than others depending on the characteristics of the planning, construction, operation and maintenance practices. Therefore, allowing the individual countries to modify the tools could be good but will also lead to non-standard tools, which makes comparison difficult. It is also difficult to study long time periods due to, e.g., technical improvements and more fuel-efficient traffic in the future.
- The software tools need to be maintained, updated and improved when new information becomes available. Responsibility for maintenance of the databases should be identified. Funding of maintenance and implementation of the software tools is a crucial issue.
- Calibrated models and reliable metrics are important. The quality of model output is dependent on the quality of the input; this concerns both measuring methods and system boundaries. Quality assurance of data introduced into databases is necessary. Quality assurance by a third party may be needed and in some countries, there is a national body that is responsible for the quality check of national databases. Many actors develop their own high-quality databases. In the tendering process, competitors may often want to use their own databases but these have not necessarily been subject to external quality assurance. There are pros and cons associated with having common databases or nation-specific databases. A wealth of data is produced on an international market and for this it is preferable to have one common source of data. On the other hand, differences between countries pose problems such as energy sources (mixes) varying between countries.
- NRAs have a crucial role for the acceptance and implementation of novel tools, such as those presented at the conference. There is a wealth of tools already available but they are seldom used in practice. There is often reluctance to load already stressed project budgets with additional demands, such as the use of novel assessment tools. Good arguments are needed for new tools to be accepted, and consensus on their introduction has to be reached for them to be used in practice. Implementation of novel techniques and models will require authorization and back-up from the senior management of the organisation. NRAs need to start using the tools internally to become acquainted with them. When using the tools, possibilities and limitations will appear that can be addressed. NRAs can then introduce the tools to their contractors.
- Contractors are very responsive to criteria and requirements in procurement. Procurement is therefore a crucial intervention point for sustainability thinking in both the client and the contractor organisation. Procurement specifications must be expressed in quantifiable terms. Tight contractual language is needed to ensure performance. “Soft language” should not appear in contracts.

4 Conclusions and recommendations

Experience from the four projects

Experience from SUNRA suggests:

- SUNRA provides NRAs with an easy-to-use planning tool to define and measure the sustainability of NRAs at organisational, corporative and project level, as well as the sustainability of individual road projects.
- The tool takes a holistic approach, covering the environmental, economic and social pillars of sustainability from a range of relevant aspects.
- SUNRA Framework 3, oriented towards individual road projects, can be applied at different planning stages, procurement being one of key intervention points. Framework 3 can be used without first having used Frameworks 1 and 2. Targets should be measurable. The NRA may need to set some mandatory topics and indicators.
- Unlike some existing sustainability rating systems, the SUNRA tool does not include a scoring based system. SUNRA can be used alongside existing rating systems or independently for setting targets, indicators and procurement criteria.
- For SUNRA to be implemented in European countries, the tool will likely need to be translated into the local language and adapted to reflect the national setting, legislation, and planning practice.

Experience from CEREAL suggests:

- For calculation of CO_2 emission from road construction and maintenance, the existing models are usually not yet as applicable as they should be.
- In order to be used, models should be easy to use, provide reliable calculation results and allow adding or changing project-specific data.
- CEREAL developed a model called Carbon Road Map, a decision-support tool to help identify low CO_2 emission solutions in road construction and maintenance.
- The Carbon Road Map has a focus on pavement maintenance and rehabilitation of in-service roads and is suitable to being used during the design phase when the type of maintenance or pavement is to be decided.
- Carbon Road Map calculates total CO_2 emissions in tonnes of CO_2-eq for different parts of the road and for the different stages of construction and maintenance.

Experience from LICCER suggests:

- LICCER covers energy use and GHG emission and can primarily be used during early planning to support decision making in the choice of one route from a few alternative routes rather than selecting a few alternative routes from several alternative routes.
- Use of the LICCER model becomes more relevant where alternative road routes differ little in length than where they differ greatly.
- It is recommended to carefully choose scenarios of energy use for infrastructure operations and maintenance and for traffic on the road during its service life. Also case-specific input data should be used where available (particularly in cases that involve large amounts of high-impact materials and heavy infrastructure) as an alternative to the default data provided in the model.
- There seems to be potential for users of the LICCER and CEREAL models in the future to use common data on transport distances as well as density and specific GHG emission of materials. Currently, depending on differences in project aims, the CEREAL data are substantially more detailed than the LICCER data.
- LICCER could be further developed so as to include economics, suggestedly taking into account the possibility of approaching cost—benefit analysis.

Experience from MIRAVEC suggests:

- It is possible to provide recommendations for road infrastructure design and operation to reduce energy use and associated CO_2 emissions from road transport.
- The MIRAVEC tool can be used to support NRAs in their evaluation on energy use as a result of different road characteristics. It should mainly be used during the planning phase, to assess either construction or maintenance alternatives/schemes.
- Schemes should be investigated on a case-to-case basis since the effectiveness of interventions depends on site-specific conditions inclusive of traffic characteristics.
- Implementation of new variables in PMS/AMS is possible but not always straight forward. When new variables are introduced, they should be balanced with the existing as well as other additional variables; careful optimisation of variables is needed.
- Effects on fuel use due to many of the identified variables can be included today. Some additional variables that could be included in the future would need further research, such as surface defects, road strength and the influence of road infrastructure features on driving speed.

Conclusions

One conclusion drawn from the ERA-NET Road Energy programme is that there is a great demand for practical tools that can assist decision makers when it comes to energy use, GHG emissions and other aspects of sustainability in the planning of roads. As the quality of the output is dependent on the quality of the input, calibrated models and reliable metrics should be used wherever possible and quality assurance (preferably by third party) of any data introduced into the tool databases is strongly recommended.

To gain a more consolidated ground for integration into the road-planning process, some of the models will need additional R&D to be fully applicable for practical use in NRAs. Further improvement to the models could be based on R&D involving case studies. Future efforts to tune the four tools could be a means of reaching a higher degree of combined utility of the tools.

In order for these models to be used in NRA decision support systems, great effort should be placed on implementing them. This will require good arguments as well as authorization and support from the senior management of the organisation. It is also important to have access to reliable data and updated models. There is a need for developing a plan for maintaining, updating and improving the software tools.

Recommendations for future activities

A plan for implementing and using the models within the NRA should be developed. A stable organisational platform must be provided to accommodate the models. Responsible bodies must be agreed and funding secured for this to happen. A careful planning of implementation is crucial to ensure the models are accepted within the NRA and its supplier organisations. One strategy could be for the NRA to use two or more of the tools in parallel. Harmonising specific data between the tools would create synergies that could be explored. In this way the NRA would become acquainted with the tools, pros and cons would be identified and handled, and then the tools could be introduced to contractors.

A close cooperation with suppliers/contractors and other stakeholders is recommended to ensure successful implementation of the models. Procurement is a key intervention point for promoting sustainability in road management. Contractors are responsive to requirements in procurement. Tight contractual language is needed to ensure performance.

Another strategy could be to use the tools in a number of case studies in several countries. When planning the implementation of the models in different European countries, careful consideration of the different national settings, legislation and planning practices is strongly recommended.

The need for development activities to improve the tools has already been identified. The NRAs will need to take a leading role here, for instance by securing good institutional conditions for further development of the models to facilitate adaptation to changes in organisational structures, priorities, internal and external demands, etc. Close collaboration between the NRA and its suppliers/contractors and other stakeholders will probably make the improvement activities more efficient and practice oriented.

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Acronyms and abbreviations

AADT	Annual Average Daily Traffic
AIT	Austrian Institute of Technology
CBA	Cost—Benefit Analysis
CDV	Centrum Dopravniho Vyzkumu (Transport Research Centre, the Czech Republic)
CEDR	Conference of European Directors of Roads
CEREAL	CO_2 Emission Reduction in Road Lifecycles
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalents
DTU	Technical University of Denmark
EIA	Environmental Impact Assessment
ENR	ERA-NET Road
FEHRL	Forum of European National Highway Research Laboratories
GHG	Greenhouse gases
ITS	Intelligent Transport System; Information Technology System
KTH	Royal Institute of Technology (Stockholm)
LCA	Life cycle analysis
LCC	Life cycle cost
LICCER	Life Cycle Considerations in EIA of Road Infrastructure
MIRAVEC	Modelling Infrastructure Influence on Road Vehicle Energy Consumption
NRA	National Road Administration
NTNU	Norwegian University of Science and Technology
PMS/AMS	Pavement Management System/Asset Management System
R&D	Research and development

SoA	State of the Art
SUNRA	Sustainability—National Road Administrations
TRL	Transport Research Laboratory
VTI	Swedish National Road and Transport Research Institute
ZAG	Slovenian National Building and Civil Engineering Institute