INTERNATIONAL ROAD FEDERATION
FEDERATION ROUTIERE INTERNATIONALE

IRF Bulletin - **March 2012**

# Environment & Climate Change

## Volume - 2

INTERNATIONAL ROAD FEDERATION
FEDERATION ROUTIERE INTERNATIONALE

IRF Bulletin
March 2012

# Environment & Climate Change

Volume - 2

## Credits and Acknowledgements

**Contributing Editor:**
Barry Gilbert-Miguet - Communications, IRF Geneva

**Editing and Supervision:**

Sibylle Rupprecht
Director General, IRF Geneva

Susanna Zammataro
Deputy Director General & Environment Expert, IRF Geneva

Barry Gilbert-Miguet
Communications, IRF Geneva

**IRF would like to thank the following persons for supplying articles, charts, comments and photographs for this publication:**

Kate Avery (TRL), César Bartolomé (Spanish Cement Association), Nicolas Bueche (EPFL), Kim de Bruijn (Centre for Sustainable Tourism & Transport, NHTV Breda University of Applied Sciences), Eke Eijgelaar (Centre for Sustainable Tourism & Transport, NHTV Breda University of Applied Sciences), Daniele Fornai (Ecopneus), Pete Kennedy (Caterpillar Paving Products), Alexander Klein (Evonik Industries AG), Natalie Kalfa (Attikes Diadromes S.A.), Dimitris Mandalozis (Attikes Diadromes S.A.), Steve Muench (Greenroads Foundation), Paul Peeters (Centre for Sustainable Tourism & Transport, NHTV Breda University of Applied Sciences), Simon Renton (VicRoads), Sarah Reeves (TRL), Susanna Zammataro (IRF).

**Cover Photo:**
Aftermath of a flash flood on a road in Tanzania, Susanna Zammataro, 2011

**Publisher:**

INTERNATIONAL ROAD FEDERATION
FEDERATION ROUTIERE INTERNATIONALE

IRF Geneva
2 chemin de Blandonnet, CH-1214, Vernier/ Geneva, Switzerland
Tel : + 41 22 306 02 60 Fax : + 41 22 306 02 70
info@irfnet.org

**www.irfnet.ch**

Last November I was in Tanzania attending a road transport conference.

I got up early one morning to join a group of fellow delegates on a wildlife safari. It was raining heavily but we felt wholly safe and secure sitting in a good car on a wonderful stretch of new road. Suddenly, however, a flash flood brought us to an abrupt halt by overturning a passing truck and virtually obliterating the road surface just in front of us.

Through this one incident – the aftermath of which can be seen on the cover of this Bulletin - two of the main impacts of climate change we had been discussing during the conference were brought vividly to life: safety – our lives had just been put in danger; economic loss – the road we were on was one of the main tourist links for the game parks and would require substantial time and resources before it could made fully serviceable again. Our guides were already desperately worried by the potential repercussions on their business.

Above all, the experience served as a traumatic reality check regarding the importance of ensuring timely and effective implementation of the kind of environmental foresight discussed at Conferences like the one we had just been attending.

How can we better guard against project decisions being made mainly on the basis of the most economic options, rather than integrating the longer-term vision required to realise the benefits of environmentally sustainable roads as an investment in the prosperity of both planet and society?

This is the challenge that IRF has taken up!

In this respect, we have been greatly encouraged by the unprecedented interest generated by our call for contributions for the Bulletin on Environment & Climate Change. So overwhelming was the response that we have been inspired to produce the Bulletin in two volumes.

This is an auspicious sign of the growing commitment to sustainability being observed throughout our sector, as well as the willingness of IRF members to really 'make a difference'.

For its part, IRF strives to support this progressive trend through its advocacy activity aimed at informing and bringing strategic focus to the individual efforts of its members worldwide. To this end, it notably serves as a bridge between international policy makers and the industry at large – ensuring optimum coordination as well as a 'common language' between the range of key stakeholders and decision makers. The IRF Environment Committee makes an important contribution to advancing and coordinating this work by offering members a dynamic platform for ongoing creative dialogue and knowledge sharing.

A recent success story in this respect has been the launch of IRF's Green Public Procurement (GPP) initiative, on which we are now working hand in hand the with the European Commission with a view to developing tangible GPP criteria that can be effectively implemented, rather than risk becoming just one more piece of well-meaning but essentially 'dead letter' legislation that nobody will ever use. We are also pushing the GPP initiative forward at an international level through the establishment – together with the International Institute for Sustainable Development (IISD) and other stakeholders – of an international platform on sustainable public procurement.

In these and many other ways our sector can make a decisive contribution. The wealth of ingenuity and cutting edge ideas featured throughout this and the preceding volume of the Environment & Climate Change Bulletin attests to boundless potential in this respect.

**Susanna Zammataro**
Deputy Director General & Environment Expert, IRF Geneva

# Sustainability & Carbon Assessment

## Greenroads

**Steve Muench** - Board Member and Founder, Greenroads Foundation; Associate Professor, University of Washington, Seattle, USA

Sustainability is a fundamental consideration for the roadway industry: the infrastructure we build, use and maintain must carefully address both our needs as humans and the health of the environment in which we live. If not, the infrastructure we create tends to fix one problem, but create another one elsewhere. We really do need sustainable infrastructure; in our case, sustainable roads. And, there really are such things as "sustainable" roads. While they may not have a great reputation in the world of sustainability, roads, at their best, connect communities, drive the economic engine, improve the environment and provide skills, meaningful work and education. When done right, that means "sustainable." And the road industry has the talent and passion to deliver truly sustainable roads. The way we look at it, roads are opportunity. They are what we make of them. At the Greenroads Foundation, we are the caretakers of the Greenroads Rating System; and we view this as our contribution to the design, construction, measurement and communication of sustainable roads.

### The Greenroads Rating System

The Greenroads rating system is an independent third-party rating system that can be used to certify sustainable roadway projects. Greenroads provides a metric to quantify sustainable design and construction practices. Projects earn points for their sustainable features and can earn certification at four different levels based on their total score. Greenroads can be used as a valuable tool to help communicate, manage and improve roadway sustainability.

Essentially, Greenroads is a collection of sustainability best practices that apply to roadway design and construction, much like the Leadership in Energy and Environmental Design (LEED™) rating system for buildings that is administered by the United States Green Building Council (USGBC). In general, these sustainability best practices are divided into two types: required and voluntary. There are 11 required best practices called "Project Requirements". At minimum, all of these project requirements must be completed in order for a roadway to be considered a Greenroad. 37 other voluntary best practices are characterised in five categories, called "Voluntary Credits". Project teams can pursue voluntary credits and earn points for their completion. Projects can also create their own credits, called "Custom Credits" and, if approved by Greenroads, these can contribute to the project's overall points total. Once complete, the Voluntary and Custom Credit point totals are summed and compared to four ratings: Certified, Silver, Gold and Evergreen. In order to achieve a rating, a project must have completed all 11 Project Requirements and have totalled enough Voluntary and Custom Credit points to meet a rating level.

### Greenroads philosophy

Several general ideas have guided the development and implementation of the Greenroads Rating System. These are:

- **Design and construction scope.** This addresses roadway design and construction. While planning and operations are essential to sustainability, the design and construction scope is intentional and results in a tool that defines design and construction features that directly contribute to sustainability on initial construction and over the life of the road.
- **In concert with existing regulation.** Greenroads respects existing regulation and does not require anything that would violate such regulation. Rather, wherever regulation allows a choice, Greenroads encourages the more sustainable choice.

- **Beyond the required minimum.** Greenroads encourages projects to go beyond the required regulatory and design minimums. Going beyond these minimums is what can distinguish a project's sustainability. It is unlikely that a project doing "business as usual" will achieve certification.
- **Flexible.** Greenroads allows projects to choose which credits to pursue. Project teams can pursue those credits that make the most sense for the project. No project is likely to attain all 37 Voluntary Credits, but there are enough options for any project to realistically pursue certification. Moreover, Greenroads works with a full range of project types: from the largest highway corridor to the smallest overlay.

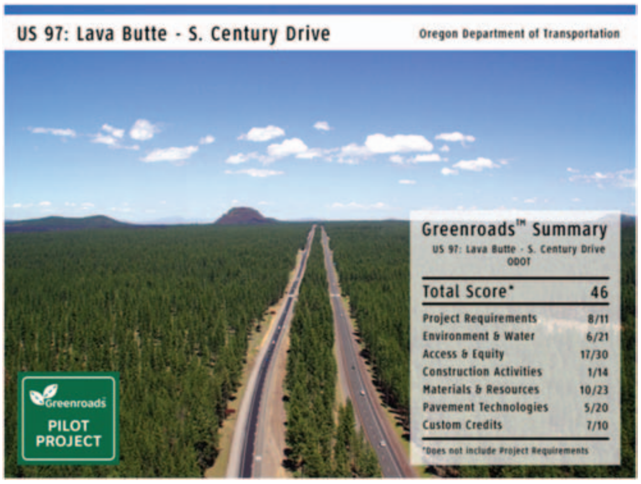



FIGURE 1. US 97: Lava Butte – S. Century Drive research Pilot Project conducted at the University of Washington.

### Using Greenroads and getting certification

Anyone can view the Greenroads manual online for free. Projects that formally register with the Greenroads Foundation and undergo its third-party review are eligible to earn a certification award and will be able to display the Greenroads logo to acknowledge their achievement.

### The Greenroads Foundation

Established in 2010, the Greenroads Foundation is an independent 501(c)(3) non-profit corporation in the U.S. that advances sustainability education and initiatives for transportation infrastructure. As the caretaker of the Greenroads rating system, the foundation manages the review and certification process for sustainable roadway projects in the U.S. and internationally. Comprised of a group of the industry's leading experts in this field, the Greenroads Foundation also provides customised training and educational services.

### Lessons learned

Sustainability is a new focus area for transportation infrastructure. While many sustainability ideas have long been practiced in the industry, the last decade has brought new ideas and a new focus to the treatment of these ideas as a cohesive set. The last five years of working on sustainability at a very practical project level have highlighted some great lessons to share. Here are four:

- Sustainability is a system characteristic, not an add-on feature. Sustainability is the highest level of what infrastructure seeks to achieve. It is a system characteristic that encompasses all other goals (e.g., safety, mobility, ecosystem health, education, employee satisfaction, etc.). These goals are an expression of (1) which sustainability components an organisation/project particularly values, (2) an order of precedence for these values, and (3) a plan to 'operationalise' these values and priorities. Thus, by adding sustainability as a value, an organisation is effectively choosing to assess its current prioritisation of values, make changes as needed and take action. Often, those changes can involve elevating environmental and social values to achieve what is often referred to as "balance" (although "balance" is rarely quantified).
- Sustainability costs less but is impractical to monetise. In one Greenroads research effort, we attempted to quantify the lifetime cost and benefit of each sustainable feature for a rural highway project. We ran into four major problems: (1) no commonly accepted methodology or tool for monetising some costs/benefits, (2) attribution of project cost components solely to one credit was not feasible, and (3) it was not


FIGURE 2. Grand Loop Highway, Madison-Norris research Pilot Project conducted at the University of Washington.

possible to extract the lifecycle cost/benefit associated with the project from a larger system. This being said, those items that *can* be monetised generally demonstrate that benefits outweigh the costs. Some credits show this even when only considering initial construction costs.

- Rating systems are specialised tools. A sustainability rating system is a specialised tool that (1) fits within a broader organisational approach to sustainability, and (2) does not address all sustainability efforts. Therefore, a rating system does not supply sustainability, but rather it serves as a tool to help communicate, manage and improve sustainability in a specific area. A well-formed approach to sustainability ensures that all areas are addressed.
- Rating systems are communications tools. Rating systems provide an understandable shorthand way to communicate sustainability, whether it is within an agency or project, amongst design and construction professionals, or to the general public. They cannot replace more rigorous accounting methods like lifecycle assessment – just as, conversely, such methods cannot substitute for rating systems.

Roads can and should be sustainable. This is a lofty goal that may take a generation to fully achieve, but the industry is already making rapid progress. Rating systems like Greenroads can and have been used as effective tools to further these efforts. They communicate commitment and can help manage and improve roadway sustainability. To learn more about the Greenroads Rating System and the Greenroads Foundation, and get involved, please visit www.greenroads.org. Let's change the world together, one kilometre at a time!

Greenroads

**GREENROADS RATING SYSTEM**

**LIST OF CREDITS (v1.5)**

| No. | Title | Pts. | Description |
|---|---|---|---|
| **Project Requirements (PR) – Mandatory for all projects** | | | |
| PR-1 | Environmental Review Process | Req | Complete a comprehensive environmental review |
| PR-2 | Lifecycle Cost Analysis (LCCA) | Req | Perform LCCA for pavement section |
| PR-3 | Lifecycle Inventory (LCI) | Req | Perform LCI of pavement section |
| PR-4 | Quality Control Plan | Req | Have a formal contractor quality control plan |
| PR-5 | Noise Mitigation Plan | Req | Have a construction noise mitigation plan |
| PR-6 | Waste Management Plan | Req | Have a plan to divert C&D waste from landfill |
| PR-7 | Pollution Prevention Plan | Req | Have a TESC/SWPPP |
| PR-8 | Low Impact Development (LID) | Req | Complete a LID feasibility study |
| PR-9 | Pavement Management System | Req | Have a pavement management system |
| PR-10 | Site Maintenance Plan | Req | Have a roadside maintenance plan |
| PR-11 | Educational Outreach | Req | Publicize sustainability information for project |
| **Environment & Water (EW) – Up to 21 Points** | | | |
| EW-1 | Environmental Management System | 2 | ISO 14001 certification for general contractor |
| EW-2 | Runff Flow Control | 1-3 | Reduce runoff quantity |
| EW-3 | Runoff Quality | 1-3 | Treat stormwater to a higher level of quality |
| EW-4 | Stormwater Cost Analysis | 1 | Conduct an LCCA for stormwater elements |
| EW-5 | Site Vegetation | 1-3 | Use native low/no water vegetation |
| EW-6 | Habitat Restoration | 3 | Restore habitat beyond what is required |
| EW-7 | Ecological Connectivity | 1-3 | Connect habitat across roadways |
| EW-8 | Light Pollution | 3 | Discourage light pollution |
| **Access & Equity (AE) – Up to 30 Points** | | | |
| AE-1 | Safety Audit | 1-2 | Perform roadway safety audit |
| AE-2 | Intelligent Transportation Systems (ITS) | 2-5 | Implement ITS solutions |
| AE-3 | Context Sensitive Solutions | 5 | Plan for context sensitive solutions |
| AE-4 | Traffic Emissions Reduction | 5 | Reduce emissions with quantifiable methods |
| AE-5 | Pedestrian Access | 1-2 | Provide/improve pedestrian accessibility |
| AE-6 | Bicycle Access | 1-2 | Provide/improve bicycle accessibility |
| AE-7 | Transit Access | 1-5 | Provide/improve transit accessibility |
| AE-8 | Scenic Views | 1-2 | Provide views of scenery or vistas |
| AE-9 | Cultural Outreach | 1-2 | Promote art/culture/community values |
| **Construction Activities (CA) – Up to 14 Points** | | | |
| CA-1 | Quality Management System | 2 | ISO 9001 certification for general contractor |
| CA-2 | Environmental Training | 1 | Provide environmental training |
| CA-3 | Site Recycling Plan | 1 | Have a plan to divert waste from landfill |
| CA-4 | Fossil Fuel Reduction | 1-2 | Use alternative fuels in construction equipment |
| CA-5 | Equipment Emissions Reduction | 1-2 | Meet EPA Tier 4 standards for non-road equip. |
| CA-6 | Paving Emissions Reduction | 1 | Use pavers that meet NIOSH requirements |
| CA-7 | Water Tracking | 2 | Develop data on water use in construction |
| CA-8 | Contractor Warranty | 3 | Warranty on the constructed pavement |

| | | | |
|---|---|---|---|
| **Materials & Resources (MR) – Up to 23 Points** | | | |
| MR-1 | Life Cycle Assessment (LCA) | 2 | Conduct a detailed LCA of the entire project |
| MR-2 | Pavement Reuse | 1-5 | Reuse existing pavement sections |
| MR-3 | Earthwork Balance | 1 | Use native soil rather than import fill |
| MR-4 | Recycled Materials | 1-5 | Use recycled materials for new pavement |
| MR-5 | Regional Materials | 1-5 | Use regional materials to reduce transportation |
| MR-6 | Energy Efficiency | 1-5 | Improve energy efficiency of operational systems |
| **Pavement Technologies (PT) – Up to 20 Points** | | | |
| PT-1 | Long-Life Pavement | 5 | Design pavements for long-life |
| PT-2 | Permeable Pavement | 3 | Use permeable pavement as a LID technique |
| PT-3 | Warm Mix Asphalt (WMA) | 3 | Use WMA in place of HMA |
| PT-4 | Cool Pavement | 5 | Contribute less to urban heat island effect (UHI) |
| PT-5 | Quiet Pavement | 2-3 | Use a quiet pavement to reduce noise |
| PT-6 | Pavement Performance Tracking | 1 | Relate construction to performance data |
| **Custom Credits (CC) – Available for all projects based on context and innovation, subject to approval** | | | |
| CC-1 | Custom Credit 1 | 1-5 | Design a new voluntary credit |
| CC-2 | Custom Credit 2 | 1-5 | Design a new voluntary credit |
| | **Greenroads Total Points:** | **118** | |

FIGURE 3.List of credits contained in the Greenroads Rating System. Full information is available at: www.greenroads.org.

## Calculating the greenhouse gas footprint of roads

**Simon Renton** - Senior Engineer, Environmental Sustainability, VicRoads, Australia

Rapidly increasing concern with climate change has led to a marked increase in the number of organisations seeking to understand their carbon footprint, and the road construction industry is no exception. Historically, road agencies have developed their own greenhouse tools to suit local conditions. These tools did not, however, allow for benchmarking of road projects across jurisdictions due to variations in the scope and methodologies applied.

Recognising the value of having a consistent approach across all jurisdictions, the Australian and New Zealand road agencies have jointly funded a project to develop a common approach to the assessment of greenhouse gas emissions associated with the design, construction and operation of a road project.

The final product is the joint effort of six road agencies (Road Maritime Services, New South Wales; the New Zealand Transport Authority, New Zealand; the Department of Planning, Transport and Infrastructure, South Australia; the Department of Infrastructure, Energy and Resources, Tasmania; Main Roads Western Australia, Western Australia, and VicRoads, Victoria), although it is anticipated that it will be utilised by all road agencies across Australia.

The project has involved two distinct stages:

- The development of a workbook to document the emission factors utilised and the assumptions made to develop a standardised approach for a suite of standard pavement designs over the whole life of a road project.
- The development of a user-friendly calculator known as **Carbon Gauge©** to identify emissions associated with each stage in the life of a road considered to generate materially significant amounts of greenhouse gas emissions, namely construction, maintenance and operation (street lights and traffic lights).

What is unique in the approach adopted by the Australian and New Zealand road agencies is that, for the first time, proponents can assess the 'whole of life' emissions associated with a particular road construction project.

A review of overseas literature had identified a variety of greenhouse calculators available in the market, or as proprietary products for internal use by specific organisations. However, these calculators were limited to the construction stage of a project. The UK Highways Agency had adopted an alternative approach, based on materials and fuels used in construction and maintenance activities undertaken in any one year, but this did not enable calculation of whole of life emissions for a specific project.

With increasing demand in Australia and New Zealand for estimation of emissions over the whole of life of a project for use in project approvals and/or Environmental Impact Statements, there was a clear need for a different approach. There was also an incentive to adopt a standard model to avoid duplication of effort between agencies, contractors and suppliers, and to provide a more consistent platform for benchmarking.

The result is a consistent and transparent approach to estimating greenhouse gas emissions over the 50-year life of any given road project.


Greenhouse Gas Assessment Workbook for Road Projects

June 2011

Transport Authorities Greenhouse Group



The approach adopted also follows the philosophy of the Australian National Greenhouse and Energy Reporting Act for determining materiality. Thus, whilst it is widely acknowledged that decisions made in the design process (i.e. the alignment, gradients and materials or equipment selected) can have a significant impact on the greenhouse gas emissions from the road during its life, the actual emissions associated with producing the design are not deemed materially significant and are not included in the workbook. Similarly, the emissions associated with decommissioning a road are not taken into account, as roads are rarely decommissioned.

The workbook and the calculator do not address emissions from the use of vehicles on the road as other tools and processes exist to do this. However, this emission source can be considered and included as an input. Over the 50-year life of a road, vehicle emissions are estimated to be the largest source of emissions, representing in excess of 90% of the total emission footprint.

The workbook is available through the websites of the participating agencies. In addition, the **Carbon Gauge©** Calculator is currently being investigated for its suitability to become a web-based online tool, which will ensure its ongoing integrity and avoid obsolete versions being used by interested stakeholders. This will also enable capture of information for benchmarking purposes, opening the potential for setting targets for road construction projects into the future.

For further information, contact any of the participating agencies by reference to the list below:

Robert Mitchell (NZTA, NZ) - Robert.Mitchell@nzta.govt.nz
Anne Welsh (DPTI, SA) - Anne.Welsh@sa.gov.au
Con Lambous (RMS, NSW) - Con.Lambous@rms.nsw.gov.au
Louis Bettini (Main Roads, WA) - Louis.Bettini@mainroads.wa.gov.au
Dick Shaw (DIER, Tas) - Dick.Shaw@dier.tas.gov.au
Simon Renton (VicRoads, Vic) - Simon.Renton@roads.vic.gov.au

## Attica: a tollway with a footprint

**Dimitris Mandalozis & Natalie Kalfa** - Strategic & Organisational Manager and Civil Engineer, Attica Tollway Operations Authority (Attikes Diadromes S.A.), Athens, Greece.

The Attiki Odos Motorway (also known as the Attica Tollway) is a modern, 65km long, urban-peripheral motorway forming a ring road around the city of Athens, Greece. It is a closed-toll motorway, with two directionally separated carriageways (each with 3 lanes plus an emergency lane), 39 toll stations and 195 toll lanes. The first road concession toll road project in Greece, the Attica Tollway was also one of the first toll motorways ever to be opened to traffic in a major metropolitan capital.

Athens is a densely populated city. It has not only a rich historical heritage but also many environmental challenges. The main purpose of the Attica Tollway was to alleviate the heavy traffic congestion problems of the greater metropolitan area and to improve accessibility to areas around the capital. The motorway was built with the utmost respect for the natural and urban environments and with the aim of ensuring optimum harmony with the surroundings, so as to conserve the Attica region and also safeguard the quality of life of communities living near the tollway. To date, the project has succeeded beyond all expectations. Average daily traffic volumes currently number more than 280,000 vehicles, exceeding original predictions, and sound environmental management has ensured the operation of a "green" tollway. In 2008, the Attica Tollway was awarded IRF's

1st Prize for Environmental Mitigation in recognition of its ongoing efforts in this respect. The company also holds ISO 14001: 2004 certification for its environmental management system, which is comprehensively applied and regularly updated.

Since the overriding mission of the Attica Tollway management team is to ensure high-quality, innovative services, such awards and certification are clearly important, but are not enough. Thus, with the ambition of going beyond contractual obligations with respect to the environment, and to keep one step ahead of constantly evolving environmental protection provisions, the company decided to proceed with the calculation of its carbon footprint.

The Attica Tollway management views carbon footprint assessment as a very powerful tool for understanding and mitigating the impact of the tollway's operational activities on global warming.

Despite the fact that the transport sector is still not included in the carbon market, the company opted to commence the carbon assessment process proactively, thereby remaining true to its corporate social responsibility and sustainability policies. This commitment was taken vis-à-vis both its clients and employees.

Indeed, apart from underpinning direct impacts on the environment, through measures to reduce emissions, carbon assessment will serve as a valuable tool for raising awareness among both the company's staff and tollway users. Employees will be afforded an early opportunity to acquaint themselves with the processes involved in carbon assessment so that, when carbon assessment eventually becomes compulsory for the transport sector, the Attica Tollway will be well prepared and 'ahead of the curve'. For tollway users and the general public, carbon assessment will serve as an excellent focus for education and stimulating good practice that can be applied in our everyday lives.

After reviewing the various assessment procedures available, the "Bilan Carbone®" methodology was chosen. This tool offered simple processes and calculations, enabling the company to assess basic business activity data (including energy bills, quantities of raw materials purchased, kilometres travelled, etc.). The corresponding greenhouse gas (GHG) emissions were then estimated in tonnes of carbon equivalent, item by item, category by category. The first calculation of Attica Tollway's carbon footprint was carried out for the year 2009, which will serve as the base year for all future estimates. The entire process was conducted with guidance from Egis Road Operations, the French shareholder of the Attica Tollway Operations Authority (Attikes Diadromes S.A.).

One of the main benefits of carbon assessment is the ability to situate potential environmental measures in perspective, and highlight those that are likely to have the most positive impacts on GHG reductions, without necessarily being the most costly or the most complex. Prior estimation of carbon emissions is also essential for ensuring due credibility and transparency. We may know that certain actions are likely to help reduce emissions, but it is only through appropriate carbon assessment methodologies that we can authoritatively determine their precise benefits or otherwise. In this spirit, Attikes Diadromes has taken the additional step of making the results public.

The carbon footprint calculation for the tollway took into comprehensive account direct energy consumption, employee and visitor travel, incoming freight transport, purchased services and depreciation. From the analysis that followed, it was established that almost 50% of the total carbon emissions from the company's activities were a result of energy consumption, in terms of electricity and fuel, while another 30% resulted from passenger and freight transportation.

After the completion of the calculation of the carbon footprint for 2009, the company proceeded to set emission reduction goals for future years, and decided on the best actions and strategies to adopt with a view to realising them. The mitigation measures that were selected mainly involved energy and fuel consumption. More specifically, they included installation of new light-sensors and meters upstream of tunnel entrances to control lighting levels in the tunnels and along the open motorway – which resulted in energy savings in the order of 20% for the first months of operation, compared to previous years, thereby not only reducing the carbon footprint of the Attica Tollway but also contributing to cost savings.

Carbon assessment for the year 2011 highlighted further progress in this field, as well as the benefits of eco-driving and switching to newer and less fuel-consuming patrol vehicles. The company is looking forward to further quantifying such impacts and developing more and more similar initiatives in the years to come.

For its achievements in the field of measuring and reducing carbon footprint, the Attica Tollway Operations Authority was awarded a Certificate of Merit in the Green Leader – MyClimate Awards, organised in 2011, for the first time in Greece, by the Centre for Sustainability and Excellence.

## Coach travel and Dutch holiday transport emissions

**Eke Eijgelaar, Paul Peeters & Kim de Bruijn** - Centre for Sustainable Tourism & Transport, NHTV Breda University of Applied Sciences, The Netherlands

The carbon footprint of tourism and travel is substantial. Accounting for 1,302 Mt $CO_2$ worldwide, domestic and international tourism is responsible for 5% of global anthropogenic $CO_2$ emissions. Tourism transport produces 75% of these emissions, with aviation and car transport alone accounting for 40% and 32% respectively (see table 1). The tourism contribution to radiative forcing – the factor used to express the contribution of all greenhouse gases to global warming – may be much higher, ranging between 5.2% and 12.5%, but clearly the margin of uncertainty is also much larger. It is clear that the main target for reducing emissions from tourism – a highly necessary aim given expected growth in tourist travel – must be tourism transport. An increase in coach and train travel, at the expense of car and air journeys, will almost certainly be required to compensate for the expected trip growth in the tourism sphere.

Table 1: Worldwide tourism emissions (2005)

| Sub-sectors | $CO_2$ (Mt) | Share |
|---|---|---|
| Air transport | 515 | 40% |
| Car transport | 420 | 32% |
| Other transport | 45 | 3% |
| Accommodation | 274 | 21% |
| Activities | 48 | 4% |
| Total tourism | 1,302 | |

This article presents a case for holidaying by coach as a low-carbon mode of tourism transport. The focus is on holiday travel by the Dutch, as a large tourism emissions database is available for the Netherlands. All Dutch emission figures are taken from this database and are for 2009, unless otherwise stated.

### Coach transport emissions

Transport and tourism transport literature demonstrates conclusively that, of all available transport modes, the (long-distance) coach has the lowest emission factor per passenger-kilometre (pkm). By way of direct comparison, the figures are consistently lower than for transport by rail, although trains would score slightly better at comparable occupancy and/or when renewable energy is used for electricity. The emission factor for coach travel ranges between 0.022 kg and 0.035 kg $CO_2$ per pkm (see table 2), a factor six to nine times lower than for air travel under 2,000 km.

Table2: Emission factors for tourism and long-distance transport by coach

| Emission factor for | Emission factor ($CO_2$ kg/pkm) | Occupancy rate used |
|---|---|---|
| Tourism transport by coach in an EU context | 0.022 | 90% |
| Coach travel in Germany | 0.024 | 70% |
| Coaches (touring cars) in a Dutch context | 0.029 | 44 pax/coach |
| National Express (UK), scheduled or network coaches | 0.030 | n.a. |
| Avanti Busreisen (Germany), long-distance bus tour operator | 0.032 | 70% |
| Motor coaches (long-distance travel) in North America | 0.035 | n.a. |

### Impacts of Dutch holidays on $CO_2$ emissions

In the Netherlands, holidays (excluding business travel) are responsible for around 8% of the nation's carbon emissions. This is substantial when compared to tourism's economic impact on the Dutch economy, which hovers around 3%. Hence the eco-efficiency (a measure to compare economic with environmental impacts - in this case $CO_2$ emissions) of tourism is not good on average.

An average Dutch holiday produces 371 kg $CO_2$, or 43 kg per day, whereas the average per day for Dutch people staying at home is 28 kg. The difference between domestic and outbound holidays is similarly large. An average domestic holiday produces 135 kg $CO_2$, or 22 kg per day, which is less than the staying at home figure. The average outbound holiday produces 600 kg $CO_2$, or 55 kg per day.

Almost half of all Dutch holidays are taken domestically, and account for a total carbon footprint of 2.4 Mt. Coaches only make up a fraction of this figure (0.008 Mt) due to their high efficiency and low share of domestic holiday business (less than 1%). Domestic holidays by coach produce the least emissions per domestic holiday of all transport types: 81 kg (18 kg per day). Bicycles score the lowest per day figure (13 kg). The differences are small due to the short distances involved in the Netherlands (see table 3).

Going abroad, the differences are more substantial. The market for outbound holidays by coach is larger than for domestic ones, although its share has been decreasing substantially – from around 10% of all outbound holidays in 2000 to 4.2% in 2010. Emissions from outbound coach holidays are 0.2 Mt, representing less than 2% of those from all outbound holidays (11 Mt). Outbound coach holiday emissions are low, both per trip and per day (see Table 3). Only train holidays show a slightly better score. This difference is possibly due to lower emission impacts from accommodation for train travellers. Coach holidays might, for example, be more linked to hotel stays than (say) camping, which tends to be used more by train travellers. Compared to an average outbound holiday emissions figure of 600 kg, holidays by coach and train are both recommendable from an environmental point of view.

Table 3: Carbon footprint of Dutch holidaymakers by transport mode in 2009 (kg $CO_2$)

| | Domestic | | Outbound | |
|---|---|---|---|---|
| | Per holiday | Per day | Per holiday | Per day |
| Car | 138 | 22 | 348 | 32 |
| Airplane | - | - | 1154 | 93 |
| Train | 103 | 20 | 180 | 27 |
| Coach | 81 | 18 | 233 | 29 |
| Bicycle | 88 | 13 | - | - |
| Other | 106 | 19 | 411 | 42 |
| Average | 135 | 22 | 600 | 55 |

### Outlook

Coaches, thus, represent a relatively clean transport mode – one for which the transport share of holiday emissions is lower than that attributable to the accommodation used. This can be contrasted with air travel, where transport emissions can exceed 80% of all holiday emissions for long-haul destinations. On the downside, when compared to other modes, the coach sector offers relatively little scope for improvements regarding fuel use and $CO_2$ emission reduction, though NOx, $SO_2$ and $PM_{10}$ emissions are set to decrease significantly in coming years. New emissions standards may be beneficial, as would be the monitoring and improvement of driving styles, but raising occupancy rates is hardly possible.

The main contribution coach transport could offer to the sustainable development of tourism would be through increasing its market share. Unfortunately, however, in the Netherlands, the trend is in the opposite direction. The share of coaches as a transport mode for all holidays taken by the Dutch gradually decreased from 3.4% in 2002 to 2.8% in 2009, and 2.4% in 2010. In comparison, the share of the most polluting mode, the airplane, keeps increasing – with the exception of a reverse trend in 2009 due to the economic crisis and the introduction of a ticket tax for air travel in the Netherlands. As the latter has since been abolished – while Germany introduced a similar ticket tax in 2011 – the growth in air travel from Dutch airports appears to be recovering strongly.

The main question, therefore, is how to increase the market share of coach travel under these difficult circumstances? Profiling coach travel as 'green' in order to attract passengers is unlikely to meet with much success as awareness of such issues is rarely reflected in changed attitudes or travel behaviour. It may even be counterproductive in countries like the Netherlands, where consumers often tend to be sceptical towards 'green' claims. Such an approach may, however, be more successful in other countries, like for instance Germany, where coach travel for holiday purposes has not been the object of such a steep decline, and was still accounting for 8% of all long holiday trips in 2010.

Coach operators may profit more by changing their whole product offer, instead of focusing on transport alone. 'Slow' travel could be an emerging market for which coaches are particularly well suited – but only if they are fully integrated into an overall product. Changing the pace and emphasis, for example by adding an overnight stay in Barcelona on the way to southern Spain, may offer experiences that are not easily available through air travel. Avanti bus travel, Germany, offers such trips in Europe (and even to as far as China) on a small scale. Low cost and good value are important factors as low income travellers in the age groups 13-17 and 65-74 are over-represented, and the coach has the potential to offer greater value/comfort than (low-cost) airplanes. On the other hand, the elderly of the near future are likely to be more affluent, so emphasis for the whole product may be better aimed at high quality (ease, luxury, freedom of choice from a large range of activities and high-quality accommodation and food) for a reasonable price, rather than at trying to beat the cheapest low-cost air travel rates.

Finally, there is a role for governments. First, the tax advantages of air transport (no fuel duties, no VAT) should be removed by introducing proper taxation for aviation. The inclusion of aviation in the European emissions trading scheme is a first step in the right direction, but far from sufficient to remove the prevailing unevenness in the market. Another important issue to consider is that coach travel works best for short and medium distances. National tourism boards could help by shifting their focus much more towards domestic and EU markets instead of long distance destinations like Asia.

*For source references used in the preparation of this article, please contact cstt@nhtv.nl. See also www.cstt.nl .*

# Life cycle analysis

## Life cycle analysis of roads

**César Bartolomé** - Civil Engineer, Research & Development Department, Spanish Cement Association, Madrid, Spain

European commitments with respect to climate change and global warming can only be achieved by adopting measures to increase the energy efficiency of road transport with the purpose of reducing greenhouse gas (GHG) emissions. Several Research and Development projects are currently developing important tools aimed at reducing emissions caused by vehicles. Very few initiatives, however, are addressing the influence of infrastructure, both on the energy efficiency of road transport and on GHG emissions. For this reason, it is essential to develop projects that focus on optimising infrastructures.

To date, there have been studies that compare the amount of emissions generated by two different roads, or which evaluate the influence of various materials on the fuel consumption of vehicles. What cannot be measured, however, cannot be evaluated. For this reason, it is necessary to initiate a project that quantifies the impacts of infrastructure on sustainability and, more precisely, on efforts to save energy. This involves identifying the causes of emissions and studying the potential to reduce them.

Recycling of materials after road demolition is a key factor when assessing the sustainability of a road

This objective is not achievable unless a thorough Life Cycle Assessment – analysing the influence of every phase on global emissions – is carried out. It is necessary, therefore, to investigate thoroughly all the variables defined during each successive stage: from design, when every decision made will affect the future behaviour of the road (materials, route, pavements, etc.); during construction, where one of the key factors will be to minimise transport; during the service life, which will account for 80% of the total energy consumed; right through to demolition, where the suitability of materials for recycling will be key.

This article aims to analyse the different stages and variables that have a high influence on energy consumption associated with road transport.

### Life Cycle Assessment

Life Cycle Assessment (LCA) was conceived as a tool to assess the environmental impacts of products during the different stages of their life, 'from cradle to grave'. This approach considers energy and raw materials as limited resources that are consumed faster than they are replaced. The main advantage of LCA lies in its capacity to evaluate environmental impacts in an integrated manner, following three main rules:

1. Environmental impacts are not only generated during the manufacturing stage, but throughout the complete product life cycle.
2. Products do not exist in isolation. Their manufacture and use is dependent on other products and services. It is necessary, therefore, to assess the whole production system.
3. Environmental impacts associated with products are diverse, and not limited merely to $CO_2$ emissions.

### Life Cycle Assessment applied to roads

As introduced above, any model aimed at evaluating the energy efficiency of roads must consider the design, construction, operation and demolition stages – assessing each phase and applying appropriate coefficients to reflect its importance to the whole.

In such a model, many variables can be incorporated. Incrementing the number of factors is not always the best solution, however, for reasons of cost effectiveness. A balanced approach will consider variables that cover a very high percentage of the total energy consumed by a given road (and also by the key activities associated with it), but which are technically and economically feasible to address. Building up such a model involves focusing mainly on the design and operational stages. The former clearly affects the whole service life of the road, and any decision made will condition its energy efficiency, while the latter will account for upwards of 80% of total energy consumed during the entire life cycle, as evidenced by a number of studies (Source: *Ulf Hammarström et al., ECRPD project, 2008*).

The main problem at the design stage is selecting, from among all the variables that influence road construction and operation, those factors that are relevant to energy behaviour. In this respect, neither longevity nor route factors are negligible.

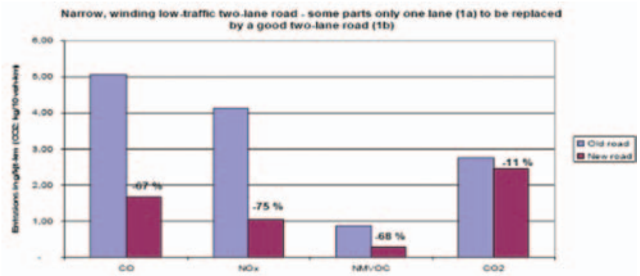
Enhanced longevity means less-frequent maintenance, lower consumption of raw materials (cement, aggregates, steel) and lower energy consumption – not only due to less rehabilitation and reconstruction works *per se*, but also thanks to fewer congestion problems associated with these activities. Meanwhile, the number of kilometres run by vehicles is directly proportional to the amount of fuel they consume. Reducing the distance between two points will reduce fuel consumption in the same ratio.

Concrete pavements have traditionally been considered a robust and durable solution

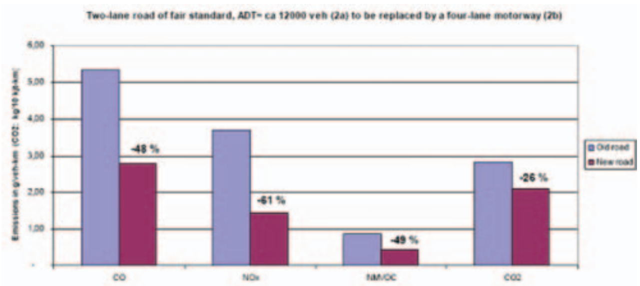
But length is not the only variable that affects energy efficiency, since capacity and the number of curves and slopes will also have significant bearings on the fuel consumption of vehicles using the given infrastructure.

A study entitled *Environmental Consequences of Better Roads*, carried out by SINTEF, the largest independent research organisation in Scandinavia, analyses three different scenarios under which changing the design characteristics of a road can reduce the emissions generated by vehicles, and thereby increase its energy efficiency. The three cases studied were:

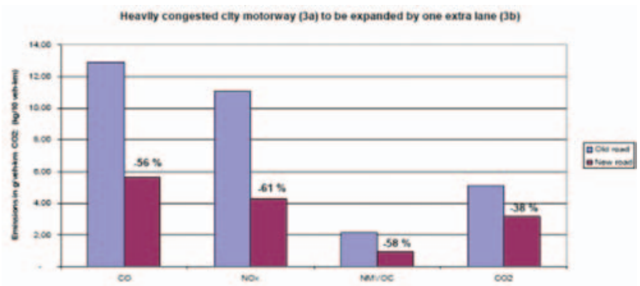
1. A single-lane road with sharp curves, carrying very low traffic (200 vehicles/hour) that crosses small villages, which is replaced by a two-lane road that avoids crossing the villages, although it maintains the same amount of traffic.
2. A two-lane road, crossing two villages, that has already attained maximum capacity, which is replaced by a four-lane motorway that bypasses the villages. The volume of traffic is the same in both cases - around 1,200 vehicles/hour.
3. A congested arterial motorway in a large city, with a traffic volume of 5,000 vehicles/hour, which is expanded by one extra lane.




Reduction of emissions for the first case study




Reduction of emissions for the second case study




Reduction of emissions for the third case study

(Source: SINTEF Technology and Society, Road and Transport Studies "Environmental Consequences of Better Roads", February 2007)

The results in all three cases were similar. The amount of emissions decreased considerably, evidencing the importance of shortening roads, reducing the number of curves and increasing capacity in order to avoid congestion. Better roads in terms of improved alignment, width and capacity – which enable traffic to flow steadily and thereby consume less – were shown to represent a positive contribution towards a sustainable environment.

During the construction stage, most energy consumption and emissions are due to transportation. For this reason, maximum emphasis should be given to solutions that make optimum use of materials readily available along the route of the proposed road itself.

The phase that consumes the highest amount of energy, however, is inevitably the service life of the road. This stage commonly lasts upwards of fifty to one hundred years, and the energy consumption during this period is derived mainly from maintenance works and the fuel of vehicles using the road. With respect to the former, and as introduced above, maximum recourse should be made to durable solutions in order to optimise longevity. The latter necessitates the construction of more rigid pavements that enhance the efficient forward propulsion of vehicles.

Fuel consumption of vehicles is influenced by the stiffness of the pavement

Last but not least, the model must proactively take into account the potential influence of roads on the global energy efficiency of society, especially in urban areas. Whiter pavements, for example, reflect sunlight, reducing the temperature of the air and saving significant amounts of energy in cooling systems. It is estimated that, depending on the material used, the pavement albedo of a road can be increased by 0.1. Together with other measures, this could help achieve an overall increment of 0.1 in the total urban albedo. Studies carried out in the USA estimate that this could lead to a potential saving in excess of US$ 1 billion per year in net annual energy bills (source: *H. Akbari, S. Menon and A. Rosenfeld, "Global cooling: effect of urban albedo on global temperature", 2007*).

The final stage of the life cycle assessment of a road is demolition. Future generations must not be made to suffer a legacy of negative impacts – such as land degradation and fragmentation of territory – left by badly designed roads at the end of their service lives. Maximum use of materials that have the capacity to be recycled using a minimum amount of energy must be the preferred choice when making decisions about the kind of roads we want for our society.

## Asphalt mixture choice: a decision-aid model

**Nicolas Bueche** - Traffic Facilities Laboratory, Swiss Federal Institute of Technology (EPFL), Lausanne, Switzerland.

Due to the continuous development of warm mix asphalts (WMA) as alternatives to hot mix asphalts (HMA), the choice of the most favourable mixture for a given project is not necessarily straightforward. When considering greenhouse gas (GHG) emissions and energy consumption from road construction, few of the GHG calculators currently available are able to perform a comparison at the asphalt mixture scale – despite the clearly important effects of the asphalt mixture type on overall energy consumption and emissions. Moreover, the choice should ideally take into account aspects such as mechanical performance and other qualitative criteria.

To redress this situation, a multi-criteria model has been developed in the framework of PhD research. The proposed model aims at comparing different types of asphalt mixtures and helping the road owner in the decision making process.

### Model architecture

The multi-criteria model is divided into two parts. In the first part, the data to be used for the decision analysis are generated through a complete life cycle inventory (LCI), and the evaluation of the mechanical performances of the asphalt mixtures (i.e. alternatives) are entered. The second part of the model consists of the decision making process. An overview of the model is presented in Figure 1.

### Part 1 – Life cycle inventory and performance indicators

The proposed multi-criteria model takes into account GHG emissions, energy consumption and economic aspects over the whole life cycle of the asphalt mixture. To achieve this, a life cycle inventory is performed according to the boundaries indicated in Figure 2.

The mechanical performances are also taken into account in the decision process. Two indicators (raw indicator and normalised indicator) are defined for the following mechanical performances of the asphalt mixtures: water sensitivity, rutting resistance and fatigue resistance.

Figure 1 provides a summary of the various data sources used in the model in order to perform the LCI and establish the performance indicators. The mechanical performances database was established in the first part of the research, during which a detailed investigation of WMA mechanical behaviour was achieved.

### Part 2 – Global evaluation model

The methodology as developed and implemented comprises four independent levels (Figure 1), each bringing its own contribution to the decision making process.

In the first level, a Pareto representation is used to identify the dominant processes over the lifespan of each asphalt mixture. This first level does not compare the various alternatives, but focuses on the LCI phases of the asphalt mixtures. A first comparison of the alternatives is conducted at the second evaluation level. To achieve this, various graphical analyses are used in order to highlight the potential outranking alternatives. In these first two levels, raw data are used, without any treatment or weighing.

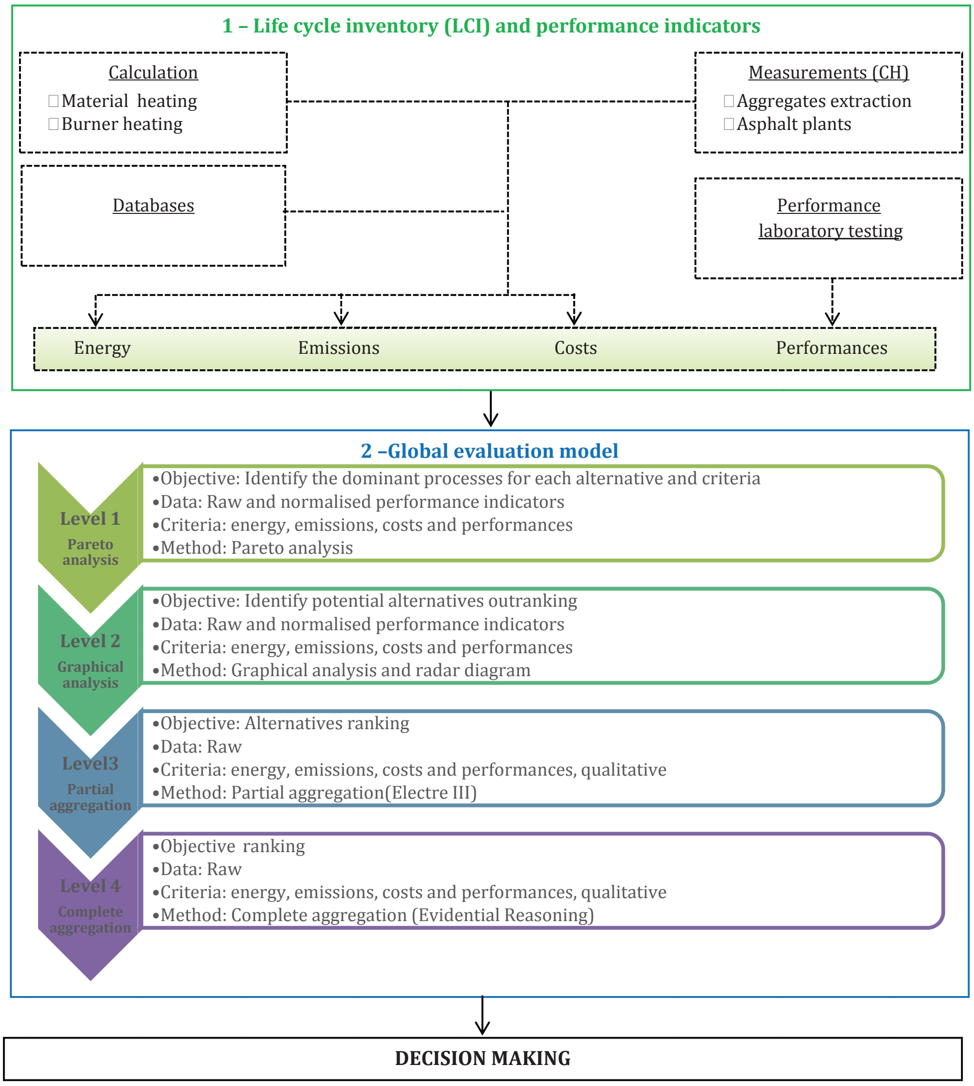



Figure 1: Overview of the multi-criteria model architecture

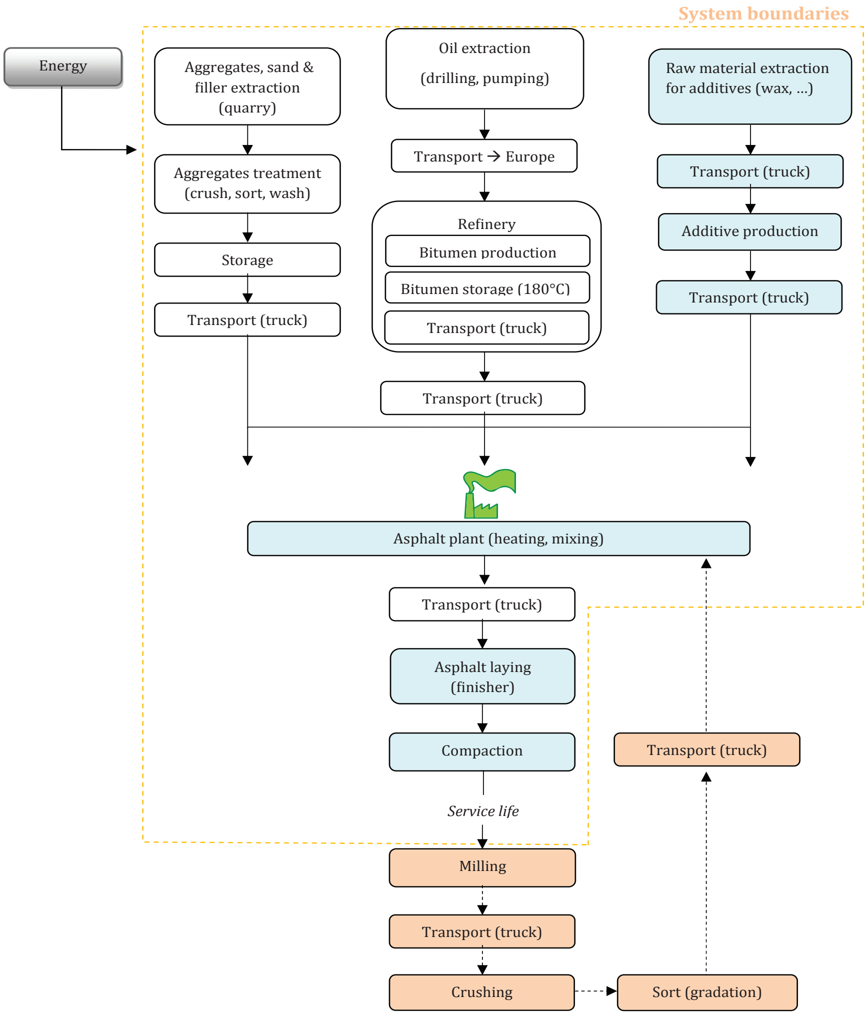



Figure 2: Life cycle inventory boundaries

User preferences and qualitative criteria are introduced at the third analysis level, through the introduction of Multi-attribute Decision Making (MADM) methodologies. There are two main "families" of MADM methods, namely partial and complete aggregation, each having their own distinct advantages and properties. There is no perfect MADM method; the choice of method depends on the type of problem analysed. Thus, existing methods applied in MADM domains were selected for implementation in the specific context of asphalt mixture evaluation. Besides the quantitative criteria considered in the first two levels, two additional qualitative criteria are added at the third evaluation level:

- **Production complexity in plant.** The production complexity depends on the type of asphalt mixture. For instance, some WMA technologies might require a foaming nozzle or moisture control system that could increase the production complexity compared to traditional HMA.

- **Asphalt mixture sustainability.** The sustainability of the asphalt mixture depends on the type and content of additives used in its production.

In the third evaluation level, a partial aggregation method using pseudo-criteria is proposed. The favoured option in this respect was the ELECTRE III method, which has been widely applied in the environmental domain. This method presents the particular property of considering various outranking degrees by comparison of two alternatives, and does not allow compensation between criteria for a given alternative.

The fourth evaluation level uses an algorithm derived from the Evidential Reasoning approach. This consists of a complete aggregation method, based on the Dempster-Shafer theory, but modified for application in the framework of MADM. The fourth evaluation level is also the most complex, but it allows the model to take into account the occurrence probability of a given performance, and data unknown. Finally, the utility of each alternative is calculated.

### Model implementation and results

The model developed has been implemented in Visual Basic, allowing considerable flexibility and adaptation to project requirements.

Figure 3 gives an example of the results obtained for the first two evaluation levels. While the Pareto analysis (level 1) considers each alternative and criteria separately, the radar chart (level 2) provides a first comparison of the alternatives. Note that this type of representation has an important "visual" impact for the reader, but does not translate the outranking degree between two alternatives.

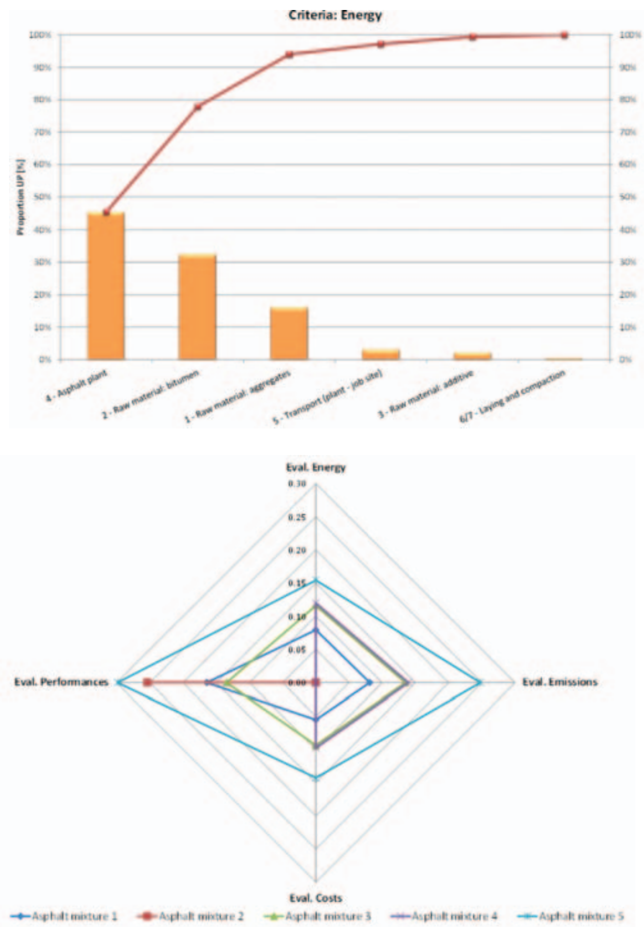



Figure 3: Illustration of results from Level 1 (Pareto analysis, top) and level 2 (graphical analysis, bottom)

In the third level, a Siskos-Huber ranking method has been chosen in order to analyse partial aggregation results and derive a ranking of the alternatives. The complete aggregation method (level 4) calculates the utility for each alternative separately (Figure 4). The analysis conducted using MADM methods also enables evaluation of the robustness of the solution through dedicated sensitivity analyses (weighing, method parameters, …).

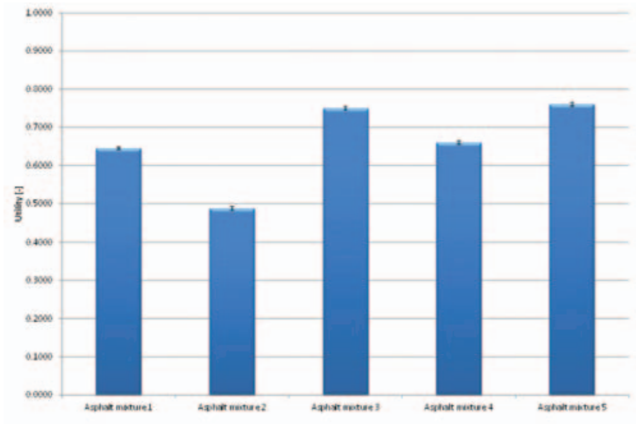



Figure 4: Illustration of results from level 4 (complete aggregation)

### Preliminary conclusions and perspectives

The multi-criteria evaluation method proposed offers a pertinent, flexible and robust tool that helps improve the decision making process, thus encouraging innovation. The model considers not only emissions, energy consumption and economic aspects over the whole lifespan, but also the performance parameter that is essential in any decision process. Moreover, key qualitative parameters can also be included as and when appropriate. Besides permitting a choice of preferred alternative, the use of multi-attribute decision making methods further enables an assessment of the robustness of the proposed solution.

The model has been implemented in a very flexible way, allowing adaptation of the various parameters to the project requirements. The tool is currently available and some further applications are in progress.

The model will be used in the framework of a Swiss Federal Road Administration project called PLANET, which started in 2011 and will finish in 2014.

## The green choice for road marking systems

**Alexander Klein** - Evonik Industries AG, Germany

The European Union has recently adopted a set of proposals aimed at promoting green public procurement. These guidelines call on public purchasers to take environmental factors into consideration when procuring products, services or works for infrastructure investments.

Until now, a lack of comprehensive environmental impact data comparing the various available road marking systems has made selecting environmentally friendly materials difficult. The study introduced in this article is aimed at filling that information gap by providing a comprehensive analysis of the respective environmental impacts of the four road marking technologies most commonly applied in the European Market. These are high solid solvent-borne (SB) paints; water-borne (WB) paints; thermoplastics and thermo spray plastics (TP and TSP), and cold plastics and cold spray plastics (CP and CSP).

For the analysis of cold plastic road markings (MMA cold plastics), DEGAROUTE® reactive resins from Evonik Industries were chosen, together with Evonik binders for high solid solvent-borne paints, and additives for thermoplastics. For water-borne paints, the evaluation of the binder was based on publicly available information regarding binders for water-borne road markings. The parameters studied included the Global Warming Potential (GWP - describes a product's contribution to the greenhouse effect and is measured in $CO_2$-equivalents), Acidification Potential (AP - describes a substance's potential to build acids and is measured in $SO_2$-equivalents), Eutrophication Potential (EP - is an index for over-fertilisation, resulting in increased algae growth and is measured in phosphate equivalents) and various Ecotoxicity influences relating to humans (Human Toxicity Potential - HTP), freshwater organisms (Freshwater Aquatic Ecotoxity Potential - FAETP) and soil organisms (Terrestric Ecotoxicity Potential - TETP).

## Ozone pollution

An increase in respiratory ailments, particularly among children and especially during the summer months, has been linked to elevated ozone levels close to the ground. One factor contributing to the formation of ground-level ozone is the release of VOCs (Volatile Organic Compounds), for instance from paints, stains and varnishes containing solvents that evaporate during drying. Photochemical Ozone Creation Potential (POCP) has, therefore, been widely used to quantify the ability of a VOC to produce ozone through photochemical reaction. This parameter was also a particular focus of the study.

## Cradle to grave evaluation

The assessment of a road marking material's environmental impact can only be considered comprehensive if it covers all the factors that contribute to this impact throughout the entire lifecycle of the given material. Lifecycle assessment (LCA) in accordance with ISO 14040 / ISO 14044 standards begins with the raw materials employed and extends throughout the production, application, usage, renewal, disposal and/or recycling of the material, and further includes all necessary transport, packaging and auxiliary materials.

Auxiliary materials used in the formulation of road markings may include binders, fillers and reflective materials, such as glass beads and pigments. Pigments (generally titanium dioxide) are often a major contributor to the ecotoxicity of a marking material, something that may not be reflected in the statutory hazardous-substance classification of the product.

The lifecycle assessment carried out in the study introduced here considered all impacts over a period of ten years (pavement lifetime). It evaluated the marking systems applied on the pavement surface of a typical German federal road bearing a daily traffic load of between 10,000 – 15,000 vehicles per day. The parameters were evaluated per kilometre of road section, each marked with spray-applied lines: two full edge lines and one interrupted, 12 cm. wide centre line (skip line).

So-called Type II markings (applied in accordance with the German DIN EN 1436 and ZTV M 02 standards) possessing enhanced wet night-time visibility characteristics (with a Retro reflected Luminance (RL) measured under wet conditions of at least 35mcd/m2lx according to the more stringent ZTV M 02 standard) were also investigated for the study. The service life of this type of marking is defined by reference to the length of time this minimum retro reflectivity (RL≥35mcd/m2lx) is maintained under traffic wear.

## Results contradict common assumptions

The long-term and holistic approach adopted for the lifecycle assessment – considering the environmental impacts of the materials over their entire useful life – overturned some common assumptions regarding their environmental impact.

Water-borne paints (WB), typically containing a small percentage of solvents, are generally considered to be VOC-free compared to solvent-borne paint (SB), which has a solvent content of about 25wt%. Therefore, WB paints provide considerably lower ground-ozone pollution for road markings whenever climatic conditions allow their application. However, contributions to ground-ozone pollution arise not only from solvents, but also from high-boiling formulation components, and from the manufacturing process for titanium dioxide and drop-on glass beads. CSP does not contain a solvent component, but rather a monomer component. A small percentage of this component tends to evaporate during spray application prior to the chemical solidification of the road marking material on the pavement, which contributes to POCP.

For thermo spray plastics, only the contributions from the raw materials and gas consumption during application in molten state were considered for the study. POCP relevant effects, from organic compounds degassing from the hot surface during the application of the product, were not taken into account due to the lack of data on the chemical nature of these. Figure 1 illustrates the POCP impact of the four road marking systems considered, relative to the corresponding results obtained from the Cold Spray Plastic evaluation.

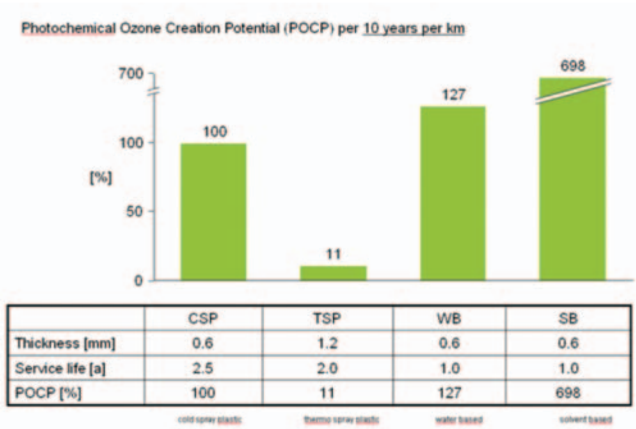



Figure 1: The POCP impact of four different road marking types per 10 years, per kilometre, relative to the corresponding impact of a road marking made of cold spray plastic (CSP).

However, it is the durability of a road marking system – in other words its service life – that largely determines its overall ecological impact. Those systems possessing greater durability under high traffic loads clearly offer superior ecological advantages compared to less lasting solutions. The POCP of, for example, cold-spray plastic is revealed to be considerably lower than that of solvent-borne paints, particularly when the relatively long useful life of cold-spray plastic markings is taken into account.

The more durable CSP or TSP systems require less frequent renewal of the road marking – and, thus, less total raw

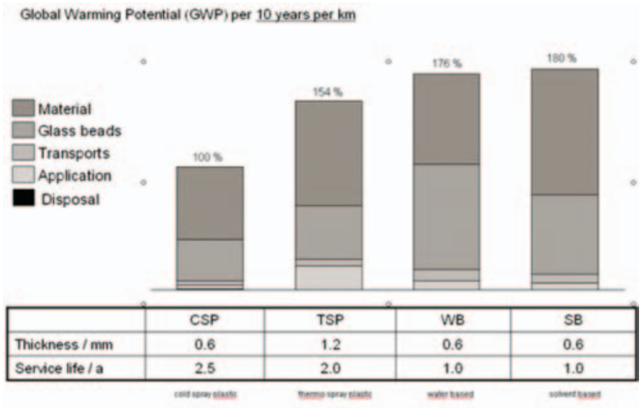



Figure 2: The global warming potential (GWP) of four different road marking types per 10 years, per kilometre, broken down into contributions from marking material, glass beads, transport, application and disposal.

material consumption. This gives rise to a relatively low GWP compared to paint systems. Figure 2 provides a breakdown of the various GWP contributing factors and, from this, the significance of both road marking material and drop-on glass beads becomes obvious.

In summary, while paint systems may still be an economical solution for road markings in low traffic situations, the more durable CSP and TSP systems tend to be more resource-efficient and environmentally friendly under conditions of moderate and high traffic loads, and will contribute considerably less to ozone pollution.

The study introduced above was conducted in accordance with DIN ISO 14040 and 14044 (ISO 2006) and has been reviewed by a panel of external experts.

*The author may be contacted through: alexander.ak.klein@evonik.com*

# Technology

## Blended, bladed and compacted proof of the benefits of sustainability efforts.

**Pete Kennedy** - Caterpillar Paving Products

To the passer by, the haul road near Tamanrasset, Algeria, initially appears to be little more than evenly graded clay. It is no engineering marvel either, as the road runs flat and straight through a portion of the Sahara Desert. Even the locals don't pay much attention to it. It's a haul road, and few ever travel it.

First looks, however, can be deceptive. Learn more about the road and it becomes apparent it is much more than levelled clay. It is blended, bladed and compacted proof that sustainable efforts can create considerable savings.

### Time for repair

Tamanrasset was established centuries ago along the trans-Saharan trade routes. The routes evolved into the Trans-Sahara Highway, and Tamanrasset remains a key outpost today. It is an oasis where citrus fruits, apricots, dates, figs and other produce are grown.

It's also a key centre for the energy industry, with several large facilities located nearby. A single clay road serves many energy-related facilities, connecting them to the Trans-Sahara Highway.

The need for repairs to that road came as no surprise given the pounding of the heavy trucks that use the road and the sun. Temperatures in the desert city of about 70,000 inhabitants are among the highest ever recorded. Highs have hit 47.4º C (117º F) in both July and August. The average temperature in July is 35.9º C (97º F).

The baked clay can become brittle, crack and break down as the heavy trucks haul their essential cargoes. Extreme temperature changes over the course of the year - with average lows falling to 6.4º C (44º F) in January - also take their toll. Those involved with the reconstruction project believe that the temperature fluctuations probably had as much to do with the deterioration of the road as the extreme summer heat.

### Concerns - and solutions

Slowing trucks made it clear that repairs were overdue. Yet there were challenges, many of them associated with cost. The road is 50 km (31 miles), a length that would require considerable spending to repair. Moreover, there was another key concern besides cost. The road leads to energy businesses that wanted to implement sustainable practices on the very route leading to their facilities. These combined considerations led all involved to opt for reclamation - one of the road construction industry's most environmentally friendly practices:

- Reclamation would eliminate aggregate usage and hauling, by recycling the existing materials.
- Stabilising the reclaimed material through the use of a soil additive would lead to another sustainable opportunity. The additive, a bonding agent that extends road life, was chosen in part because of its organic makeup.
- In addition, the reclamation/stabilisation efforts would be handled by fuel-efficient Cat® Rotary Mixers that also meet the most up-to-date emissions standards. The equipment's improved technology was sure to create efficiencies that would impact positively on both project cost and environmental sustainability.

### The process

The first step in the road repair sequence consisted of a dozer from the contractor, Chebli & Tellawi Corp., making a rough levelling pass and removing large stones that had been brought to the surface by the heavy trucks and the temperature fluctuations of the desert. A water truck then sprinkled the roughly graded surface. Next, a Cat RM500 Rotary Mixer made four parallel mixing passes at a depth of 20 cm (7.9"), working across the road's 9 m (30') width. The RM500 pushed a tanker truck containing the bonding material. That emulsion was delivered by hose from the truck to the RM500. It was then blended with the reclaimed material in the mixing chamber of the RM500, enabling single passes to recycle the existing road as well as add and mix the bonding agent. A motor grader made a finished grading pass, followed by a soil compactor.

The process highlighted a number of financial and sustainability benefits, including:

- A stronger, smoother road surface that improves travel speeds and lengthens the working lives of haul trucks
- Improved fuel efficiency for the trucks that regularly travel the road
- An organic bonding agent that extends road life
- Recycling *in situ*, eliminating the need to load and haul away old materials
- *In situ* recycling also eliminates the costs of purchasing and hauling in new materials

By eliminating steps and saving time, the process also requires less fuel, and reduces other factors contributing to machine owning and operating costs.

### Lessons

The contractor and the Cat machines executed the project as planned. Sustainability and cost-containment goals were both met. The following were among the key lessons learnt:

- **Bonding agents can be sustainable and effective.** The bonding agent used was made from calcium and lignin, a complex polymer extracted from paper pulp. Lignin is environmentally friendly as it is a natural fibre found in trees and plants. The bonding agent was also chosen because of its compatibility with the existing clay road. The agent helps make clay more elastic, preventing material from breaking apart. The organic binding agent further facilitated compaction.
- **Technology plays a crucial role in sustainability efforts.** The RM500 used on the jobsite has key technological features built in that help maintain uniformity and consistency. The technology ensures the proper amount of additive is blended, helping conserve materials. This helps crews purchase and haul only the materials needed, creating further efficiencies. Proper blending, meanwhile, helps extend the life of the road.
- **Training helps, too.** Crews that handled the work had not previously used the rotary mixer. They received training to help them maximise the machine's potential. It proved to be time well spent. When the job started, the Cat RM500 was able to work more efficiently, and more cost-effectively, because of the training provided.
- **Customers want to do the right thing.** Many customers, like those utilising the Tamanrasset haul road, are eager to find sustainable solutions. Some are willing to pay more for such solutions. Nearly all would chose a sustainable process if the costs were roughly equal. In this case, a sustainable process actually created significant cost savings. It's hard to think of a circumstance under which a customer would not choose a solution that is both more cost effective and more sustainable.
- **Sustainable solutions are often time savers as well.** Eliminating the need for the delivery, placement and compaction of new aggregate saved considerable time. This was crucial as the haul road was the only way in and out of the energy facilities. Efficient as it was, the repair caused considerable disruption. Once the work was started, it had to be completed quickly. Weather also added time pressures. The project started in February, when the average temperatures ranged from 7.5º-20.6º C (46º-69º F). But the likelihood of the season's first heatwave increased with every passing day. The time saved proved crucial as the heat approached, and the contractor was able to finish the work before summer arrived, with obvious benefits for both customers and crew.

### A perfect result

The road was completed - on time, and well within budget. The road's life was extended by years due to the well-planned process and the unique organic bonding agent.

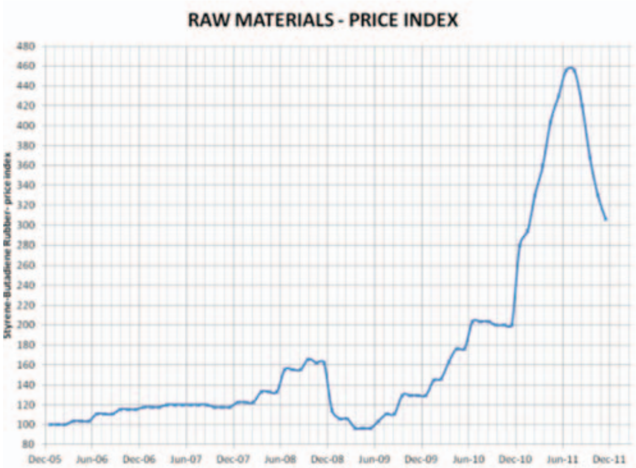
Today, the haul trucks not only travel more smoothly and efficiently, they also provide living proof that sustainable projects can be cost savers too.

## Rubberised asphalts: an evergreen technology?

**Daniele Fornai** - Research & Development Manager, Ecopneus, Italy

Asphalt manufacturing in the Italian market touched an historical low during 2011, confirming a trend that has seen a progressive reduction in road infrastructure investments over the last decade, with production of bituminous conglomerates and asphalt concrete declining by 40% compared to 2006 figures (source: The Italian Asphalt and Road Association - SITEB).

Notwithstanding, the price of raw materials has not been affected proportionally to this reduction in demand, and attained unprecedented highs during the first months of 2011. For example, the selling price of synthetic rubber has more than quadrupled since 2006 and this has had dramatic impacts on the sector, highlighting the need

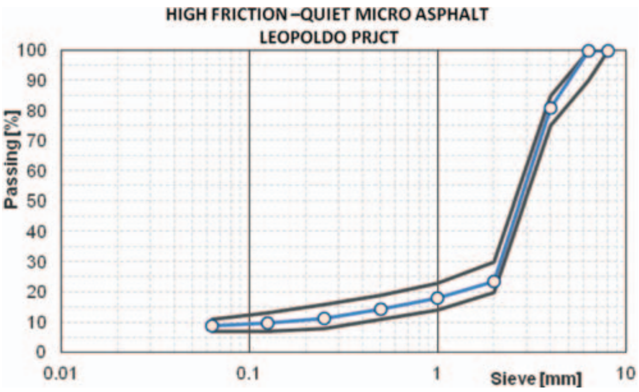



for sustainable investments in infrastructure, as well as greater policy emphasis on resource efficiency. In periods of financial crisis, public procurement procedures with respect to road maintenance may tend to be more oriented towards seeking out the lowest price rather than the best value for money. Whilst understandable in the short term, this unfortunate reality will inevitably impact negatively on the quality and durability of the roads in the longer perspective.

The same logic applies to equipment. Very cheap tyres, for instance, wear out faster, increase the vehicle's fuel consumption and may increase the risk of road accidents, again illustrating that short-term choices may be economically and environmentally inappropriate in a longer timeframe. This explains why the European Commission has deemed it necessary to introduce an obligation to label tyres on sale in the European market. Regulation (EC) No 1222/2009 on the labelling of tyres with respect to fuel efficiency and other essential parameters stipulates that, with effect from November 2012, the labels must notably provide information regarding rolling resistance (index of fuel consumption), wet grip (index of safety on wet roads) and exterior noise (index of impact on the community). The potential advantages of the scheme are evident in terms of the economic, social and environmental benefits expected to flow from wider uptake of "AAA" (best in class) tyres. The resultant fuel savings will, for example, have a positive impact on greenhouse gas (GHG) emissions, while fewer road accidents will reduce the associated societal costs and the noise mitigation benefits should not only bring about quality of life benefits for communities but also produce infrastructure cost savings with respect to noise barriers and so forth.

Most current road construction and maintenance best practice guides share similar sustainability principles aimed at optimising the use of precious resources. For example, it is commonly agreed that a wearing course made up of poor aggregates and less than 4% bitumen won't last long in time. It is further generally accepted that the initial savings achieved cannot justify the increased maintenance/replacement costs that will inevitably follow. Nevertheless, instances of cheap bids exacerbated by lack of on-site controls bringing about undesirable long-term consequences remain all too frequent, and the economic and environmental impacts of such bad management are often dramatic. The carbon footprint of short life pavings can be huge - for example, when the energy consumed for manufacturing, paving and then milling the pavement is weighed up. Moreover, large quantities of waste are generated (RAP – reclaimed asphalt pavement), more frequent work zones cause traffic disturbances, delays and inconvenience, and there is a greater risk of accidents due to poor paving conditions.

A number of projects and proposals have been instigated in Italy with the aim of highlighting best practices in sustainable road management. Among these, the use of rubberised asphalts represents an opportunity that has been neglected for far too long. Such modified asphalts been studied for more than 30 years throughout the world, and have consistently been found to show superior mechanical and functional properties, ensuring longer durability in all climates compared to conventional materials.

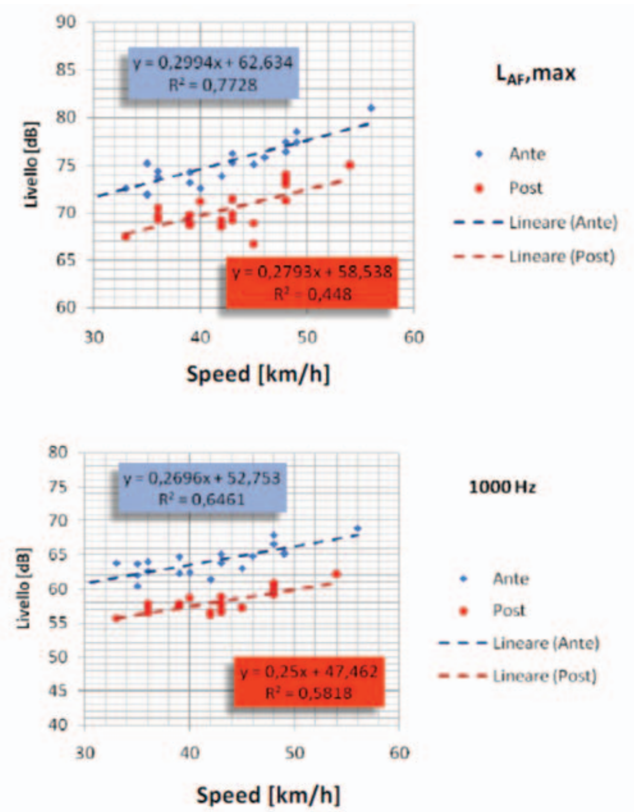



In Italy, however, rubberised asphalts continue to be viewed by many as "a new technology," and this hampers its acceptance by the relevant public authorities. In the current climate of budget restrictions, public decision makers tend to stick even more closely to old methods, even if this means the perpetuation of poor quality products that require constant maintenance. Fortunately, there are always a few individual visionaries as well as foresighted European funding programmes that inspire public and private organisations to think differently.

The visionaries are moved by curiosity – the will to explore and to test unconventional solutions for solving old problems. They are the innovators behind the slow but relentless diffusion of new technologies. Meanwhile, the European programmes serve as a catalyst bringing together key stakeholders and spurring the evolution towards projects that are specifically "Life Cycle Oriented".

In recent years, the EU interest has been directed towards stimulating a "recycling society", which includes amongst its objectives the mitigation of urban noise and the reduction of deaths and injuries caused by road accidents. As a consequence, Italian projects that study, develop and utilise rubberised asphalts as a "sustainable resource" have multiplied.

Statistical pass-by acoustic measurement of AR mixture - HUSH project

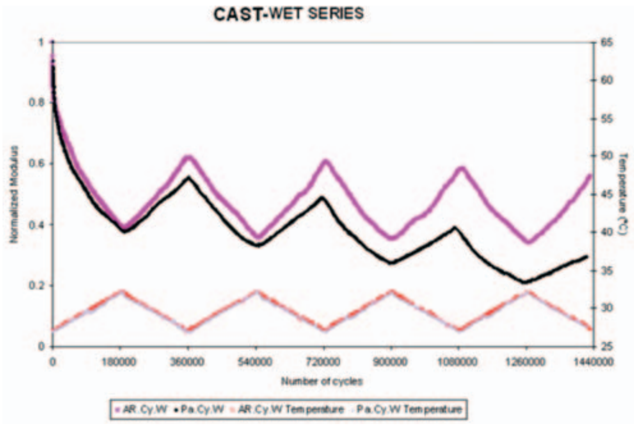



Among the most recent of these, it's worth mentioning the "Progetto Leopoldo" (Tuscany Region and University of Pisa) that assessed and optimised the safety features and environmental sustainability of certain road pavements. Rubberised asphalts (dry and wet) were studied and a thin friction course was optimised to provide a high friction coefficient (+10÷20% with respect to the traditional ones) and high road noise reduction (from 3 to 6 dB with respect to dense-graded hot-mix asphalt - DGHMA).

The acoustic properties of rubberised asphalts (gap/open) have been analysed in a growing number of pilot tests performed over the last 4 years. The main methods used for noise measurements have been those of "pass-by noise" or "close proximity" (CPX – ISO 11819-2).

One of the most interesting initiatives on noise reduction currently underway is the "HUSH" (Harmonisation of Urban noise reduction Strategies for Homogeneous action plans) project that aims to harmonise national norms on noise management at a European level. Again, rubberised asphalts offer outstanding tyre/road noise mitigation qualities in this context.

MOISTURE SENSITIVITY - AR Open Vs Porous Asphalt




Moreover, the exceptional mechanical properties of these mixtures have been extensively studied at the Università Politecnica delle Marche in Ancona, Italy, (F. Canestrari, E. Pasquini, F. Cardone, F. A. Santagata *et al*), with recent findings confirming superior fatigue resistance, reduced moisture sensitivity and excellent thermal cracking sensitivity.

Last but not least, in 2009 the Province of Turin, with scientific support from the University of Turin, launched a development project aimed at evaluating the use of rubberised asphalts on roads under its administration. The project produced a detailed rheological analysis of asphalt rubber binders and extensive characterisation of a "Gap Graded" mixture that has accordingly been utilised to pave 16,000 m² of highway. This activity continues as part of the TyRec4life project, which calls for the use of modified asphalts and is financed through the European three-year Life+ programme. This project will evaluate the use of secondary aggregates as well as warm mix asphalt technology in asphalt rubber (AR) mixtures and undertake a preliminary assessment of rubberised asphalts (dry).

*Ecopneus is a non-profit limited company set up by the principal tyre manufacturers and importers operating in Italy to manage the tracing, collection, treatment and recovery of the lion's share of the 380,000 tonnes end-of-life tyres (ELTs) generated in the country each year.*

# Adapting to Climate Change

## Increasing the resilience of roads: a focus on adaptation to climate change

**Kate Avery & Sarah Reeves** - Senior Climate Change Consultants, TRL, Wokingham, UK

Until recently, climate change research in the transport sector has been focused on understanding the impacts transport has on the climate and how to mitigate these. It is becoming increasingly apparent that a good understanding of the impacts climate has on transport is also critical for the long term sustainability of transport systems.

Road assets are constructed to withstand the environment in which they are built and are maintained accordingly; however the environment is changing. The warming of our planet and the consequential changes in weather patterns are now unequivocal. Knowledge on how these climate changes affect transport systems, and the actions that can be taken to reduce the risk of adverse impacts, is required to maintain and improve current levels of mobility.

Individual regions of the world are projected to experience differing changes in climate variables. All regions, however, will experience an increase in temperature, changes in rainfall patterns, more extreme weather events, rises in sea level and seasonal changes. In terms of the road sector, these climate changes have the potential to cause a number of impacts on asset infrastructure including:

- Flooding;
- Heat damage;
- Landslides;
- Bridge scour;
- Subsidence and heave;
- Soil erosion and increased dust; and
- Infrastructure loss due to sea level rises.

Extreme weather events such as intense rainfall and high temperatures can cause severe asset damage; however rises in average temperatures and changes in seasonal cycles can also increase deterioration rates, leading to infrastructure failure. In addition to asset damage and the costs incurred for reconstruction, changes in climate and the impact on road assets have the potential to severely disrupt travel; endangering the safety of travellers, preventing access to essential services, compromising the transport of goods, and impeding emergency services.

**Increasing the climate resilience of roads**

Improving the resilience of road networks to climate change requires an understanding of the vulnerabilities of the network to weather events; an assessment of how the level of risk changes over time; identification of actions to reduce the risk where appropriate, and the development of an action plan. An integrated and holistic approach to adaptation will increase climate resilience more efficiently and cost-effectively than an *ad hoc* approach; requiring longer term planning than used for traditional asset management, and consideration of wider issues such as the interconnections between transport modes and other sectors, and the influence of adjacent land use. Another critical factor is ensuring that high-level strategic planning is linked to decisions made on the ground about materials, design and maintenance procedures.

To identify climate vulnerabilities and evaluate future risk, a strong foundation of high quality asset information is essential. Our experience has shown that the uncertainties associated with climate projections are considerably outweighed by a lack of information on the road networks themselves. Asset inventories may be incomplete, particularly for drainage infrastructure, and asset management systems do not always contain the data required to assess resilience; or are set up in way that such data is difficult to extract. These knowledge gaps need to be addressed to support the identification of climate vulnerabilities and subsequent adaptation actions.

The information needed to assess the risk from climate change includes:

- General asset information including location, design, materials and condition;
- Spatial details of geology, topography, hydrology and use of adjacent land;

- A knowledge of climate thresholds of assets, beyond which failure occurs;
- How asset deterioration rates change with climate;
- The asset characteristics which increase climate vulnerability;
- Future climate change projections for the area in question;
- Information on future developments, e.g. new housing developments, new technology and changes in demographics.

TRL is currently involved in a number of research projects that are using this type of information to investigate the vulnerability of transport networks to climate change. FUTURENET (Future Resilient Transport Networks) is a four-year research project, jointly funded by the UK Engineering and Physical Research Council and the Economic and Social Research Council as a part of the "Adaptation and Resilience to a Changing Climate" programme. FUTURENET (www.arcc-futurenet.org) is developing methodologies and models to assess the climate resilience of transport systems and identify future vulnerabilities. The overall aim of FUTURENET is to answer the questions: what will be the nature of the UK transport system in 2050, both in terms of its physical characteristics and its usage, and what will be the shape of the transport network in 2050 that will be most resilient to climate change?

TRL is also funding research on the pluvial flooding of road drainage systems. The project is developing two models; one to calculate the user delay costs associated with different severities of flooding on different road types, and the second to identify the sections of road most vulnerable to pluvial flooding. The project will examine past flood events to determine the characteristics that make a section of road more susceptible to pluvial flooding, and use these to highlight future vulnerable areas.

These and other adaptation projects applying climate projections to the transport sector show how experts in different areas, such as climate modelling, civil engineering, hydrology, geology, economics and social sciences, need to come together to increase climate resilience.

### Prioritising adaptation action

Adaptation action needs to be prioritised according to the level of risk, within budgetary constraints. An initial reaction to the need to adapt road networks to climate change can be to focus on expensive engineering and construction projects. Although this is part of adaptation in some cases, monitoring an asset or doing nothing may be the most appropriate response. The risks of the potential damage and disruption caused by future weather events need to be weighed against the cost of the adaptation action to identify the most cost-effective solution. Monitoring or projecting change in risk over time can assist in identifying the most cost-effective time for action; a decision to act may be safely deferred to a later date allowing future budgets to be planned.

A decision also needs to be made on the level of acceptable risk; depending on the type of road, traffic volume and strategic value of a route. For example, the acceptable risk level for a rural, low-volume traffic road with a number of alternative routes will be higher than that for a major national road, a main route into a city or a route to a hospital. In the same way that road authorities set up priority routes for salting during icy conditions, they may wish to identify strategic routes and assets that need to be more resilient than the rest of the network.

### Adaptation in developing countries

In developing countries, increasing the climate resilience of roads requires consideration of networks that are often in poor condition due to low-quality construction or inadequate maintenance levels. There are also difficulties in accessing asset information, lack of technical solutions and limited resources to carry out adaptation work.

Improvements in road network conditions can increase climate resilience. However, climate change projections and impacts on pavement design need to be explicitly included in development projects – in construction, development of standards and training of local engineers – to ensure that climate resilience is increased. It is significantly more cost effective to take climate change considerations into account when constructing a new road, rather than retrofitting at a later date. For countries with limited resources, this is a crucial consideration.

### The Resilient Mobility Initiative

In order to focus attention on the need for climate adaptation in the transport sector and promote actions and policy making to develop robust transport networks, TRL has developed the Resilient Mobility initiative. In addition to raising awareness, the initiative draws together the range of activities required for creating resilient transport networks, from strategy and risk assessment to the development of engineering solutions and technical standards. Resilient Mobility is an international initiative, working to reduce the damage and disruption caused by climate change impacts in both developed and developing countries. For more information about the Resilient Mobility initiative, please visit the website www.resilientmobilty.com.