INTERNATIONAL ROAD FEDERATION
FEDERATION ROUTIERE INTERNATIONALE

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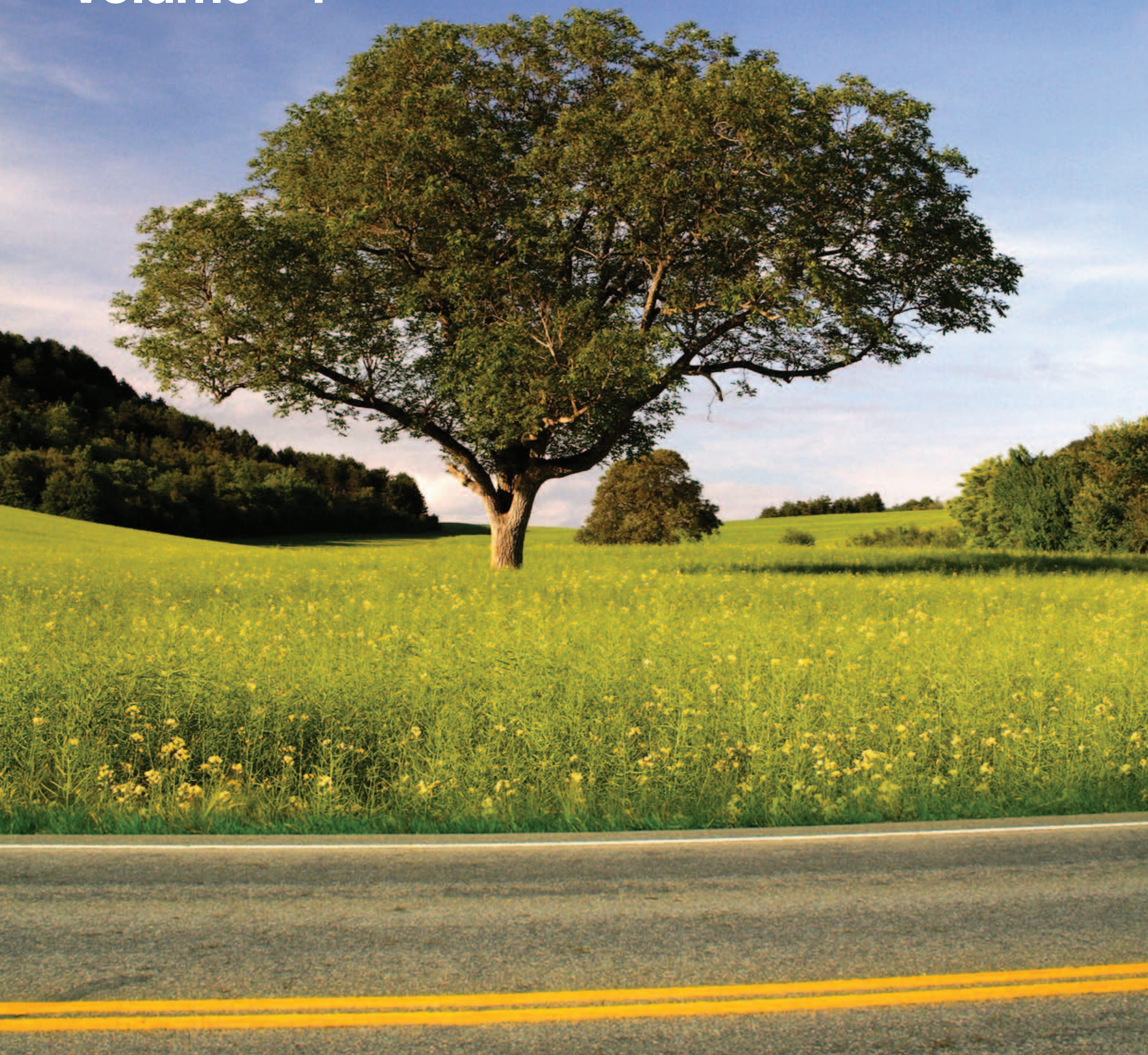
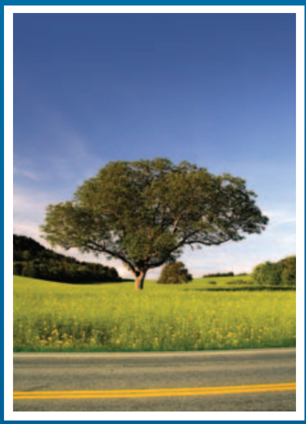
Environment & Climate Change

Volume - 1





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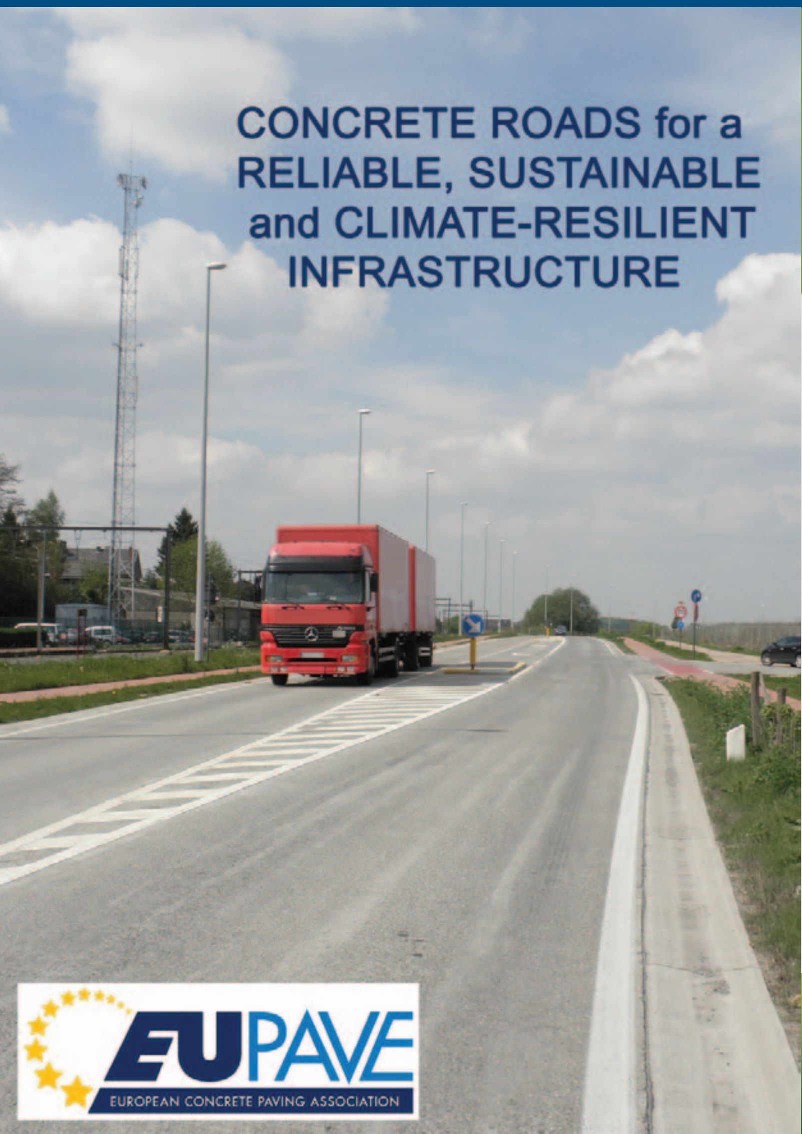


From the first dedicated journal on Environment to this issue on Environment and Climate Change, there have been ten IRF bulletins. Each issue had a focus on safety, reliability, affordability, congestion, sustainable materials and construction traffic management , to name but a few, and together they help to define our understanding of a sustainable transport system.

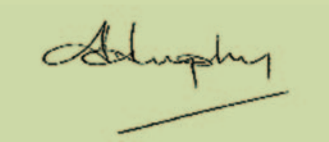
Recently, I was asked at a conference as to whether the industry was truly achieving significant improvements in sustainability or whether the changes were simply "playing around the edges".

Whilst I believe that even in my relatively short time within the road industry there has been a marked increase in the level of drive and support for appropriate technological innovation, it is also clear that a paradigm shift in sustainability will require further changes at all levels of the sector, the economy and the community. Above all, it will involve some level of risk taking.

Risks are necessary to make changes happen. An industry that is unwilling to take risks will become stagnant with no ability to innovate. As we move towards a carbon constrained world, innovation is required to enable our industry to move beyond assessment, and develop creative strategies that connect the shorter term benefits of emission reduction with benefits expected in the more distant future.

In the meantime, we need to protect our finite resources and increase our risk appetite for new approaches such as increased levels of RAP (Reclaimed Asphalt Pavement), low energy mixes, perpetual and porous pavements and a move towards lean construction. Inclusion of environmental externalities, whether it is for carbon, biodiversity, noise or air quality impacts, will also test our decision making. But if we approach sustainability with an open mind, we undoubtedly will achieve beneficial outcomes for the environment and for our industry.

Sometimes the willingness to take a risk even when the challenge is great, is exactly what industry needs to be truly sustainable.



Dr. Helen Murphy
Director, Environmental Sustainability VicRoads, Australia

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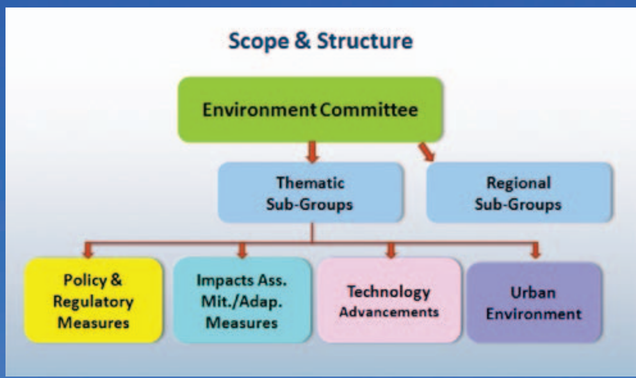
Steering the way to greener road infrastructure

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

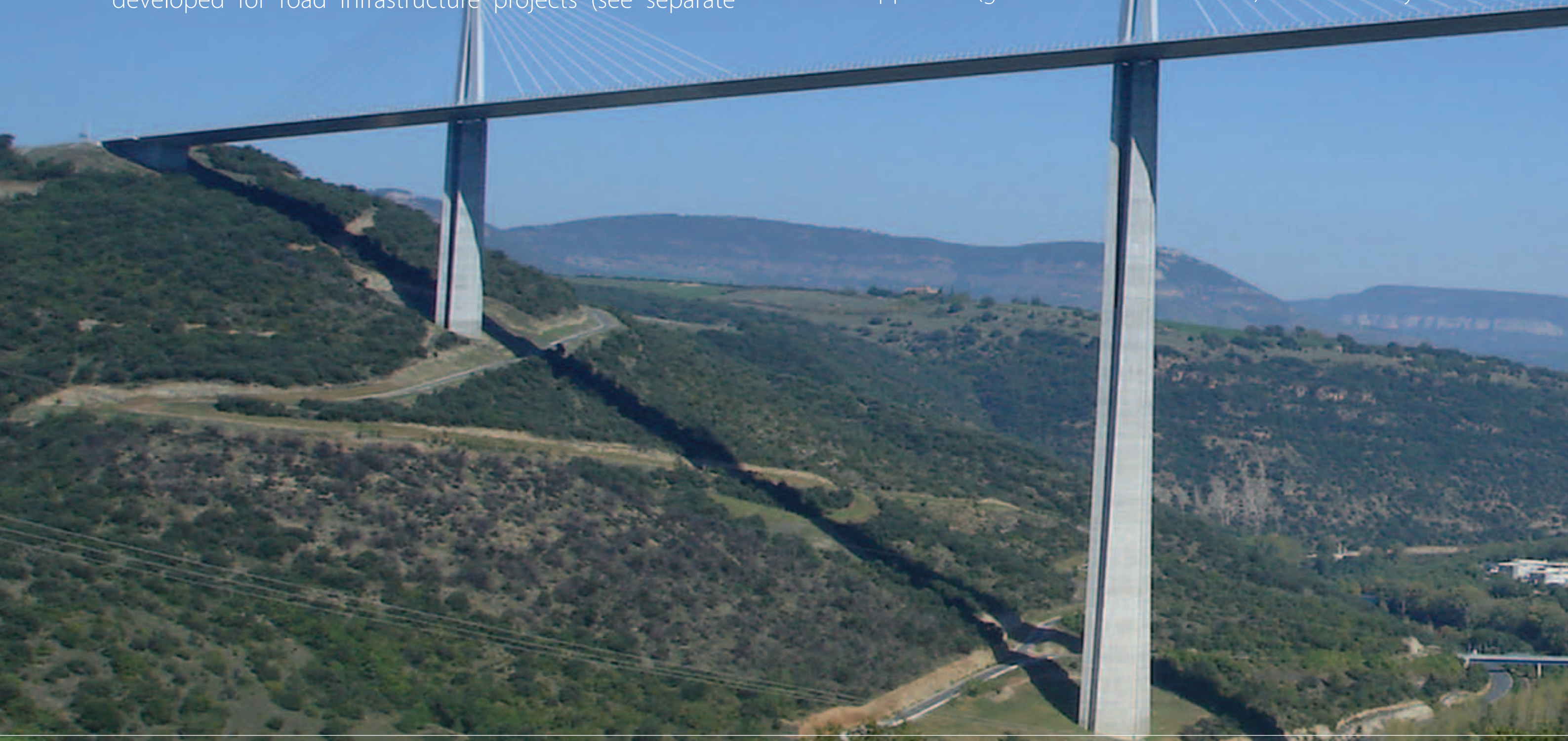
Achieving sound environmental and sustainability outcomes has long been an integral part of IRF members' policy and practice. The landmark **Environment Policy Statement** launched at the beginning of this year reaffirms IRF's resolve to be at the vanguard of efforts to further improve the environmental performance of the road sector. As the statement emphasises, this can be achieved without unduly compromising the mobility and access on which economic development and growth largely depend.

Through the Policy Statement, IRF and its members have committed to a comprehensive series of political, regulatory and fiscal recommendations. Rather than promote an ideological approach, the document highlights that **IRF values viable, cost-efficient solutions with the potential to bring about tangible improvements** in the environmental performance of the sector.

In keeping with IRF's pro-active approach, two flagship initiatives are already being implemented. The first is **CHANGER, a greenhouse gas calculator** specifically developed for road infrastructure projects (see separate article). This new software tool represents an important first step towards the definition of a common methodology for enabling authoritative benchmarking, against which road infrastructure projects may be assessed.



The second initiative is built around an active commitment to **advocate** for the wide adoption of **green public procurement** (GPP) criteria within the sector. Besides clearly positioning the Federation in the wider policy and regulatory arena, this involves raising awareness within the Federation and among its members, notably through the work carried out in the **IRF Environment Committee**. This dual strategy represents a first attempt to reverse the top-down approach (government »»» business) that currently



tends to characterise the elaboration and adoption of GPP criteria at national or supra-national level (e.g. in the European Union) - and which is often one of the main barriers hindering effective implementation and scaling up. In line with this commitment, IRF is also investigating the potential for an international **sustainability rating system** for roadway design and construction. This concept could offer a viable and practical means to define basic roadway sustainability attributes, enhance sustainability assessment and confer due market recognition for sustainability efforts.

Such efforts are of vital significance given the prevailing perception – particularly vis-à-vis the road sector - that environmentally-friendly technologies, materials and practices are an expensive luxury that governments simply cannot afford to pay for. The mission of the IRF Environment Committee is to correct this erroneous stance.

The Committee functions as a catalyst to raise awareness, promote immediate practical action and inspire innovation throughout the sector. The Committee's work is organized around four main focus areas: 1. Policy and regulatory measures; 2. Environment and climate change impacts assessments & mitigation and adaptation measures; 3. Technology advancements; 4. Urban environment. Work in each of these focus areas is carried out within a dedicated sub-committee.

If you wish to learn more or get involved, do not hesitate to contact Susanna Zammataro at IRF Geneva, **szammataro@irfnet.org.**

Publications and proceedings relating to IRF environment events are available on www.irfnet.ch

Policy & Regulatory Measures

VicRoads sustainability initiative: a star rating tool for roads

Dr. Helen Murphy - Director, Environmental Sustainability, VicRoads, Victoria, Australia

VicRoads, the statutory road authority for Victoria, Australia, has recently released its sustainability rating tool, named INVEST (Integrated VicRoads Environmental Sustainability Tool).

The launch of INVEST took place at Melbourne Zoo and was attended by over 100 contractors and consultants. During the proceedings, Gary Liddle, Chief Executive of VicRoads, noted that INVEST demonstrated the organisation's commitment to sustainability, and supported the key directions of its Sustainability and Climate Change Strategy.

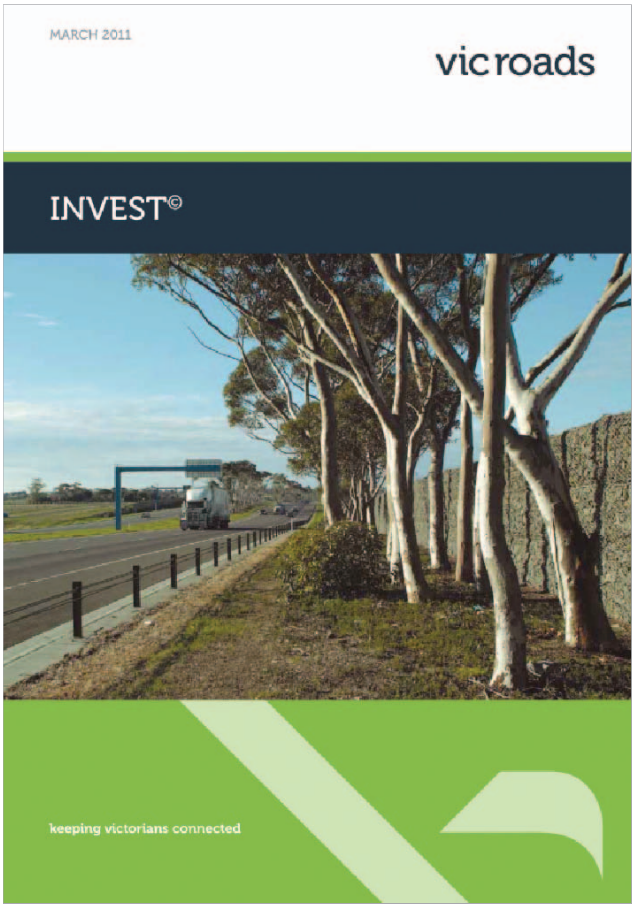
The aims of INVEST are to:

- encourage the investigation and implementation of innovative ideas that will contribute to improving sustainability in road projects
- recognise outstanding sustainability practices
- increase awareness of sustainable practices in road projects
- establish benchmarks for sustainability and encourage continual improvement

Similar to other rating tools, INVEST is a certification programme that distinguishes road construction projects according to the extent to which they incorporate sustainable initiatives. An international review panel has been engaged to oversee the implementation of the programme.

The sustainability rating tool will be used for VicRoads projects to establish benchmarks for future projects. The scope is currently limited to large construction projects and, as with most sustainability tools, the maximum benefit will be obtained if it is used early on in the project.

The long-term goal for INVEST is to raise the sustainability benchmarks across road construction projects and enable non-price attributes to be assessed as part of tender evaluation processes.



INVEST is a dynamic tool and will evolve concurrently with changes in industry standards, community expectations and new and emerging technologies.

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From low emission zones to low greenhouse gas zones

Dietrich Leihs - Senior Solution Manager for Urban Traffic, Kapsch TrafficCom AG, Vienna, Austria

The European Union (EU) Ambient Air Quality Directive has made clean air a civil right. Any European citizen may now call on his or her local government to take appropriate steps to reduce emissions from health threatening pollutants. Practically, municipalities have little option but to comply if threshold values are being exceeded. Usually, the only option is to reduce pollutants from traffic by regulating vehicle access. Low Emission Zones (LEZ) are the response in this respect. At the time of writing, some 160 such zones have been created in Europe and more will emerge. Of the existing zones, some impose blanket bans while others a charge based on the Euro emission class of vehicles opting to enter the zone (see examples below).

	Drive ban	Charge
All Vehicles	e.g. German LEZ	e.g. Milan Ecopass
HGV	e.g. Netherlands LEZ	e.g. London LEZ

Experience to date

Blanket driving bans theoretically achieve an immediate reduction in pollution. When applied to heavy goods vehicles (HGV) from the commercial sector, such pollution reductions are achievable. For example, the electronically enforced, HGV specific LEZs in The Netherlands led to a significantly higher share of Euro-4 and Euro-5 vehicles within the zone than outside, resulting in a concentration reduction of -0,2 ... -1.1 $\mu g/m^3$ for Nitrogen Dioxide (NO_2) and -0.1 ... -0.6 $\mu g/m^3$ for PM10.

In contrast, driving bans are not likely to affect sustainable changes of mindsets and mobility habits when applied to the general public. Private vehicles that fail the access criteria immediately become virtually worthless, provoking public and media debate about government overriding individual rights. The ensuing controversy tends to completely outweigh the ecological justifications and obscure the necessity to change behaviours for a more sustainable future. In addition, as the financial implications of LEZ aimed at private cars may particularly tend to impact disadvantaged sectors of the population, exemptions from the drive ban and long transitional periods are frequently applied to smooth deployment, but compromise the achievement of rapid pollution reduction. Often, the environmental impacts are barely measurable in initial phases – a weakness that can be exploited by lobby groups and further prejudice public perceptions regarding the true benefits of LEZ.

Charging, on the other hand, tends to offer a more gradual but ultimately more sustainable behavioural change. As the affected populations are not excluded outright from entering the city, they are afforded more leeway to adapt in accordance with individual capabilities and needs. The London LEZ for instance, which extends over almost 1,500 km^2 is aimed at the commercial sector. HGV within stipulated Euro emission classes have to purchase a day-pass ticket costing £200 (£100 for vans and minibuses). The immediate impact was that fleets were reorganised – and, even prior to this, a near 100% compliance with the appointed minimum emission class was recorded. Whilst the zone does not specifically target CO_2, the introduction of newer and more fuel-efficient vehicles as a result of the fleet reorganisation stimulated by the scheme naturally decreases these emissions.

A similar experience is demonstrated by the Ecopass initiative in the Italian city of Milan. Private vehicles in the worst pollution class have to pay €10 for a day-pass ticket, compared to between €2 - €5 for less polluting vehicles. Meanwhile, the most modern vehicles, including those running on liquefied petroleum gas (GPL), benefit from free access to the zone. The scheme proved so successful that polluter cars were reduced by 56.7% in the first year of operation. Consequently, the initiative achieved a tangible reduction of pollution in and around the zone, for example reducing CO_2 emissions by 9%.

From LEZ to L-GHG

Based on these experiences, charged schemes seem to provide a better strategy for reducing Greenhouse Gas (GHG) emissions than politically-sensitive drive bans.

Indeed, by analysing existing LEZ based on charging, tangible traffic cuts can be observed. This results in proportionate reductions in GHG, as illustrated in figure 3 using data from the Milan Ecopass. In the long run, LEZ stimulate a shift from old cars to new, compliant vehicles. As alluded above, however, by reference to London, no zones currently target CO_2 emissions specifically. Consequently, while initial CO_2 reductions may be recorded as a result of fleet renewal, emissions will tend gradually to go up again as general traffic increases. This trend is demonstrated in Milan, where the daily traffic volume in the zone was initially cut from 98 thousand to 87 thousand vehicles as the scheme encouraged usage of less polluting vehicles. The strategy, however, did nothing to sustainably change driving behaviour and so congestion remains a serious problem even as new vehicles with less polluting engines replace old cars. Congestion, of course, results in well publicised issues of increased fuel consumption due to 'stop-and-go' driving in traffic as well as particle matter emissions caused by tyre and brake abrasion in even the most efficient electric vehicles. Meanwhile, as more and more vehicles become

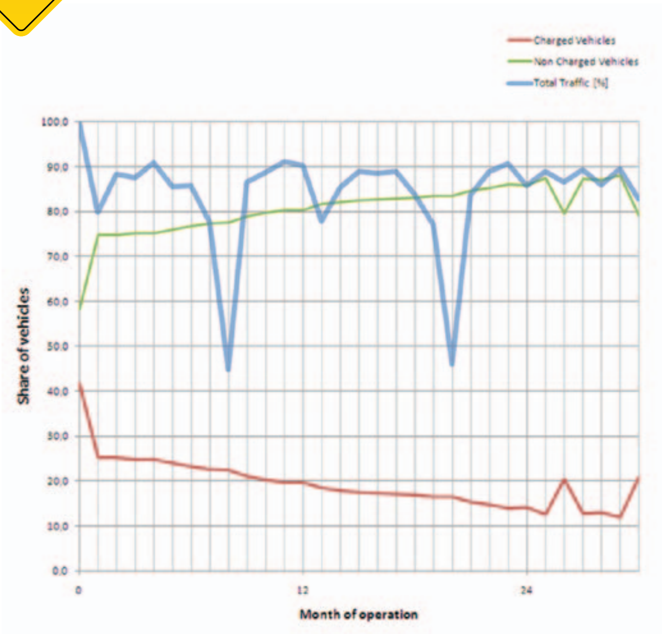

Fig. 1: Monthly traffic development within the Ecopass area from its launch in January 2008 until June 2010 ("0" is the reference data); Total traffic references to the pre-Ecopass numbers; the share of charged and non-charged vehicles by reference to the total traffic.

compliant – with polluter cars being replaced by Euro class 4 & 5 vehicles - the revenues collected diminish, ultimately jeopardising the financial sustainability of the scheme itself!

How then can we shift from LEZ to Low Greenhouse Gas Zones (L-GHG)?

The public appears to perceive GHG and pollutants the same in their capacity to damage the air. It follows that we should, theoretically, be able to turn a conventional LEZ into a L-GHG by employing essentially the same arguments. However, there is very little knowledge regarding the vote sensitive issues involved in practice and public consultation is required to fill this void. **If credible public awareness and information building does not take place due to a surfeit of generalisations, and/or contradictory information, any measure will struggle to gain acceptance, irrespective of its underlying merits.** This process of information building should be initiated early on in order to ensure the formulation of clear environmental and transport policy targets. Any failure in this respect at the level of political decision-making, may inevitably result in the emergence of dubious coalitions, sending out confusing and often misleading signals to the general public.

Milan provides one caveat indicating the importance of public awareness and consultation efforts regarding LEZ based on charging. Though the general public was aware of the worsening air quality in Milan, they did not consider car traffic as the main source of pollution and no public consultations were held because the decision making process took place against a backdrop of controversy. The Ecopass programme was, indeed, launched amid strong opposition among political allies of the governing Mayor. Ultimately, the whole vote-sensitive debate was reduced to a simplified "polluter pays" principle. This not only failed to raise significant public awareness and support for the wider issues, but also spawned a number of questionable interest groups campaigning for and against the scheme.

The Milan initiative did, however, offer a few glimmers of optimism that a conventional LEZ based on charging can be successfully turned into an L-GHG. By analysing the time period immediately following the introduction of the scheme, two behavioural changes could be observed:

1. The polluter cars were reduced by 56.7% in the first year of operation.
2. Car traffic dropped by 5 million vehicles in the first year of operation. This was accompanied by a parallel growth in public transport, with an additional 35 million rides being recorded over the same period.

The lessons learned from the Ecopass programme are the following:

- The 'polluter pays' principle can be an effective tool for encouraging behavioural changes, provided it is viewed in overall context, but the nature of the scheme affects the permanence of behavioural changes.
- Including GHG emission reduction in the strategy promotes the selective decarbonising of cities.
- Key prerequisites for introducing such a scheme are a robust consensual decision-making process and credible public consultation to generate awareness and acceptance.

The accompanying policy options should be primarily focused on offering alternatives (P&R, public transport, cycling, etc.), providing education (shaping public consciousness about carbon footprints) and 'lifestyle' issues (commuting, alternative modes of working, etc.).

As no scheme is likely to induce the abandonment of private car use, the crucial question remains as to how long the shift from fossil fuel to alternatively powered vehicles will take. This evolution can be stimulated through incentives to stimulate behavioural changes, and LEZ based on charging can fulfil a crucial role in this respect.

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Environmental impact assessment of transportation projects in Greece

Christos Spirtzis & Alexander Koulidis
President of the Technical Chamber of Greece, and Chemical Engineer to the Special Environment Service of the Ministry of Environment, Energy and Climate Change, Athens, Greece.

This article endeavours to present an integrated picture of the environmental permit procedures that apply to the design, construction and operation of transportation projects in Greece.

It introduces four key aspects of the Environmental Impact Assessment (EIA) procedure required.

1. Basic concepts

EIA aims at assessing and mitigating the possible negative impacts that a proposed project may have on the environment, taking into account the natural, social and economic dimensions. The purpose of the assessment is to ensure that decision-makers consider the environmental impacts likely to flow from a project before deciding whether or not to proceed. Furthermore, EIA provides a basis for drastically reducing anticipated impacts through appropriate mitigating measures – for example by shifting the project design towards more environmentally-friendly solutions and/or by integrating protective measures into the procedures for construction and operation of the project.

In Greece, EIA has a solid legal basis (see next section) and has been applied for some 20 years now, enabling the consulting firms and administrative services working in the field to acquire extensive experience.

The application of the EIA process in Greece consists of three elements: the EIA report, the consultation procedure and the final decision.

Due to growing demand for ever more rigorous and detailed environmental management, EIA reports have evolved into comprehensive and authoritative multi-disciplinary studies, often stretching to hundreds of pages backed up with extensive charts and illustrations. As a result, while

Figure 1: Greening all free surfaces of a highway project is usually imposed via EIA.

the full range of environmental issues may be exhaustively examined, the reports themselves have tended to become increasingly unwieldy and expensive.

The consultation procedure involves the public and the administrative departments with relevant environmental jurisdiction. It is often a time-consuming and difficult process, as objections from the public and follow-ups from the project proponents are invited and heard. In the end, the resulting "fermentation" of perspectives usually leads to increased acceptability for the project.

The final decision includes approval of the environmental terms and pre-conditions that the project is obligated to meet during construction and operation. In rare cases, when the environmental impacts cannot be sufficiently mitigated or counterbalanced, a project can be denied approval altogether.

Legal basis

The Greek constitution commits the State to protect the environment by taking appropriate preventive and restraining measures. As the constitution stands at the top of the hierarchy of legal rules in the Greek system, this commitment is the main starting point for the EIA procedure, as well as for most of the country's thematic environmental legislation. In parallel, European Council Directive 85/337/EEC (as amended by Directive 97/11/EC) calls for appropriate assessment of the environmental impacts of a wide variety of projects in Member States, and sets out a detailed framework for the relevant procedures.

The Greek EIA system is in line with both national and European provisions. These include the requirements for elaboration, publicity, and administrative approval that are essentially defined in Law 1650/1986 (as amended by Law 3010/2002) and Joint Ministerial Decisions 15393/2332/2002 and 11014/703/F104/2003.

Pursuant to these stipulations, proposed projects are classified according to four distinct classes. Roads, highways and stretches of national network are class A1 projects and demand a detailed EIA procedure. Regional roads are class A2 and require a less rigorous but still relatively demanding assessment, while smaller projects are classified as A3 or B, and are subject to a much easier assessment.

It is noteworthy that, the EIA phase of a major scheme is when the project plan makes its first public appearance. Since there is no prior stage of public consultation, EIA offers people a first opportunity to air their views. This often leads to a wide public discussion, not only regarding the environmental aspects of the project but also the social, regional and economic dimensions.

Current status

The numbers of EIA applications in Greece are quite large. At the central administration level, about a thousand EIAs are carried out each year, while at regional level the annual number of EIAs exceeds five thousand. If additional associated tasks (like modification or renewal of environmental terms, screening of very small projects etc.) are taken into account, the total administrative burden surpasses twenty thousand cases each year. These figures attest to the fact that the environment in Greece plays a major role and is covered by a detailed protection system. On the other hand, however, the figures highlight some over fragmentation of projects, as well as a degree of over-regulation, notably with respect to smaller activities and installations.

The timeframe of EIAs is also frequently extended. Although the legal texts require that the whole procedure should be completed within no more than four months, durations greater than a year are not rare. This happens mainly because the relevant authorities are overloaded and short of the necessary personnel; while the complex legislation on various aspects of the environment (forests, protected areas, water resources etc.) makes matters worse.

Despite such difficulties, however, the overall record of the EIA process attests to a generally high quality, both

Figure 2: Cut and Cover helps to maintain a cohesive natural surface for flora and fauna.

with regard to environmental protection and the project acceptability dimension. Indeed, as the main issues are comprehensively addressed and resolved in open and transparent ways through the EIA process, there is very little scope for controversies and legal doubts at later stages of a project.

Future developments

In September 2011, a new law on EIA was introduced in Greece, aimed at improving the effectiveness and quality of the relevant procedures. A number of procedural steps have been substantially simplified, and there is a clear shift towards standardisation and digital tools. It is hoped that, as a result of the new legislation, the number of EIA cases will be significantly reduced and that the whole procedure will henceforth require much less time. The line between the regional and national level is drawn more clearly, and decentralisation has been further enhanced.

Figure 3: Sound barriers are a common measure to mitigate impacts of highways on the urban environment

The full application of the new law will require due elaboration of the detailed provisions, which will be provided through a series of administrative acts (joint ministerial decisions) that will be promulgated shortly. While these details could either reinforce or somewhat lessen the potential of the main law, the fact remains that EIA in Greece is likely to become more effective and significantly simplified.

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IRF Policy Statement
Environment

Context and Stakes

Environmentally sustainable roads represent an investment in the long-term prosperity of both planet and society.

Today more than ever, it is evident that **economic development and transport are inextricably linked.** Just as development increases transport demand, so, conversely, the availability of transport stimulates further development by enabling trade and economic specialisation. Growth and poverty reduction cannot be achieved without physical access to resources and markets. Similarly, quality of life flows from physical access to jobs, health, education and other amenities.

Transport-sector CO_2 emissions represent 23% of overall CO_2 emissions from fossil fuel combustion. The sector accounts for approximately 15% of overall greenhouse gas emissions (OECD/ITF 2010). With emissions predicted to increase by two thirds over the next thirty years, any **credible and coherent future strategy** must emphasise innovative thinking and cooperation across the full range of stakeholders aimed at improving the environmental performance of the road sector, without unduly compromising the mobility and access on which economic development and growth largely depend.

Finding the right balance between commitment to reduce the environmental impacts of the road sector on the one hand, and economic development, trade and mobility imperatives on the other, requires a comprehensive mix of policy, fiscal and regulatory measures - with the capacity to determine changes in travel behaviour as well as the most appropriate logistical responses and technology choices. **IRF makes a commitment to a stronger pro-active role** and a broader view of the interdependencies and public/private hierarchies. Price mechanisms alone are likely to be neither politically or socially acceptable, nor sufficient to adequately address the challenges.

Rather, price mechanisms must be viewed as just one potential component within a **much wider strategic approach** that better reflects the full complexity and interdependence of the issues that need to be addressed. These range from land-use considerations right through to well-documented priorities of, for example, energy and resource conservation, habitat and biodiversity protection, landscaping and health (notably the impacts of growing exposure to noise and air pollution). Questions regarding the durability of existing infrastructures also need to be factored into this already substantial equation, as changes in seasonal weather patterns due to global climate change create new challenges for the design and construction of roads. Coastal zones contribute greatly to GDP around the world. Any significant increase in sea level will have tremendous negative impact on this economic contribution.

IRF's position and recommendations

Achieving sound environmental and sustainability outcomes is an integral part of IRF members' policy and practice. They are **fully committed to:**

- Safeguarding the environment whenever possible;
- Mitigating adverse effects through pro-active consideration of environmental issues at every stage of planning and implementation;
- Managing and using resources efficiently;
- Continually improving infrastructure environmental performance.

IRF recognises the multiple benefits of sound environmental impact assessment and management, incorporating the efficient use of materials and energy. It is further committed to ensuring that the road infrastructure sector increasingly contributes at the forefront of global efforts to reduce greenhouse gas emissions.

In this context, IRF advocates that sustainable management is most effective when environmental challenges and opportunities are taken into consideration early and pro-actively at every stage of the life-cycle of road infrastructure. The return on investment metrics (ROI) should broaden the range of metrics to include mobility and access. In keeping with its commitment to promoting this fundamental objective, IRF makes the following core recommendations:

Political, regulatory and fiscal measures

- **Cost-benefit analysis** should be the basis of political, regulatory or fiscal measures aimed at protecting the environment;

- Efficient **land-use planning** is an essential pre-requisite for determining the optimum interfaces between the environment, roads and users;
- Setting guidelines and **green rating systems** for environmentally effective road infrastructure planning, construction and management is an important tool for stimulating the application of best practices and to this end it should be better promoted;
- Environmentally friendly **products and processes** developed by the private sector should be given recognised value within procurement procedures.
- Comprehensive and coherent **transport policies**, including promotion of effective public transport as well as eco-driving, are a key starting point for addressing the environmental challenges associated with the road sector. Limiting road capacity has proved an unsatisfactory and unrealistic measure for improving environmental conditions. "Stop-and-go" traffic conditions produce comparatively high emissions. "Keep the traffic moving" should be a priority objective of all traffic management initiatives, particularly those in urban areas.
- Operational efficiency of existing infrastructure through more efficient and systematic deployment of **Intelligent Transport Systems (ITS)** should be encouraged.

Impacts assessment

- Strategic **environmental impact** assessment is a fundamental component of road network planning;
- The development and use of **tools to determine the carbon footprint** of road infrastructure and traffic should be encouraged. These tools can be used to assess and reduce the environmental impact considering alternative solutions
- **Life-cycle analysis** methodologies should be adopted as a guiding principle for the assessment and selection of materials and technologies.
- Network **resilience to climate change**, in particular, flood and related risks should be carefully assessed and addressed in the planning process for new road construction and/or the upgrading of existing road infrastructure.

Mitigation

- **Landscape improvement** should be an integral component of all road construction and rehabilitation projects in order to mitigate the infrastructure environmental impact. It should also be undertaken in a manner that recognises and respects the associated historical, cultural and community values. Whenever possible, measures to improve the visual quality of the existing road network should be taken.
- **Materials and energy** are key finite resources, and must be used in a manner that recognises, and is compatible with, supply limitations and life-cycle costs. Particular emphasis should be given to re-using and recycling resources to the maximum extent.
- **Maintenance** should be carried out in such a way, so as to reduce the environmental burden it could incur. When components need to be replaced, alternative technologies and recycling/reuse should always be considered.
- The potential of road infrastructure for **alternative energy production** should be further investigated.
- **Water pollution** resulting from road and traffic operations should be carefully assessed and monitored to enable prevention and mitigation of harmful effects.
- **Noise pollution** must be addressed as part of an integrated approach, taking into account the interactions of pavements, tyres and vehicles.
- **Monitoring of all environmental impacts** of the infrastructure during the period of operation is crucial in measuring the success of all design and construction considerations and improving any problems that may arise.

IRF believes that, if widely adopted and wisely applied, these recommendations will prove that economic development and protection of the environment need not be irreconcilable goals and that **viable green road infrastructure is today a reality.**

Assessing CO_2 Emissions

CHANGER – The IRF tool for assessing GHG emissions in road infrastructure projects

The CHANGER team - IRF Geneva

Climate change resulting from human activities is recognised as one of the most urgent environmental issues facing the global community. The transport sector produces about 15% of global Greenhouse gas (GHG) and 23% of energy-related carbon dioxide (CO2) emissions (OECD/ITF 2010), and these numbers are expected to rise rapidly. The development of emissions monitoring and assessment tools is part of an endeavour to realise low carbon transportation strategies set up by governments. Up to now, however, what has been lacking is a common methodology offering a credible and universally accepted system of measurement for defining strategy and monitoring progress. CHANGER (Calculator for Harmonised Assessment and Normalisation of Greenhouse-gas Emissions for Roads) – developed by the International Road Federation - marks a significant breakthrough in changing this situation.

Specifically tailored to road infrastructure projects, CHANGER is an user-friendly software that enables both public and private entities to monitor and assess GHG emissions generated during the various stages of the road construction process.

The ultimate goal of this tool is multifaceted:

- Facilitating a detailed environmental analysis of road projects;
- Providing a basis for comparative analysis of various road-building techniques and materials;
- Optimising road construction site supply schemes with respect to raw material providers, choice of suppliers, delivery locations and material transport modes;
- Enabling an estimation of the carbon footprint of road construction activities.

Concept and Modelling approach

A carbon footprint is a measure of the carbon dioxide (and other potential greenhouse gases) arising as a result

of a specified activity or product. Quantifying the carbon footprint of an activity or product allows the sources of the impacts to be understood, investigated and managed.

Carbon footprinting is an emerging technique. It is not an exact science but a modelling exercise with no current internationally defined and agreed methodology. Broadly, the techniques required in carbon footprinting are generally similar to those of energy analysis and life-cycle assessment (LCA). The International Standards for life-cycle assessment (ISO 14040 series on Environmental Management) are non-prescriptive, providing a framework for LCA practitioners rather than setting rigid rules and prescribing the datasets to be used.

CHANGER adopts a comprehensive "input-output" modelling approach.

The calculation model is based on a set of equations that enable accurate estimation of overall GHG emissions (outputs) generated by each identified and quantified source (inputs).

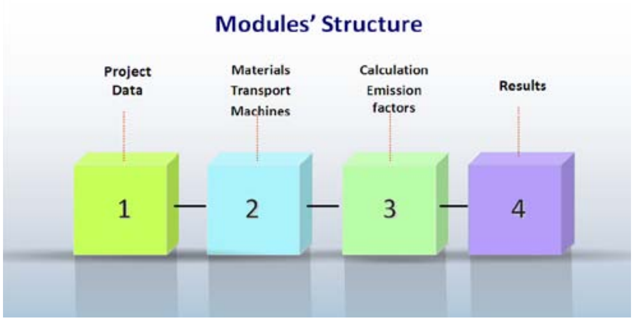
Structure and boundaries

CHANGER currently comprises two main modules:

- Pre-construction (clearing and piling, cut export and fill import transport).
- Pavement (on-site impacts, construction materials, materials transport, construction machines).

The scope of the model does not include – at the moment – maintenance activities, provision and powering of street lighting, any road marking or road signage, or any impact associated with using the road.

Every module follows the same logical stages (Figure 1).



First, input data specific to the project are entered. Then, materials and energy flow are quantified. These quantities are subsequently assessed with emissions factors in order to calculate the total output of GHG emissions attributable to the road construction process. Wherever possible, the effects of three greenhouse gases are considered in the calculation: carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). Once assessed, these GHG emissions are converted to carbon dioxide equivalent.

Carbon dioxide equivalents are commonly expressed as "million metric tonnes of carbon dioxide equivalent" ($MMTCO_2e$).

Table 1: Global warming potential (GWP) factors applied

GHG	GWP Factor (100 years)	Comment
Carbon dioxide (CO_2)	1	The reference unit against which all other GHG emissions are benchmarked
Methane (CH4)	21	Methane is 21x more potent than carbon dioxide as a greenhouse gas. This means that 1 kg of methane has a global warming potential of 21kg CO_2e
Nitrous oxide (N_2O)	310	Nitrous oxide (N_20) 310 Nitrous oxide is 310x more potent than carbon dioxide as a greenhouse gas. This means that 1 kg of nitrous oxide has a global warming potential of 310kg CO_2e

The research has been organised in a series of successive and interlinked stages:

- Compilation of an exhaustive inventory of GHG sources during different stages of construction;
- Estimation of the intensity level necessary for evaluating the identified emissions sources;
- Compilation of the applicable emissions factors in accordance with Intergovernmental Panel on Climate Change guidelines;
- Setting up the calculation equation:

$$Emissions = \Sigma S_i * Emission\ Factor\ with\ S_i = Source\ (A*I)_i$$

where sources are specified in units compatible with the emission coefficient; A = activity level and I = intensity.

Functionalities

The pre-construction module takes into account:

- **Clearing and piling:** estimates are generated for machine use, fuel consumption based on the ground surface area cleared per unit of road surface, and emissions from transporting removed vegetation.
- **Cut exports and fill imports transport** to and from the road site: based on a simplified diagram, the user selects the relevant sites and enters the respective distances, tonnes of material and transport modes (road, rail or in-land water).

The pavement module takes into account:

- **On-site impacts:** electricity and fuel consumption on the construction site.
- **Pavement construction materials:** this section encompasses several menus (unbound materials, hydraulically bound materials, bituminous bound materials, metals, rubber and plastic, etc.), from which the user can easily select the materials required for construction of the different layers of the given pavement.
- **Materials transport:** Figure 2 shows how CHANGER helps assess the emissions generated by transportation of the identified materials.
- **Construction machines:** the model estimates the number of working hours per type of machine and number of pavement layers. The total consumption of fuel is determined on the basis of the characteristics and efficiency of the material used.

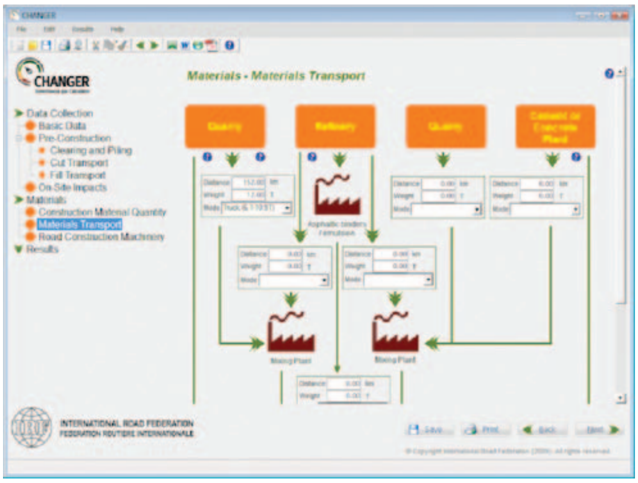


Figure-2

Dropdown menus and data entry wizards are designed to enhance user-friendliness at every stage. Moreover, CHANGER automatically generates comprehensive reports – either aggregated (total) or disaggregated (inherent to one or more steps of the process) – that can be conveniently exported to Excel, Word, PDF or HTML.

Validation process

By virtue of its extensive and varied membership – both in terms of geographical coverage and fields of specialisation – IRF has benefited from technical support from a wide range of industry and technical partners throughout the development of the projects. This has been particularly invaluable for ongoing review and validation of the modelling approach and databases, as well as for testing and comparison.

The LAVOC (Traffic Facilities Laboratory) of the Swiss Federal Institute of Technology (Ecole Polytechnique Fédérale de Lausanne - EPFL) has analysed and validated both the quality and reliability of the databases and the calculation procedures.

An example of results obtained with CHANGER in India*

The Karnataka State Highways Improvement Project (KSHIP) is an initiative by the Public Works Department (PWD) of the Government of Karnataka, India (GoK) to undertake improvement of roads consisting of state highways and major district roads. From the feasibility study, the GoK selected 268.59 km of roads for upgrading in a phased manner. The proposed project is grouped into five contract packages consisting of eight road links spread across the state of Karnataka. As a proactive measure, CHANGER was used on five projects to quantify GHG emissions. Table 2 shows the results obtained from the projects.

CO_2e per km (t) for the proposed project packages varies between 897 tons for WEP2 to 3228 tons for WEP1. Variation in results for CO_2e per km of different sub-projects is due to the following disparities:

- Quantities of required construction materials depending on the length of the road and cross section of the road projects.
- Lead distances for construction materials depending on sourcing of the raw materials and the location of project.

* Courtesy of URS Scott Wilson

Table-2: Results obtained with CHANGER in India

Project	Link	Description	Length (km)	Package length (km)	CO_2-e emissions (t)	CO_2-e per km (t)
WEP1	67A 67B	Hoskote - H Cross (Hindagnala Cross) H Cross (Hindagnala Cross) - Chintamani Bypass	23.50 28.90	52.40	169,132	3,228
WEP2	T8 M7D	Haveri (NH4) - Hangal Hangal - Tadasa	31.80 43.46	75.26	67,500	897
WEP3	21B	Dharwad - Saundatti	38.50	38.50	60,631	1,575
WEP4	13A 13B	Tinthni - Devadurga Devadurga - Kalmala	32.45 41.35	73.80	92,041	1,247
WEP5	6C	Chowdapur - Gulbarga	28.63	28.63	46,870	1,637

- Number of cross drainage structures and length of lined drains for the five projects determined by the project requirements.

Additional factors also contributed to the variation of results, for example the projected traffic dictating the pavement type and thickness, foundation strength, location and geology, existing road layout and pavement condition, etc.

Case study results indicate that the production and transport of the materials used in road constructions produce the most significant environmental burdens. Production of the bitumen and cement, crushing of materials and transport of materials are the most energy consuming single life-cycle stages of the construction.

Future development

CHANGER is an evolving tool subject to ongoing review and development. Work is underway on complementing the existing pre-construction and pavement modules with a new module devoted to maintenance activities. Similarly, the databases will be regularly updated to reflect the very latest science as well as cutting-edge research on techniques, materials and equipment. Updates are made available to the users directly on CHANGER website: **http://www.irfghg.org**

As governments and industry are increasingly required to evaluate and reduce GHG emissions and international financial institutions look to include compulsory GHG assessment of road construction projects in tendering procedures, CHANGER provides a unique "clear path" methodology simplifying the processing and analysis of complex technical information necessary for carbon footprinting.

A video of CHANGER is available on **www.irfghg.org**:

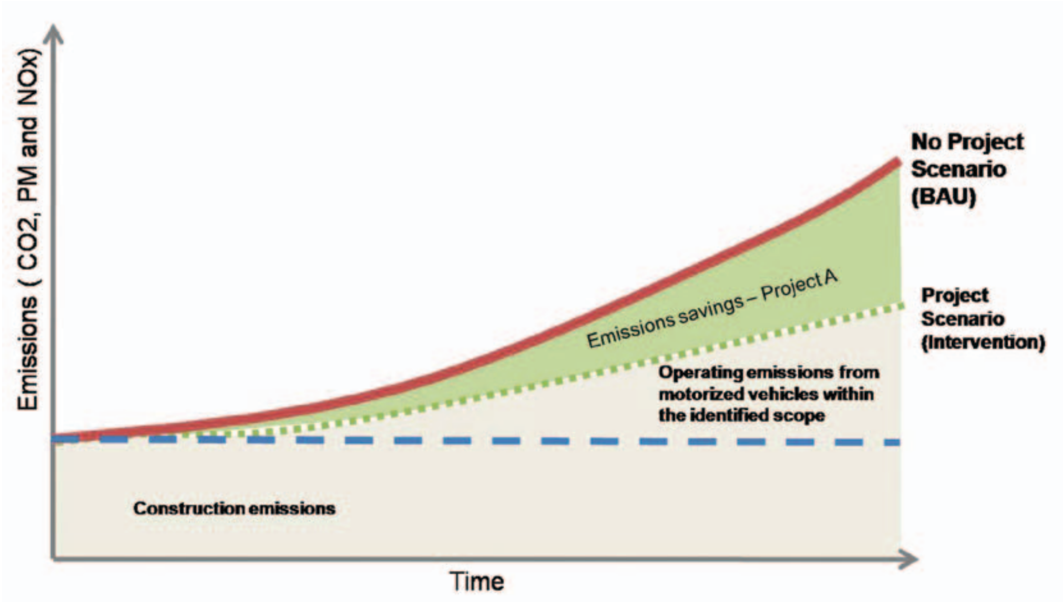
Tool to quantify emissions from different projects - TEEMP

Sudhir Gota, Alvin Mejia & Bert Fabian -
Clean Air Initiative for Asian Cities Center, Manila, Philippines

Transport is an important component in achieving sustainable development. However, it is also intertwined with major challenges facing our cities today, such as climate change, air pollution, energy security and poor quality of life.

In 2006, the International Energy Agency (IEA) estimated that the transport sector accounted for 23% of energy-related carbon dioxide (CO_2) emissions globally. The transport sector is also said to be the fastest growing sector in terms of CO_2 emissions as it is expected to quadruple its 2005 energy use by 2050. It is also a major culprit with respect to the deterioration of air quality in many cities, particularly those in the developing world. The World Health Organization (WHO) estimates that 1.1 million deaths globally are attributable each year to urban outdoor air pollution, with 83% occurring in low and middle income countries.

Currently, most developing countries and cities are moving towards sustainable transport through what can be described as a top-down approach, i.e. creating sustainable transport policies at the national level and implementing them at the local level. Thus, there are policies that need to be strengthened or established at the national level, like vehicle emissions standards, fuel economy standards and certain economic policies that promote sustainable transport. However, creating such policies also results in a demand for good transport projects, which provide wide-ranging benefits. Traditional tools and methodologies for evaluating the emissions impacts of such projects require a lot of time and data, consequently requiring huge financial resources. Thus, methodologies and tools that would enable rapid but sound assessment of the emission impacts of transport projects using readily available data are much needed to promote quality investments in the transport sector. This has created a necessity for simple Excel-based models that are freely available and which can be used to aid project selection.



It is important to note that, while the discussions surrounding methodologies for calculating carbon emissions from transport projects are relatively new, the calculation of fuel savings from transport projects has been in common practice for many decades (from as early as 1960s) as this is a key parameter in establishing a project's economic viability. It follows that, once an analyst can capture fuel measurement from a project, calculating CO_2 emissions can be achieved through a simple multiplication of the carbon content of the fuel. However, this dimension has been neglected largely due to institutions and researchers bickering over the assumptions and boundaries for CO_2 quantifications in projects. It is ironic that millions of dollars of investment are being distributed at a project level based on an accepted methodology and assumptions for calculating fuel savings, but that no methodology can be agreed upon for calculating the CO_2 impacts of the project once implemented .

Also, the clamour for high accuracy has resulted in huge costs for measurement. A methodology like CDM (Clean Development Mechanism) needs vast resources while the TEEMP tools (see below) can be utilised at minimum cost. One of the main reasons for low penetration of CDM in transportation is due to the high costs associated with the development, survey, data requirements and validation procedures inherent in the methodology. CDM Methodologies AM31 and ACM 16 are data intensive and carry high costs, both upfront (300,000 – 500,000 USD) and annually (typically 200,000 USD due to 6 surveys each year). Assuming even a 20 USD rate for a tonne of carbon dioxide equivalent (CO_2e), a project would need to achieve at least a total reduction of 25,000 tonnes of CO_2e emissions over its lifetime in order to recover the cost of CDM project application (excluding monitoring and other costs).

Transport Emissions Evaluation Models for Projects (TEEMP)

In 2010, recognising the need for a rapid but sound methodology for estimating emissions from transport projects, the Clean Air Initiative for Asian Cities (CAI-Asia) Center – together with the Institute for Transportation and Development Policy (ITDP), the Asian Development Bank (ADB), Cambridge Systematics, the United Nations Environment Programme (UNEP) and the Scientific and Technical Advisory Panel of the Global Environment Facility (GEF) –developed a series of Excel-based, free-of-charge spreadsheet models collectively known as **"Transport Emissions Evaluation Models for Projects"** (TEEMP). The TEEMP tools are flexible, Excel spreadsheet models primarily designed to evaluate the impacts of transport projects

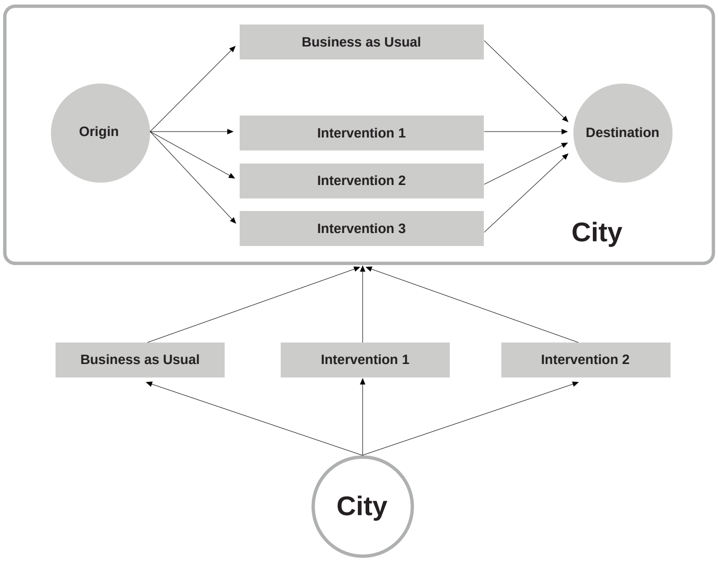


Figure 1. Structure of the TEEMP Models

on CO_2 emissions, as well as to some extent air pollutant emissions, using data gathered during project feasibility studies and actual operations. The results of TEEMP evaluation can help facilitate decisions regarding reasonable directions for action as well as alternative options. TEEMP offers a set of quick and responsive tools which utilise efficient data to robustly forecast CO_2 emissions – and also comprise a set of default encoded parameters based on evidence drawn from existing urban transport projects. The TEEMP tools were initially developed for evaluating the emissions impacts of ADB's transport projects, and have been modified and extended for GEF projects.

The TEEMP tools assist analysts in comparing different project alternatives and designs, and even assess impacts of diverse investment strategies for both intercity and intracity transport projects. The basic structure of TEEMP models is provided in Figure 1.

The current menu of TEEMP includes tools for estimating emissions and emissions savings from the following projects:

1. Walkability improvement.
2. Bike sharing.
3. Bikeways.
4. Roads – Expressways, Rural Roads and Urban Roads.
5. LRT/MRT (Light Rail Transit/Mass Rapid Transit).
6. BRTS (Bus Rapid Transport Systems).
7. Railways.
8. City Sketch Analysis and Other Strategies: Commuter Strategies, Pricing Strategies, Eco-Driving , Pay as you Drive Insurance (PAYD).

The methodology encompasses with and without project cases and captures both construction and operation stages. Emissions savings are quantified on the assumption that no major improvement would have occurred in the scenario without the project. The models developed for project evaluation borrow heavily from detailed methodologies such as COPERT *(an MS Windows based software aimed at the calculation of air pollutant emissions from transport)* and allow users to enter default values. The impact of speed on emissions is considered, while age (age deterioration factors), grade and temperature are not considered to reduce the assumptions. Since the motive of the methodology is to compare project alternatives using data mainly collected at the feasibility stage, there is a need to link emissions methodology with the data collated to capture fuel saving, which is a primary benefit/cost of the project (road users cost).

Over the last year, TEEMP has been applied to nearly twenty projects. Applying TEEMP to various projects has stimulated many arguments and insights, which are helping policy makers to implement better projects. Some of the lessons learned are summarised below:

- Construction emissions constitute a small share of the total carbon footprint of roads, but a significant share of MRT projects.
- Emissions quantification based on shorter project lifecycles may provide flawed results.
- Speed has a significant impact on emissions. Estimating future speeds accurately is, therefore, critical.
- Impacts of Capacity Expansion:
    - Short Term: It is incorrect to assume that higher speeds always reduce emissions.
    - Long Term: Induced traffic should not be neglected in emissions quantification.
- Road maintenance can significantly alter the emissions profile of vehicles.
- Public transport projects have a high emission reduction potential, with similar impacts for MRTS and BRTS.
- Modal shift can contribute to significant emission reductions.
- Heavy rail is more energy efficient than roads for freight transport.
- Including and improving bike lanes and sidewalks in projects provides huge CO_2 benefits.
- Air quality impacts are highly correlated to CO_2 emissions.
- The impact of emissions on the economic analysis of projects can vary from marginal to significant, depending on the project viability.

References:

1. *2004. IEA and CRA. IEA/SMP Documentation and Reference Case Projection.*
2. *Estimates for 2004. WHO.2009. Global Health Risks – Mortality and burden of disease attributable to selected major risks.*
3. *A litre of fuel costs $1-2 approximately. Assuming that it emits 2.5 kg of CO2, fuel worth $400-800 will be required to emit a tonne of CO2. The current market cost of CO2 is in the range of 10 to 20$ per tonne, however, and it can thus be argued that fuel savings are the main driver with regard the economic viability of transport projects and not CO2 emissions.*
4. *http://www.transport2012.org/bridging/ressources/documents/2/1165,UNFCCC-CDM-Workshop-Bonn-3_3_11-Out.pdf*
5. *See http://cleanairinitiative.org/portal/TEEMP*
6. *For detailed literature, please refer to the 2010 ADB publication, Reducing Emissions from Transport Projects*

For Future Inland Transport Systems: A United Nations project to reduce CO_2 emissions in inland transport

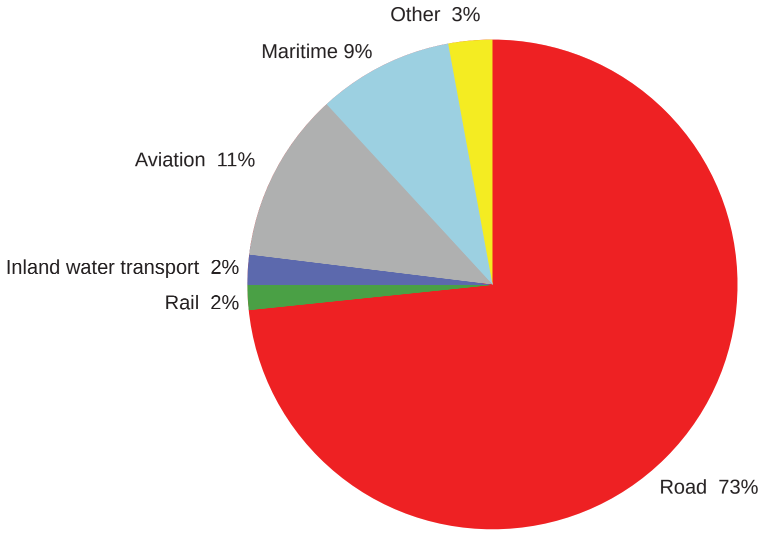
Romain Hubert - Mechanical Engineer, Transport Division, United Nations Economic Commission for Europe, Geneva, Switzerland.

The Development and Implementation of a Monitoring and Assessment Tool for CO_2 Emissions in Inland Transport to Facilitate Climate Change Mitigation is a global project funded by the United Nations Development Account (UNDA).

It will be implemented by the United Nations Economic Commission for Europe (ECE), as lead agency, together with the four other UN Regional Commissions. A number of experts from different fields will contribute to the final outcome, and cooperation with other institutions is welcomed.

This ambitious 3-year project was launched in January 2011. It aims at developing and using a standard monitoring and assessment tool for CO_2 emissions in inland transport (road, rail and inland navigation), including a transport policy converter that will support the choice among policy measures to be implemented by the governments. The tool will enhance international cooperation towards future sustainable transport policies. As it will pave the way **for F**uture **I**nland **T**ransport **S**ystems, it has been given the acronym **ForFITS**.

ForFITS will be based on a common methodology and a common approach to data collection and sampling methods. The integral transport policy converter will offer policy options for interactions to reduce CO_2 emissions from inland transport modes. ForFITS will facilitate the exchange



Global CO_2 emissions in transport 2008
Source: CO_2 emissions from Fuel Combustion, IEA (2010)

of comparable information and will encourage historic evaluation within a country if consistently applied. In this respect, it will forge international cooperation towards sustainable inland transport systems.

Once ForFITS is implemented, verified and validated it will be available online, together with a detailed user manual. Pilot tests will be performed in each United Nations region.

In 2013, awareness raising workshops and training courses on the use of ForFITS will be organised in each United Nations region. These will be aimed at policy makers, members of international governmental organisations, non-governmental organisations and industry, as well as potential users at a more technical level.

Implementation status

A questionnaire on inland transport CO2 emissions was sent out to all stakeholders at the beginning of May 2011. Already, a large number of replies have been received, mainly from countries within the ECE (Europe), ESCAP (Asia & the Pacific) and ESCWA (western Asia) regions. The replies show wide variability of data in terms of the details and information obtained on national inland transport CO_2 emissions.

Based primarily on the replies to the questionnaire, as well as on desk research, a Global Status Report is on schedule to be published by the time this Bulletin goes to press.

ECE has also started to define the structure and methodologies for the assessment models to be developed in cooperation with consultancy services. A further step aims at setting up a methodology for assessing inland transport CO_2 emissions based on information relating to road, rail and navigation activities. Socio-economical parameters will be included to provide for assessing the impact of policy measures on emission trends.

Upcoming events

The project team shortly intends to set up a Peer Review Panel (PRP) to appraise a detailed concept document based the approach proposed for the development of ForFITS. Authoritative feedback from the PRP panel will be taken into account and guide ECE in the subsequent development of the tool.

In March 2012, ECE plans to convene an International Expert Meeting (IEM), bringing together key specialists, governments and stakeholders, to present the first project outputs, along with the Global Status Report and a comprehensive list of recommendations for the further development of ForFITS. This meeting will also aim at further refining the methodologies and potential applications for the final ForFITS tool.

For more information visit the ForFITS website at ***http://live.unece.org/trans/theme_forfits.html*** *or contact* ***romain.hubert@unece.org***

Technology Advancements

Concrete pavements in tunnels: Evaluation of the positive impacts on CO_2 emissions and safety in Italy

Eng. F. Miseri & Prof. Eng. P. Di Mascio - AITEC (Italian Association of Cement Producers) & Department of Civil, Building and Environmental Engineering, Sapienza University of Rome, Italy.

Italy has about half the total mileage of tunnels in Europe, amounting to 1,230 km. Most of the tunnels will require retrofitting by 2019 in order to upgrade their safety standards in accordance with the requirements of the relevant European Directive (EU 2004/54/EC).

Concrete pavement is the best solution for this kind of road infrastructure work, due to the specific characteristics of concrete. Compared to asphalt, concrete pavements can increase traffic and tunnel safety for a number of reasons, including:

- The light colour, which improves visibility and enhances road user awareness.
- The greater reflective capacity of concrete (0,10 against 0,07 for asphalt) calls for less lighting, which reduces energy consumption as well as the costs associated with installing and maintaining lighting installations.
- Concrete is incombustible, non flammable and does not emit any harmful gases. It therefore ensures maximum safety in the event of a fire.
- In case of fire, concrete pavement also ensures good conditions for evacuation and firefighting by the rescue team and fire brigade.
- Concrete does not deform when exposed to high temperatures and, for the most part, retains its mechanical characteristics. In contrast, asphalt is combustible and loses its mechanical properties in high temperatures because the mineral aggregate is no longer bound by the bitumen.
- Concrete guarantees longer service life (at least 30 years can be anticipated) and requires less maintenance and repair work. Furthermore, there is less unevenness on the road; thereby ensuring good levels of road surface smoothness, and also grip on the carriageway due to the slow rate of deterioration of skid resistance.[5] These characteristics provide for less works and fewer tunnel closures.

All these advantages of concrete enhance environmental protection and support the sustainable development of roads. Less maintenance and repairs enable raw material savings and, at the end of its life cycle, concrete can easily be used as an aggregate for road courses or new concrete. The potential energy savings contribute to decreased CO_2 emissions (approximately 30% compared to asphalt pavements that are not brightened).

Positive impacts on CO_2 emissions

The light color of concrete pavements in tunnels offers obvious advantages for both drivers and infrastructure managers.

The 1,230 km of tunnels on the Italian network are managed by Highway Concessionaire Companies and by ANAS (the Italian National Autonomous Roads Corporation). Currently, they all have asphalt pavements.

We have estimated the energy savings (kW/km/year) that could be obtained by replacing asphalt in these tunnels with concrete pavings, using data calculated by Tecno-Engineering 2C s.r.l. This was based on one of the existing software lighting systems designs, applied to "cross-sections" of some standard Italian tunnels.

To simplify the calculation we have focused exclusively on areas where there is no strengthening of supplementary illumination.

Depending on carriageway dimensions, the results vary from 17,520 kW/km/year for a 10.50 m carriageway (2 lanes/shoulders), to approximately 117,000 kW/km/year for a 14.95 m carriageway (3 lanes/emergency).

Estimated power consumption in Megawatt (MW)/years up to 2020 was derived from data referencing a standard lighting system and considering the length and width of existing and planned Italian tunnel carriageways. These estimations are in accordance with the following two scenarios:

- Business As Usual (BAU) scenario: asphalt pavements.
- Best Available Technologies (BAT) scenario: replacing existing pavements with concrete ones.

The results are summarised in the following table:

2010	BAU MW/year	101,2
2016	BAU MW/year BAU MW/year 50% Converted	131,7 113,2
2020	BAU MW/year BAU MW/year 100% Converted	150,7 108,2

This enables us to estimate a possible scenario of total savings achievable in MW/year, depending on replacement rate, as summarised in the table below:

2016	Assumption: 50% conversion	18,5 MW/year
2020	Assumption: 100% conversion	42,5 MW/year

We have assumed a conversion factor of 0.5 kg of CO_2 per kilowatt hour (kWh), as suggested by *Confindustria*, the Italian organisation representing manufacturing and service companies. The factor takes into account the mix of Italian power plants. According to the scenario defined above, we have estimated the benefit obtainable from the resultant reduction of CO_2 emissions in million tonnes of oil equivalent (Mtoe), as summarized in the following table (1Mtoe=3MtonCO_2).

2016	Assumption: 50% conversion	0,003 Mtoe/years
2020	Assumption: 100% conversion	0,007 Mtoe/years

Whilst this is only an estimate, based on averages, it is nevertheless instructive in terms of highlighting and raising awarensess among Italian stakeholders regarding yet another area of potential for the road sector to make a significant contribution towards efforts to reduce global warming.

The results take into account existing tunnels, tunnels under construction and those planned in the coming years.

Positive safety and economic impacts

Whilst this article focuses on the environmental dimension, the use of concrete pavement in tunnels also has significant potential impacts on safety. The high number of tunnel fires occurring in Europe has highlighted the importance of an appropriate choice of materials for tunnel construction, in order to ensure safe and reliable access for traffic.

In cases of fire, an incombustible and non-toxic road pavement, such as concrete, contributes to the safety of users and rescue teams alike, and protects both the structure and equipment of the tunnel.

Another important road safety dimension is skid resistance, which deteriorates much more slowly on Exposed Aggregate Surface (EAS) concrete pavements. Besides reducing the risk of accidents, this has the added advantage of limiting user disruption as maintenance activities can be performed less frequently.

Last but not least, many decision makers are increasingly convinced that concrete surfaces offer significant economic benefits when whole life cycle (maintenance) costs are taken into account. This is even more tangible when user costs are added to the equation (e.g. reduced user disruption due to less maintenance activities). For all these reasons, concrete roads offer socially acceptable solutions, which further advance sustainable mobility.

The future lies in low-temperature asphalt

Andreas Biedermann - Head of Pavement & Materials, Deputy Chief Technology Officer, Ammann Group, Switzerland

The asphalt industry can make a significant contribution towards reducing CO_2 emissions, which represent the largest proportion of man-made greenhouse gases. One possibility is to offer high-quality asphalt that can be mixed and laid at lower temperatures. Considering that around 50% of production energy is consumed by heating the asphalt, lowering the temperature also achieves significant savings in fuel consumption.

The technologies involved

Producing standard asphalt for road construction is an energy intensive process as the aggregates need to be heated to about 180°C before they are mixed with bitumen. This heating and drying process accounts for about 95% of the energy consumption of an asphalt mixing plant. Reducing the energy required for this process enables a substantial reduction in overall CO_2 emissions.

Besides reducing energy consumption and CO_2 emissions during production, lower-temperature asphalt offers a second advantage in that it also leads to a huge reduction in emissions during laying. Low-temperature asphalt can be laid at around 110 °C or lower; and a rule of thumb suggests that reducing the asphalt temperature by 10 °C cuts emissions during laying by half.

Different methods are available for producing low-temperature asphalt. They are mainly based on the use of additives or special binding agents, as well as the use of foamed bitumen and modified mixing cycles. In modern asphalt mixing plants, it is possible to combine these approaches to achieve high quality asphalt at lower production temperatures. Depending on the method chosen, the temperature can be reduced by 20°C to 70°C.

The higher the reduction, the more sophisticated the production process becomes. Ammann has developed experience in a wide range of production methods and offers solutions for all sorts of temperature reducing systems. Thanks to this know-how gained in different regions, we are able to advise on all stages – from the choice of additive right through the mixing cycle, and also on the thermal process (drying / heating).

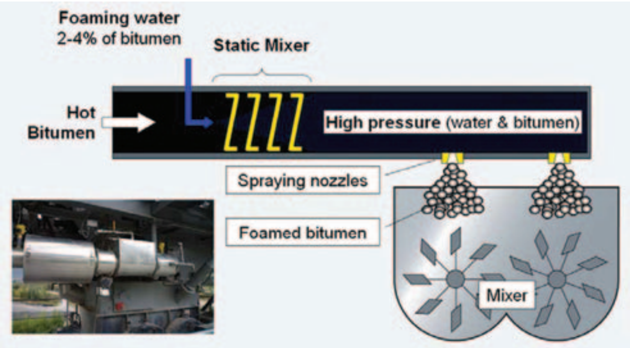
Low-temperature asphalt: High quality, reduced emissions

A comparison of three important low-temperature asphalt technologies

Technology	Production temperature Savings	Principle	Necessary modifications to plants
Bitumen foam	115 °C –5 kg CO_2/t –1.5 kg oil/t	Bitumen is foamed and can therefore cover the aggregate and be installed at lower temperatures	- Foam generator for bitumen and feed material - Control adjustments to the mixing cycle
Waxes	130 °C –3.5 kg CO_2/t –1.0 kg oil/t	Addition of wax to the bitumen; the asphalt is easier to process at high temperatures	- Feed option for additives, e. g. in the bitumen tank or in the bitumen flow - Modified bitumen is available
Zeolites	140 °C –2.7 CO_2/t –0.8 kg oil/t	Water bound in a special filler is released and makes the asphalt easier to process	Feed option for special fillers (zeolite)

Foamed bitumen is of lower viscosity than non-foamed bitumen at similar temperature and is, therefore, easier to mix with warm aggregates, and coats the stones very well. The use of foamed bitumen allows the temperature of the aggregates – and therefore that of the asphalt mix – to be reduced by approximately 60 to 70 °C without compromising the quality. The core component for producing asphalt with foamed bitumen is the Ammann Foam Generator. Its basic principle is as simple as it is ingenious: hot bitumen is pumped into the foam generator and cold water is injected into the flowing mass of 150 °C bitumen. The water is immediately heated above boiling point by the hot bitumen and partially evaporates. Since the water steam is gaseous, the mixing of the water and the bitumen takes place under high pressure. The resulting mix of steam, water and bitumen is pressed through special nozzles in the mixer. After the mixture has left the foam generator, the water expands completely and the foam is generated.

The production process using foamed bitumen has proven its suitability and a growing number of roads are being laid using this technology. Ammann has equipped plants across Europe and other continents with bitumen foaming systems, and supports asphalt manufacturers and road



Bitumen Foam Generator: Precise mixing of hot bitumen with water

builders introducing this trendsetting technology. The low-temperature asphalt can be laid and compacted using the usual standard equipment.

Paving at 110 °C, compaction even below 80 °C

In 2010, Hans Weibel AG laid 1,500 tonnes of low-temperature asphalt, applying the WAM Foam® process, on a busy district road near Koppigen in the Swiss region of Emmental. The ACT 22 N W-ecophalt® used was laid as a base and wearing course.

The asphalt was produced 40 kilometers away in Oberwangen. The Ammann Universal NG 320 asphalt mixing plant is equipped with a recycling addition, a twin shaft four-tonne Amix mixer and a foam generator.

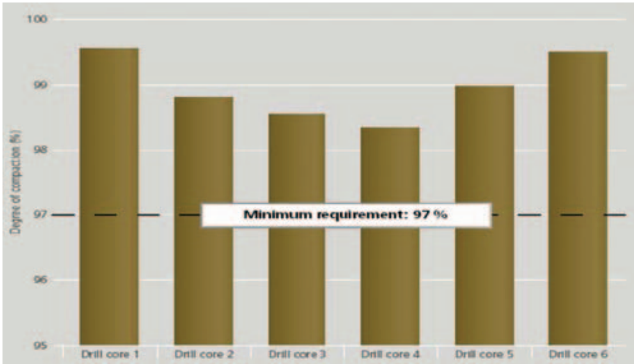
The advantages of using the low-temperature asphalt became apparent as soon as laying started: It reached the construction site even at a temperature of around 110 °C and was compacted using an AV 95-2 at temperatures below 80 °C. Despite high summer temperatures, therefore, working on the construction site was relatively comfortable – not only due to a lack of bitumen emissions, but also thanks to significantly less heat radiating from the asphalt surface.

Drill core analysis revealed that the asphalt surface demonstrated the required degree of compaction at every measured point despite the demanding logistical circumstances. Road marking work began shortly after the last pass of the roller, which meant that the road could be reopened to traffic the following morning.

Low-temperatures – The way forward

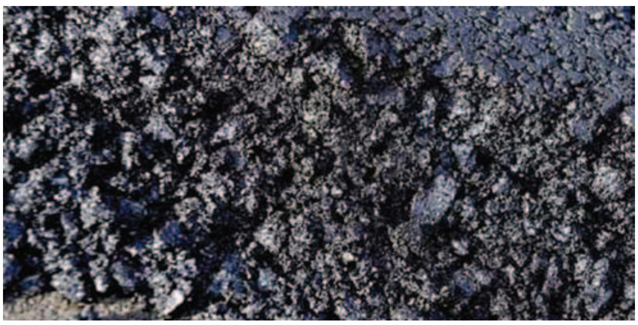
Five good reasons for reducing the production temperatures can be highlighted:

- Less energy required to heat the aggregates.
- Less CO_2 emitted during production.
- Lower emissions from the hot mix during truck loading at the asphalt mixing plant.
- Lower emissions on the road construction site during laying.
- The technology is available and appropriate.



Asphalt drill cores with foamed bitumen fulfill requirements to a high degree.

Samuel Probst, Manager at Belagswerke Hans Weibel AG needs no persuading about the benefits of producing at low-temperature with foam bitumen: "The use of foamed bitumen technology enables us to achieve energy savings of 1.5 kg of fuel oil per tonne of asphalt. We were able to save around 7.5 tonnes of CO_2 emissions during the installation work at Koppingen and, therefore, make a contribution towards sustainable road construction. There are no problems with the quality of the asphalt mix produced and it meets every requirement of the applicable standard, both at the plant and after laying. The laying work at Koppigen was a positive and promising experience. We are convinced that low-temperature surfaces will prove a major breakthrough for the asphalt and road building industry."



Low-temperature asphalt with foamed bitumen can be installed at around 110 °C with no com-promise in quality.

Adapting to Climate Change Impacts

Improving the resilience of transport networks

Carl Reller - Environment and Urban Design Manager, New Zealand Transport Agency

The purpose of this study was to conduct a national profile of New Zealand's road and rail networks to identify areas at risk from inland flooding due to climate change. The basis was regional distribution of existing flood events and projected future flood average recurrence intervals (ARI) based on increased frequency of extreme rainfall.

The method assumes that the future change in flood risk at a given location is proportional to the increase in extreme rainfall at that location. This is based on the premise that a given percentage increase in heavy rainfall translates into a similar percentage increase in peak river flow.

Relationship of land transport infrastructure to low-lying coastal areas

With respect to road infrastructure, responses were received from 16 of the 24 state highway network operations regions. The data indicate that all but one region have recorded floods affecting the state highways in the past. However, the lack of information on dates when the floods occurred and uncertainty with respect to the frequency of recurrence, coupled with a shortfall in data for approximately 30% of the network regions precluded a regional comparison.

While certain parts of the state highway network are vulnerable to flooding – and climate change is set to increase this flood risk – the study was not able to present a national profile of current risk (based on recorded flood events) or provide estimates of future risk (based on changes in flood ARI). The main barrier is the absence of a central database of asset vulnerability to extreme weather events.

For all transport networks, the current design standards and design philosophies require review and standardisation in order to respond adequately to climate change.

Future considerations

For the state highway network, adaptation response in the short term should focus on the systematic collation of data on extreme weather events that cause disruption/damage to the network – with more detailed flood risk studies for those parts of the identified network currently prone to flooding. Catchment-based flood modelling should be considered in high-risk areas to refine risk assessments for critical assets (e.g. bridges and major culverts), and to identify `near miss' sites (areas not currently affected but which could be at risk under future scenarios).

Other future considerations, in terms of assessing how the flood risk from climate change affects surface transport networks, could include the following:

- A systemised, centralised database of floods and their impacts to provide the backdrop for sound flood management policy making. *Ericksen*, 1986 (quoted in *Walton et al*, 2004) noted that no one agency in New Zealand maintained a consistent and comprehensive database of flood events and their impacts - a situation that remains unchanged.

- Documenting details of current flood events and flood mitigation projects – recording, in particular, responses to predicted climate change conditions (including quantification of costs and benefits) to optimise the targeting of adaptation funds. *Walton et al* (2004) note that sensible analysis of how the costs of flooding may change because of future climate change scenarios can only be undertaken if there is some understanding of past and current flood losses.

- Estimation of the increase in area to be included in the 100-year floodplain would give a good national overview of the impacts of increasing rainfall on flooding. *Suarez* (2005) reports that flooding impact estimates in the US are based on work by the National Flood Insurance Program (NFIP). The flood insurance studies developed under the NFIP involved the detailed modelling of coastal and riverine flooding to produce Flood Insurance Rate Maps. These maps show the 100-year and 500-year floodplains: areas that, in any given year under current conditions, have a probability of being flooded equal to 1% and 0.2%, respectively.

Key messages and future directions

Key messages dealing with broader aspects of climate change are set out below:

Lack of national datasets: limitations in the availability, quality or completeness of national datasets required to evaluate strategic implications of climate change risks to national transport networks (e.g. high resolution coastal topographic data for use in inundation risk profiling) was a recurring theme of the study.

Gaps in transport data: existing asset management systems, held by transport providers, are not usually set up to provide the kind of information required to predict effects on the networks from climate change. High-resolution elevation datasets of transport assets are not generally available, particularly with regard to national coverage. There is a need for transport providers to map their national assets to a high resolution, so as to enable risks from climate change (e.g. floods, coastal inundation and landslips) to be assessed at the local/regional level. Such datasets are essential for determining current network resilience, and to provide a basis for climate change projections.

Vulnerability of transport networks to extreme weather: a corollary of the above is that the current vulnerability of surface transport networks to climate extremes is not well documented. The quality and irretrievability of nationally consistent data on weather events also varies widely. More robust systems are needed to assist evaluation of the significance of extreme weather events and weather variability in the design, cost, mobility and safety of existing networks. Analysis of current weather events that affect transport systems will assist future forecasting of effects under climate change. Data required to conduct such analysis could include:

- The nature of the weather event and climatic conditions;
- The physical extent of affected infrastructure, including location and elevation details;
- The nature of adverse effects, such as period of disruption to normal operations, extent of damage, cost and nature of repairs.

Greater use of weather forecasting systems: This is related to the above aspect. While providing an excellent basis on which to make operational decisions, such systems may also be used to collect information on the weather events that cause disruption to transport networks – duly supplemented by incident reports, including quantifiable observations about the extent of damage or disruption to network assets, users and adjacent properties.

Linkage of climate change to asset management: there is a need for better integration of climate change considerations into the current asset management programmes of transport providers (covering planning, design, operation and maintenance), as well as linkage to wider sustainable transport initiatives (such as priority transport corridors and lifelines perspective).

Regional/local impact analysis: the impacts that a changing climate might have on transportation infrastructure and services are very dependent on regional climate and local site characteristics. These require local-scale modelling of such effects in order to provide a basis for cost-effective adaptation responses. Higher resolution climate models for regional and sub-regional studies would support the integration of region-specific data with transportation infrastructure information.

Risk analysis tools: in addition to more regionally specific climate data, transportation planners need new tools to address the uncertainties inherent in projections of climate change. Such methods are likely to be quantitative and based on a probabilistic framework with greater clarity on uncertainty for end-user risk management. Given the long-term timeframe of climate change (e.g. +50, +100 years), other factors such as demography, future land use and technological advances also need to be taken into account in the risk analysis model.

Integrated transport planning approach: the study provided an initial analysis of where climate change (e.g. risks from flood and coastal inundation) could affect parts of individual transport networks. Future studies need to consider the risk to transport systems as a whole. For example, the risks to ports from climate change do not depend simply on the vulnerability of the port infrastructure; they also rely critically on the transport networks servicing the ports. Climate change, therefore, needs to be considered in the context of an integrated transport network. This could take the form of an issues/options study on an integrated adaptation framework for climate change impacts on the surface transport network.

Economic evaluation: a wider assessment of the economic cost of climate change on surface transport is necessary. Calculating the true economic impact of climate change is fraught with "hidden" costs. Besides the replacement value of infrastructure, for example, there are real costs of re-routing traffic, lost workdays and productivity, provision of temporary shelter and supplies, and potential relocation and retraining costs. Systematic collection of data relating to such impacts should be investigated in future.

On a final note, the analysis of how a changing climate might affect transportation in New Zealand is at an early stage. The research themes listed above are needed to enable engineers, scientists, planners, network operators and policy makers to more fully understand the risks from climate change, and to improve the resilience of transport systems in response to these threats.

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Climate change impacts on road networks

Caroline Toplis - Consultant for URS Scott Wilson, Nottingham, U.K.

Due to the inertia that exists in our climate, past and current greenhouse gas emissions mean that the Earth's climate is likely to undergo a certain level of climate change over the next forty years [Intergovernmental Panel on Climate Change, 2007]. Key global climate change projections (of varying severity and magnitude) all foresee that sea levels will rise, summers will become hotter and drier, winters will become milder and wetter; and storms, extreme rainfall, periods of drought and prolonged heatwaves will become more frequent.

These projected changes are set to have significant impacts on the construction, maintenance and operation of global road networks, with many impacts already being experienced. Drier and hotter summers will lead to more incidences of pavement deterioration and subsidence. Wetter winters and more frequent heavy rainfall events will result in increased incidences of flooding, particularly in low-lying areas and floodplains, and a higher risk of landslides. More frequent and severe extreme weather events will have safety impacts, and will also have the potential to cause damage to structures on or close to the road network. The prospective indirect impacts of climate change include modal shift, damage impacts on local ecosystems and biodiversity, and repercussions on planning and the local economy [Defra, 2009].

Road deterioration caused by temperature and rainfall extremes

Historically, road construction and maintenance policies have been based on past climate conditions, but now

it is necessary to base them on projections for the future to minimise the impacts of changing weather patterns and events. In order for road networks to be resilient to a changing climate, road network owners, designers and other decision-makers need to take action to adapt their policies, practices and standards - so as to minimise the disruption and costs caused by future climate change whilst also aiming to reduce the carbon emissions from construction and maintenance activities.

A methodology to inform climate change adaptation planning

URS Scott Wilson has developed a methodology and associated tool to help road network owners, designers and other decision-makers to understand the likely risks posed by climate change and to develop adaptation responses to reduce the impact of these risks. The methodology consists of:

- Identifying projected climate changes for the region being assessed;
- Developing a comprehensive, local risk-based assessment of the network's vulnerabilities to future climate change and extreme weather events;
- Identifying potential adaptation responses that can be implemented to minimise the identified impacts of climate change on the road network;
- Identifying the most effective adaptation responses based on a 'multi-criteria analysis'; and
- Developing and implementing an Adaptation Action Plan that can be easily monitored and reviewed.

Understanding climate change projections

Climate change will not affect all parts of the world uniformly. Therefore, in order to understand the potential risks of climate change on a specific road network, an assessment of location-specific climate change projections should be carried out.

The Intergovernmental Panel on Climate Change (IPCC) has developed a series of future global climate models, covering a range of future emissions scenarios (www.ipcc.ch). Some countries have also developed national projection research programmes (such as the UK's UKCIP) whilst, in other countries, climate change research is confined to small pieces of work carried out by universities.

Where possible, projections assessed should include changes to average conditions, such as temperature, sea level rise and precipitation, and also projections for changes to the frequency and magnitude of extreme weather events, such as heatwaves and heavy rainfall. Decision-makers also need to take into account the region's particular geography and topography when developing an understanding of key risks to the network.

Risk and Probability Assessment

Once a 'picture' of future climate change projections for a specific region has been established, a risk and probability

Bridge damage following a flooding event

Table 1: Climate Change Risk Register

Impact	Risk Score (RxPxI)
Pavement failure	18
Prolonged and/or more rapid growth of the soft estate	18
Lack of capacity in the drainage system and flooding	18
Heat damage to structures	12
Water scour to structures	12
Heat damage to pavement surface layers	12
Subsidence and heave	12
Less disruption by snow and ice	12
Landslips	8
Embankment erosion	8
Tree damage	8
Increased network use by cars and bikes as people avoid public transport during hot weather	4
Fire	3
Increased recreation and leisure-based travel	2
Plant and animal species changing. Shifting patterns of migration	2

assessment of potential impacts can be carried out. In order for this to be achieved, key risks should be identified and undergo an assessment based on:

- **Risk impact (R):** Likely magnitude and severity of the impact.
- **Probability (P):** Probability of the impact occurring.
- **Influence (I):** Level of influence of the owner/designer/decision-maker to increase resilience and/or manage the impact.

Each aspect is scored out of 3 (with 3 being the highest) and then multiplied together to give a final risk score (out of a maximum of 27). This allows risks to be ranked in order of impact severity and magnitude, probability and level of control, influence and responsibility. Table 1 shows an example of a road network Climate Change Risk Register.

Adaptation Action Plan Development

For climate change risks to be minimised, existing policies and standards need to be adapted appropriately. Potential adaptation responses should be developed to address risks identified (from Table 1).

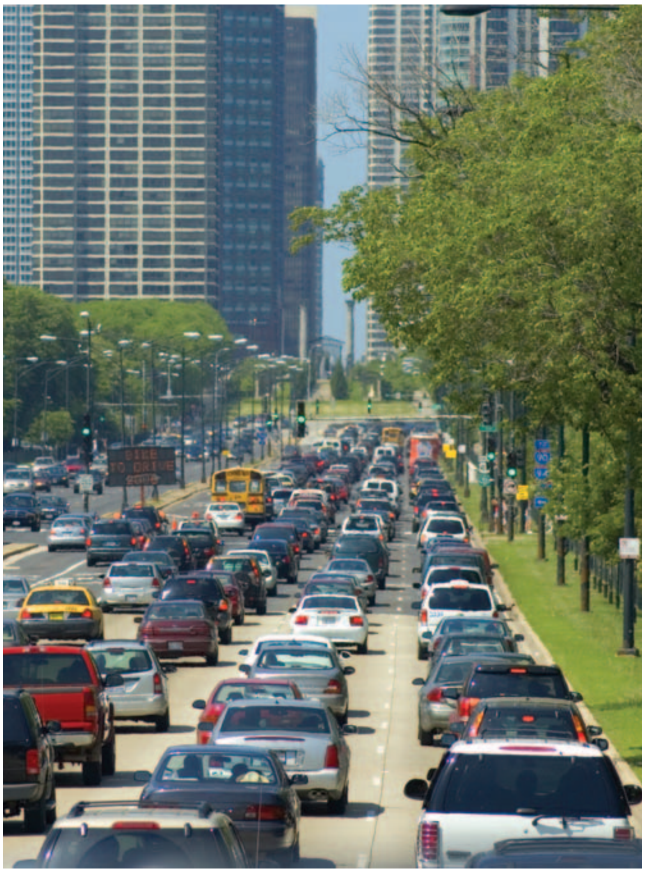
Each potential adaptation response should undergo a structured multi-criteria analysis (MCA) to identify the most

Table 2: Adaptation Action Plan

Adaptation Response	Score (Out of 3	Timescale for implementation
Carry out a risk assessment to identify which structures are most at risk from climate change and recommend to inspection/maintenance regimes.	2.75	Immediate
Undertake a risk assessment to determine vulnerable drainage assets and establish a prioritised scheme for maintenance.	2.75	Immediate
Carry out inspections to assess which parts of the network are most at risk from excessive heat.	2.6	By 2012
Carry out flood studies to identify the most vulnerable areas of the network and establish actions to reduce the level of risk.	2.55	By 2014
Invest in asset management reviews and carry out drainage surveys to improve the knowledge of drainage assets, hydraulic capacity and asset ownership.	2.25	Immediate
Review current material specifications to assess their resilience to climate change Consider changing material choices.	2.15	Immediate
Increase verge maintenance frequencies to reduce the risk of 'root invasion' and vegetation ingress.	1.95	By 2015
Use polymer-modified and 'stiffer' binders that are less prone to binder stripping	1.85	By 2020

effective and realistic options for implementation. MCA, or 'weighting and scoring', techniques are different to typical cost-benefit analysis (CBA) methods as they allow for several criteria to be taken into account simultaneously, and for decision-makers to be integral to all stages of the process. Also, they do not require the use of economic valuation to accommodate climate impacts in the decision-making process, but may still include it.

To assess the range of adaptation responses developed, a list of evaluation criteria is established. Criteria selected should represent the views and concerns of the decision-makers. Examples of evaluation criteria include: capital and whole-life cost, practicality, public acceptance, and the risk of taking no action. The criteria selected are ranked in



order of importance. Using a scale to rank the evaluation criteria allows for a relative assessment of the responses to be conducted, and an aggregate evaluation score to be established for each adaptation option that addresses the priorities of the relevant decision-maker.

Each response is scored between 1 and 3 (with 3 being the most favourable) against each criterion. These scores are used alongside the criteria weightings to obtain a final score for each of the potential adaptation responses. This process allows for the adaptation responses to be ranked according to their suitability for implementation and used to form an Adaptation Action Plan. Table 2 shows an example Adaptation Action Plan for a road network and includes timescales for the implementation of each response.

The Adapting to Climate Change Application (ACCA)

URS Scott Wilson has developed an Adapting to Climate Change Application (ACCA), a tool underpinned by the methodology described above, to allow users to identify the potential future impacts of climate change on their project(s), and ways in which resilience to these impacts can be increased.

The ACCA informs what action needs to be taken to adapt assets, services and policies to the effects of a changing climate. It is applicable across regions and sectors and enables government bodies to fulfil their responsibilities under climate change legislation. Similarly, it helps all organisations to understand the risks and opportunities that their operations and investments will face in the future and how their practices and processes could be adapted to mitigate the impacts of climate change.

For more information on the ACCA, please contact Caroline Toplis at ***caroline.toplis@scottwilson.com***