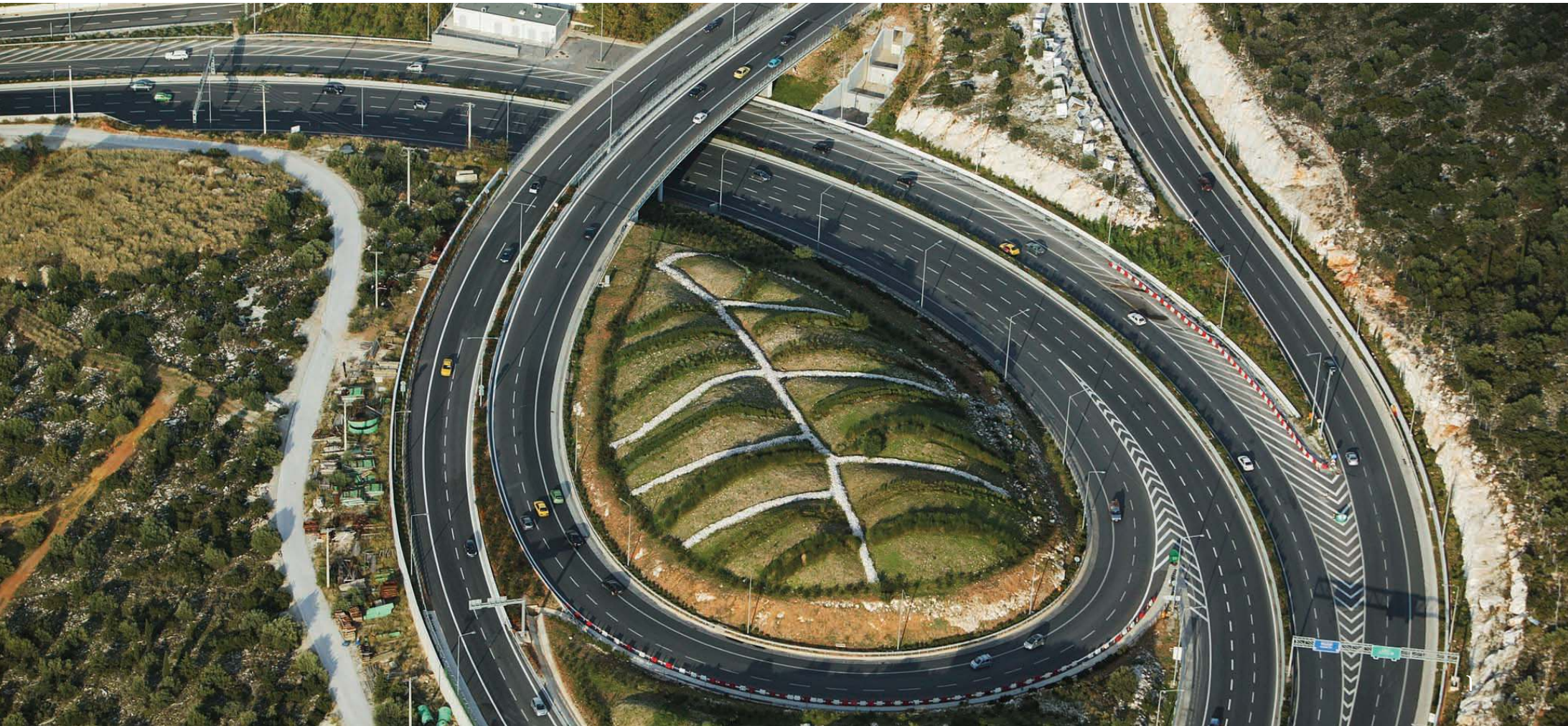
INTERNATIONAL ROAD FEDERATION
FEDERATION ROUTIERE INTERNATIONALE

Moving Towards Green Road Infrastructure

Case Studies and Lessons Learned



Credits and aknowledgments

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Editorial

If one tries to describe how quality of life has improved over the past few decades, without a doubt, one will realise that most aspects that describe our lives are tightly linked with the ability to travel or to transfer goods from one place to another. Transportation enables people to have better access to jobs, goods, services, education, and, when transportation opportunities are insufficient, the quality of life is poor. However, nowadays, it is also evident that increased transportation opportunities can also pose a palpable threat to our quality of life, with adverse effects on the environment and our heath.

Urban areas around the world nowadays show increasing signs of environmental stress, notably in the form of poor air quality, excessive noise and traffic congestion, while also incurring significant habitat segmentation. Also, based on the latest studies by the European Environment Agency, transport accounts for around a third of all final energy consumption in the EEA member countries and for more than a fifth of greenhouse gas emissions.

We need sufficient transportation to maintain our quality of life, without destroying our environment and our health. Environmental protection, mitigation and sustainability are words that have become parts of our everyday lives and it is well-understood that human activities now have a serious effect on the environment. It is essential, hence, to bring about ways to balance our needs and activities with respect to their effect on the environment and that transportation becomes "greener" and more sustainable, so as to reduce its share in environmental threats.

The need for sustainable roads has been set, it is unquestionable. It is just a matter of how many will follow and how quickly. The IRF's stated intent is to encourage better, greener and more sustainable road systems world-wide, considering not only the new road projects that are to be constructed (which are becoming more and more scarce in the developed countries), but also the existing roads and motorways, and the way they are operated and maintained. To achieve this, the IRF, through its current Environment Committee (former Environment Working Group), has been aiming to promote and advocate environmentally-sustainable road infrastructure, through discussion and exchange of knowledge and good practices amongst the members.

Since its inception in 2007, the members of the Environment Committee have produced a CD Rom presenting "Innovative Practices for Greener Roads" and, earlier this year, the IRF Policy Statement on the Environment, which affirmed the commitment of the International Road Federation to the development of environmentally-sustainable roads, as an investment in the long-term prosperity of both planet and society. The publication that you now hold in your hands is the result of the WG's long search for road projects that integrate sustainability in various stages, including planning, design, construction, maintenance and operation. These case studies are described analytically, and the respective lessons learned are stressed in each case. It is our hope that these case studies will provide guidance and generate inspiration to all the readers of the industry wishing move towards greener roads.

"Innovative Practises for Greener Roads", the IRF Policy Statement on the Environment and the current publication "Moving Towards Green Road Infrastructure: Case Studies and Lessons Learned" form the 3 key goals that were set and accomplished by the Environment Committee.

Having served as Chairman of the IRF Environment Committee for the past 6 years, I would like to thank all the members for their commitment and invite you all to participate actively in the new Environment Committee, so as to achieve the best results possible.

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Acronyms and Abbreviations used in this paper

AQMA	Air Quality Measurement Areas
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CO	Carbon Monoxide
CO2	Carbon Dioxide
DO	Dissolved Oxygen
EAP	Environmental Action Plan
EEA	European Environment Agency
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EMS	Environmental Management System
HC	HydroCarbon
IRC	Indian Road Congress
IRF GRAA	International Road Federation Global Road Achievement Awards
LED	Light Emitting Diode
MTRD	Maximum Theoretical Relative Density
NATS IP	Norwich Area Transportation Strategy Implementation Plan
NAQS	National Air Quality Strategy
NCC	Norfolk County Council
NO	Nitrogen monoxide
NO2	Nitrogen Dioxide
NOx	Oxides of Nitrogen
NSW	New South Wales
NZTA	New Zealand Transport Agency
NZ	New Zealand
PM	Particulate Matter
RA	Rubberized Asphalt
RAP	Recycled Asphalt Planning
RTA	Roads and Traffic Authority
RSPM	Respirable Suspended Particulate Matter
SEA	Strategic Environment Assessment IRC
SPM	Suspended Particulate Matter
TVOC	Total volatile Organic Combinations
UK	United Kingdom
VOC	Volatile Organic Compounds
WMA	Warm Mix Asphalt
WRAP	Waste and Resources Action Programme

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Introduction

Transportation plays a crucial role in the quality of our lives, as it connects us with goods, services, as well as each other. Through technological advancements, people can travel further and faster than before and today, in the 21st century, it is impossible to imagine life without mobility through complex transport systems.

However, based on the latest studies by the European Environment Agency (EEA), in the EEA member states, around 30% of all final energy consumption and more than 20% of greenhouse gas emission is due to transportation. A large proportion of noise nuisance and urban air pollution is also caused by transportation. Furthermore, infrastructure threatens wildlife by endangering their habitats, when the landscapes they live in are divided.

Environmental protection, mitigation and sustainability are words that have become part of our everyday life, as it is well-understood that, in order to satisfy human needs, human activities now have a serious effect on the environment. It is essential, hence, to bring about ways to balance our needs and activities with respect to their adverse effects on the environment.

The International Road Federation's (IRF) stated intent is to encourage better road systems world-wide. The IRF environmental foundations are safeguarding the environment, mitigating adverse environmental effects, ensuring efficient resource management, and improving infrastructure's environmental performance. The organization also supports that "sustainable management is most effective when environmental challenges and opportunities are taken into consideration early and proactively at every stage of the life-cycle of road infrastructure" (IRF Policy Statement – Environment, pg 1.)

To help achieve these aspects in future road infrastructure projects, the IRF has searched and identified case studies that integrate sustainability, with regards to the following:

- Road Planning
- Design
- Construction
- Maintenance and Rehabilitation
- Management and Operation

The following sections will describe each stage of the road infrastructure life-cycle in greater detail, while using case studies to draw conclusions on the lessons learned.

1.1 Introduction

Even though roads are fundamental for the movement of people and goods, they give rise to various environmental problems. Due to the extreme growth in the amount of road traffic, these obstacles have taken on a new dimension. This is why it has become crucial to take the environmental impacts into account early on in the road development process.

The most effective way to do this is through a Strategic Impact Assessment. This evaluation provides an early and pro-active consideration of the environmental constraints and opportunities, and its intentions are to minimise the adverse and maximize the favourable effect on the environment. There are many areas in the world that already require such evaluations. In Europe, for example, European Community law requires an assessment of the environmental impacts of each infrastructure project prior to their construction. Besides environmental, there are many economic and social advantages in conducting an early Strategic Environmental Assessment, which proves that it should be a central part of every road infrastructure planning process.

1.2 Strategic Environmental Assessment

A Strategic Environmental Assessment is "a preliminary process for reviewing and evaluating policies, plans and programs, as well as other draft proposals for large-scale projects and initiatives" (Sadler, 1996, p. 15). Its intent is to determine potential environmental impacts and help include them in the decision-making process. It has become more frequently used since the 1990s and it plays a huge role in promoting sustainable development. The scheme of a SEA is to make environmental and sustainable development a responsibility of every plan, policy and program. It entails three main endeavours: advocating sustainable development, determining environmental impacts and conducting the environmental assessment. The following table (Table1.1) shows example indicators that a SEA uses to measure environmental impacts in the transportation sector.

Table 1.1: SEA in the transportation sector: impact and examples of indicators

Impact	Examples of indicators
Climate change	GHG emissions (CO2, CH4, etc), vehicle-km, fuel consumption
Acidification	Emissions of SO2, NOx
Natural resource use and depletion	Intensity of resource use, energy consumption, land consumption (notably, inter-modal comparison)
Loss of biodiversity	Land consumption and fragmentation of ecologically sensitive areas, disappearance of or damage to habitats and species
Air quality	Emissions or concentrations of pollutants, exposure of the population to pollutant concentrations
Water quality	Number of sources affected, concentrations of pollutants, distance of infrastructure from sensitive sites
Visual impacts	Scale and key physical characteristics
Severance	Barriers, population size in affected areas
Noise and tranquillity	Noise levels, areas and populations affected
Accidents	Fatality and injury rates
Conservation of historical, archaeological and natural heritage	Disappearance or proximity of classified sites and sensitive areas

Source: ECMT-OECD, 2000, p. 20.

Even though at first sight, the SEA seems similar to the conventional Environmental Impact Assessment (EIA), it differs in many ways. The additional aspects it can provide to the environmental assessment process make it a great complement for the EIA. A SEA can expand the EIA process.

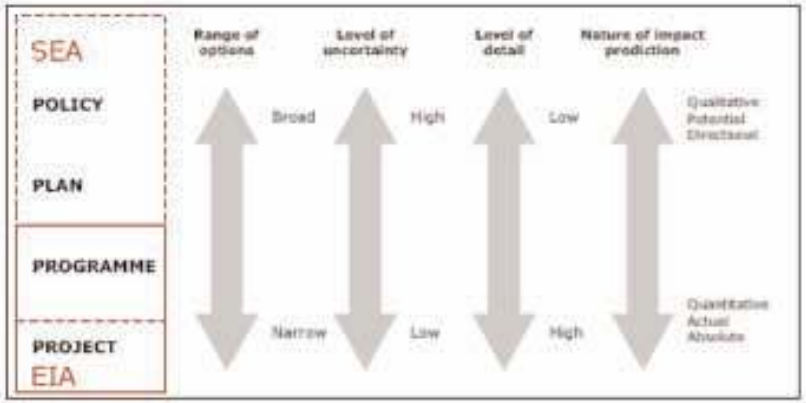


Figure 3.1 Broad trends in the nature of appraisal at different levels in the decision-making hierarchy (adapted from CEP, 2003

Souce: European Commission

Table 1.2 below summarizes the main differences between the EIA of specific projects and the SEA of policies, plans and programs.

Table 1.2: Main differences between SEA and EIA

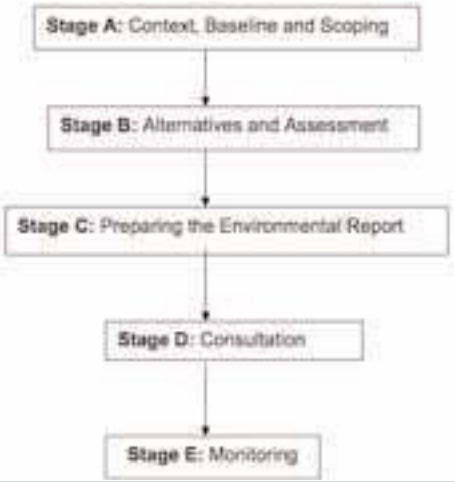
ASPECT Perspectives	**EIA** Environment	**SEA** Sustainable development
Nature of the assessment	Assessment of impacts of the construction or operation of a project downstream of the decision-making process	Development and assessment of strategies, visions and concepts upstream of the decision-making process for policies, plans and programs
Temporal and spatial scale	Short to medium term (project)	Medium to long term (geographic)
Nature of the issues	Delimited and circumscribed in time and space; local issues	Global, national and regional issues
Proactive/reactive	Reactive: A reactive approach seeks to resolve a specific question. It assesses the potential consequences of actions already determined. EIA is project specific.	Proactive: SEA anticipates future problems, needs and challenges, and examines the alternatives leading to the preferred option. It is therefore not specific to a project.

ASPECT Options (alternatives)	**EIA** Options of specific locations, design, construction, operation	**SEA** Land-use planning, technologies, fiscal measures, socioeconomic strategies
Data, methods, rigorousness of the analysis and indicators	More quantitative, technical and detailed data and methods. More rigorous analyses with less uncertainty. Indicators: legal constraints, standards and best practices	Less quantitative, technical and detailed data and methods than EIA. Less rigorous analyses with more uncertainty. Indicators of sustainability (criteria and objectives)
Governance	Public hearings, Consultation downstream of the projects, Ad hoc mediation, Mitigation and compensation measures	Public hearings, Reconciliation of the interests upstream of the projects, Consultation/collaboration and coordination between the stakeholders, Permanent partnership and collaboration mechanisms
Public's perception	More reactive (NIMBY)	Vague/distant
Role in the decision	Assessor, often an administrative requirement	Facilitator. Negotiation, learning
Follow-up	Follow-up on site	Regional and permanent observatories
Management	Technical/bureaucratic management	Adaptive approach. Integrated management

(Sources: European Commission, DG Environment)

1.3 Case study: Strategic Environmental Assessment for the Norwich Area Transportation Strategy (UK)

Aspect	Elements
Project Title	Strategic Environmental Assessment for the Norwich Area Transportation Strategy, Implementation Plan
Project Description / Summary	The Norwich Area Transportation Strategy (NATS) focuses on improving the social, economic and environmental aspects of the Norwich area. This includes improving public transport, accessibility and safety, decreasing congestion and pollution and making travel easier. The NATS Implementation Plan will put this strategy into practice. Corresponding to the European Directive 2001/42/EC Strategic Environmental Assessment (SEA), which became effective in 2004, an Environmental Report of the project was conducted. The following case study will identify the main elements of this report.
Project Development	The SEA Directive and Regulations were followed during the Strategic Environmental Assessment, thus the process included the following five comprehensive stages: (A) Context, Baseline, Scoping, (B) Alternatives and Assessment, (C) Preparing the Environment Report, (D) Consultation and (E) Monitoring. In the following, the first two stages will be briefly discussed, as they were analyzed in the cited SEA.



Source: Strategic Environmental Assessment for the Norwich Area Transportation Strategy, Implementation Plan: Environmental Report

Project Development (cont.)

A. Context, Baseline, Scoping

As the first step of the SEA process, relevant policies, plans and programs are studied and environmental conclusions were drawn from the relevant sections.

As the second step, in order to be able to forecast and monitor the effects, environmental data was collected to identify a baseline. This process would help to distinguish any pre-existing enviromental issues. Data was collected and analyzed from a variety of sources. Baseline conditions were then stated in the following areas: Air quality, Biodiversity, Fauna and Flora, Climatic factors, Cultural heritage and townscape, Soil and water, noise, Landscape, current socio-economic conditions, material and assets. This data was then used to predict the environmental changes without the implementation of the NATS IP, which was then compared to the outcomes of the IP alternatives.

During the SEA process certain environmental problems and opportunities were identified. There exist Air Quality Measurement Areas (AQMA), which bring in the possibility of using biomethane to reduce emissions and solve air quality problems. Also, housing growth can endanger the biodiversity of the area. However, habitat restoration and creation can solve this problem in many areas. A more sustainable transport system can be developed to fight climate change and public spaces can be improved. Soil and water problems may occur, which also need to be solved. The many problems that the NATS IP appeared to cause brought just as many opportunities to solve them.

Developing the SEA framework was the next step. During this part, a set of objectives were identified by which certain alternatives can be analyzed and compared. This is not part of the SEA directive, but it is a useful way to compare them. The objectives can be found in the following list:

SEA Objectives for NATS IP:

- To reduce CO2 emissions from transport
- To improve air quality in line with the National Air Quality Strategy (NAQS)
- To minimise noise, vibration and visual intrusion from transport
- To improve accessibility and reduce social exclusion
- Implement transport solutions that protect, and enhance where feasible, open space
- Implement transport solutions that protect, and enhance where feasible, biodiversity including wildlife habitats and species, and geodiversity
- Implement transport solutions that protect, and enhance where feasible, water resources
- To maintain and enhance the character of the landscape/townscape and cultural heritage including architectural and archaeological heritage
- Minimise the number and severity of road traffic accidents and maximise safety and security for everyone
- To encourage use of sustainable transport modes such as public transport, walking and cycling as alternatives to the private car
- Ensure transport infrastructure is designed to adapt to climate change effects such as flood risk and severe weather conditions
- To maintain and improve the health of the whole population, promote healthy lifestyles and reduce health inequalities

Source: Strategic Environmental Assessment for the Norwich Area Transportation Strategy, Implementation Plan: Environmental Report

Project Development (cont.)

As part of this process, the Scoping Report was sent to be reviewed by the Environmental Agency, Natural England and the English Heritage. Feedback was also given by the NCC and all of these responses were taken into account.

B. Alternatives and Assessment
The first step of this stage was to test the compatibility of the SEA and NATS objectives with the help of a compatibility matrix. The SEA objectives' high level of compatibility with the NATS objectives was confirmed, since both placed high emphasis on growth and accessibility. The SEA made sure that the NATS IP will have a positive environmental effect by giving direction to the project.

The next step explains how alternatives were selected and classified with information collected from professionals and users. The SEA then analyzed them and environment impact facts were provided. Each of these options were compared to a set of criteria (baseline) and noted.

The effect of the NATS IP and the alternatives were then predicted. An assessment workshop was convened in order to determine the impact of each scenario. Assumptions were also agreed on, which unfortunately the process relies on.

Next, the environmental effects of the NATS IP and the alternatives were evaluated. This concluded that the project has a neutral effect on the environment. Each outcome was analyzed in detail.

The last two parts will be discussed in the "lessons learned" and the "monitoring and feedback" sections.
C-D-E. These sections were not part of the environmental report cited, since they take place after the report is concluded.

Environmental Benefits

The NATS IP Preferred Package was completed after the SEA took place. It took into account the recommendations of the SEA, as well as ideas from other consultations and analyses. The NATS IP Preferred Package is predicted to have an indifferent effect on the environment.

The following graph shows the details of these impacts:

SEA Objective

1. To reduce emissions from transport
2. To improve air quality in line with the National Air Quality Strategy (NAQS)
3. To minimise noise, vibration and visual intrusion from transport
4. To improve accessibility and reduce social exclusion
5. Implement transport solutions that protect and enhance where feasible, open space
6. Implement transport solutions that protect and enhance where feasible, biodiversity including wildlife habitats and species, and geo-diversity
7. Implement transport solutions that protect and enhance where feasible, water resources
8. To maintain and enhance the character of the landscape/townscape and cultural heritage including architectural and archaeological heritage
9. Minimise the number and severity of road traffic accidents and maximise safety and security for everyone
10. To encourage use of sustainable transport modes such as public transport, walking and cycling as alternatives to the private car
11. Ensure transport infrastructure is designed to adapt to climate change effects such as flood risk and severe weather conditions
12. To maintain and improve the health of the whole population, promote healthy lifestyles and reduce health inequalities

Key:

++	Significant beneficial/desirable effect
+	Marginal beneficial/desirable effect
0	An empty cell indicates a neutral or no effect
-	Marginal negative/undesirable effect
--	Significant negative/undesirable effect

Source: Strategic Environmental Assessment for the Norwich Area Transportation Strategy, Implementation Plan: Environmental Report

Monitoring and Feedback	As previously mentioned, monitoring is the final stage of the SEA and has an important role in the process. According to SEA guidelines only those objectives need to be monitored that have incurred substantial positive or negative impacts. However, the Norfolk County Council (NCC) decided that modest unfavourable effects should also be monitored to prevent these from becoming larger problems. The NATS IP will only be successful if the implementation and enforcement is accomplished. There will be annual monitoring of the schemes and programs to determine whether they are performing as initially predicted. NCC will be conducting the monitoring through SEA indicators.
Lessons Learned	It is exceptional that SEA regulations oblige mitigation measures for SEA's when there are substantial negative effects noted during the assessment. Even though the NATS IP overall does not have positive or negative environmental consequences, the SEA project team still made suggestions on how to reduce the effects on the environment. These recommendations were focused on the areas where environmental performance could be advanced. The most significant of these, is that for each individual project an Environmental Impact Assessment (EIA) would be beneficial. This shows that the SEA and the EIA go hand in hand. Further improvements are desired, among others, in the following areas: maintenance of cultural heritages, landscape and biodiversity, while reducing climate change factors. NATS IP could also improve environmental efficiency in the matters of air quality (with alternative fuels), water (drainage systems), noise and vibration (barriers, surface) and the replacement of the habitat. The SEA also drew attention to the necessity of decrease greenhouse gas emissions, which brought the idea of fuelling public transport with Biomethane into consideration.
References	Norwich Area Transportation Strategy Report by the Director of Planning and Transportation. Rep. Norwich Highways Agency Joint Committee, 2004. Web. 2012. <http://www.norwich.gov.uk/CommitteeMeetings/Norwich%20highways%20agency/Document%20Library/8/REPNorwichHighwaysAgencyNorwichAreaTransportationStrategy12004-10-21.pdf>. Strategic Environmental Assessment for the Norwich Area Transportation Strategy, Implementation Plan: Environmental Report. Rep. Norfolk County Council Department of Planning and Transportation, 2010. Web. 2012.

1.4 General Lessons Learned and Advice on Road Planning

Legislation and consistency

The application of Strategic Environmental Assessment legislation ensures a more consistent, more comprehensive assessment, as well as a greater influence on the final decision. SEA should be a fundamental component of road-network planning.

Understanding environmental impacts at the strategic level

SEA contributes to a better understanding of the environmental effects of transport policies, plans and programs (PPPs). It provides a more efficient approach to both policy development and implementation. SEA can provide a good framework to ensure coherence between transport PPPs and environmental sustainability objectives (international, national and local).

Improved collaboration and efficiency in decision-making

In some cases, the SEA process is credited with having contributed to an improvement in communication and collaboration between the various institutions involved in transport, environmental and land-use issues. SEA can also improve the efficiency of the decision-making process.

Positive effects on subsequent project assessments

SEA can lead to the early exclusion of adverse projects or to a ranking of projects which highlights the most sustainable ones. This results in a reduction of the number of strategic and alternative projects which will need to be considered at subsequent planning stages.

Transparency and public participation

A SEA process will lead to increased transparency and to greater involvement of the public, although to date, it has been limited. These anticipated benefits tend to be more a reflection of member states' expectations in terms of future outcomes.

Land-use planning

Efficient land-use planning is essential in determining optimum interfaces between the environment, roads and users. This is why IRF supports taking environmental challenges, while opportunities are considered and dealt with early on and in every stage of the road infrastructure building process.

Cost-benefit analysis

Cost-benefit analyses are a very important part of protecting the environment and should be included in any political, regulatory or fiscal measure.

1.5 Obstacles Observed

One of the main obstacles that were observed with respect to sustainability during the road planning process was the lack of expertise. Lack of expertise is evident on two levels: 1) countries that already had SEA experience were aware that it was insufficient and were interested in continuing research and practice; 2) countries that had limited or no SEA experience were more inclined to consider the expertise acquired with project assessments as a sufficient basis to develop SEA.

In addition to lack of experience, lack of communication and sometimes lack of collaboration at the institutional level can also pose problems, although this seems to be less of an issue in countries that conduct SEAs on a regular basis.

Finally, additional bureaucracy results from having to adopt and carry out a new assessment process having additional work and procedures, which may involve longer time scales. In a limited number of countries, this was seen as a major obstacle.

2.1 Introduction

From an environmental perspective, the successful development of projects in the design phase is founded on an integrated approach covering the full range of skills relating to road projects. High-quality design will require this integration of skills to cover engineering, planning, landscape and the full range of environmental-science specialties. Sharing best practices plays an important part in improving quality, but there will always be a need to respond to individual local circumstances and there will rarely be "standard" design solutions.

In order to support the design process and maintain a clear, structured approach to project development, experience demonstrates the value of setting environmental design objectives that respond to the need for a balance between engineering, environment, cost and safety. With or without defined objectives, the application of appraisal frameworks is now common in many areas and such techniques are an important element of keeping the road sector at the forefront of environmentally-sensitive project development.

There is no doubt that more can be done to improve our approach to environmentally-sensitive design. One area where we are likely to see increased focus in the near future will be the need to improve the timeline we have available for decision making; a typical example of this would be the process for assessment of the whole-life carbon impacts of projects. We currently see many initiatives developing around the world aimed at gaining a better understanding of the carbon impact of design decisions. The IRF believes there is huge potential in sharing this knowledge and making examples of best practice readily available.

2.2 Case Studies

Case study A: A470 Dolwyddelan to Pont-yr-Afanc (Lledr Valley Improvement) (UK)

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Aspect	Elements
Project Title	A470 Dolwyddelan to Pont-yr-Afanc (Lledr Valley Improvement) Snowdonia National Park, North Wales
Project Description / Summary	The 7.2km long Dolwyddelan to Pont-yr- Afanc stretch of the A470 trunk road lies at the heart of the Snowdonia National Park in North Wales. It is arguably one of the most environmentally sensitive British highway improvement schemes in recent years. Arup was appointed in 2002 by Laing O'Rourke to prepare tender and detailed designs for the scheme. The team's brief included environmental monitoring and mitigation and implementation of site inspections and Road Safety Audits. The scheme was completed in January 2005.
Project Development	**Primary drivers for implementation** The original A470 was narrow and tortuous as it followed a steep and wooded alignment. Verges were largely non-existent and poor visibility made it difficult for large vehicles to pass and impossible for pedestrians, cyclists and equestrians to use safely. All these factors contributed to an above-average accident rate, frequent delays and congestion. Overall, the intention of the scheme was to improve road safety and journey time reliability, whilst mitigating any environmental impacts and taking advantage of enhancement opportunities. **Effectively Managing Design and Compliance** The scheme improvements involved widening and upgrading. Compliance with full design standards would have had undesirable environmental impacts along the route corridor, such as loss of stone walls, mature trees and feature buildings. This was avoided by adopting principles outlined in the design guide "Roads in Upland Areas", which calls for quality detailing and a balance between the engineering needs of alignments and visibility, and environmental aspects.

Project Development (cont.)

Elements

Applying these principles resulted in lower design speeds for the carriageway alignment as appropriate and reduced verge widths. Nevertheless, the improved carriageway width is generally 7.3m.

Roadworks
Kerbs were only used where essential for road drainage and safety reasons. All kerbs have a dark grey exposed aggregate finish to blend into the surroundings.

A new footway was built between Dolwyddelan and Pont-y-Pant with only small sections paved to replace existing sections. All other lengths of footway have a grey crushed slate finish to match adjacent walls. A community route was also constructed between Pont-yr-Afanc and Pont ar Lledr as part of the Conwy Valley Cycle Route.

Traffic signs were kept to a minimum and their locations carefully considered reducing visual impact whilst still complying with safety requirements. Public footpath signs were saved and re-erected or renewed where they were disturbed by the works. Other features like milestones and name signs were also salvaged and carefully incorporated.

Retaining walls
Where there was a safety requirement to contain vehicles, masonry or masonry-faced reinforced concrete walls and parapets were built rather than metal safety fences and parapets, which would have looked inappropriate in the National Park.

Stone from existing walls was carefully dismantled to protect resident lizards and mammals, and incorporated into the new or refurbished walls.

Other facing masonry was won from waste stone at local quarries. Overall, the scheme includes some 3.5km of new retaining walls. Where there was no requirement for vehicle containment, traditional stone walls were provided using relatively soft mortar which eliminated the need for joints.

All the concrete walls are faced with local stone masonry and incorporate refuges for reptiles, bats, and birds.

Environmental Benefits

Fitting the road carefully into the sensitive landscape of the Snowdonia National Park was one of the Client's prime goals. Getting this right was critical to the success of the project.

The landscape setting was carefully considered during design development, care being taken to limit the impact on important rock outcrops, trees and streams, as well as man-made features such as stone walls and bridges.

Environmental Benefits (cont.)

The retention and protection of these features, along with landscape mitigation such as shaping side slopes for return to agriculture, the 'dry stone wall' appearance of new walls, riven oak post and wire fencing, and re-use of salvaged stone, has integrated the new road into the landscape much as the former was.

To maximize sustainability and minimize transport of materials, much of the existing road pavement as possible was retained. Where pavement material had to be removed it was extensively reused within the lower layers of the new road, whose surface generally gives reduced traffic noise. The vast majority of aggregate used in the scheme was locally won from slate waste quarries.

Drainage

Existing road drainage was uncontrolled, running into roadside ditches and through 'scuppers' before tumbling down the heavily vegetated valley sides in places only yards from the Afon Lledr, a high-quality salmon and trout stream.

The team identified ways to rationalise pipe runs and combine some highway and verge filter drains. This eased some of the traffic management demands in the tightly-defined works corridor but still left potentially challenging excavations for oil interceptors - large tanks that use differences in specific gravity to trap hydrocarbons, preventing them from reaching receiving watercourses.

After considering the views of the Environment Agency and the Fire Service, and conducting detailed risk assessments into the likelihood of a serious pollution spill, the team designed and implemented a much smaller alternative isolation facility that allows individual outfalls to be closed manually. Procedures for operating the isolation facilities are included in the project maintenance manuals, so that the maintaining authority and emergency services know how to respond in an emergency. Out of the 19 oil interceptors originally planned, only one was eventually needed.

Treatment of existing watercourses crossing the route also presented challenges. Wide culverts were built to carry even the most intense storm flows safely beneath the road and down to the Afon Lledr. Large slate blocks found during construction were saved and used to line the stream channels, returning them to their original appearance of natural watercourses.

Ecology

The Lledr Valley is blessed with diverse flora and fauna, and from the outset, the importance of the valley for bats, otters, and reptiles was recognized. The Illustrative Design contained several conservation features, including an artificial hibernaculum for Lesser Horseshoe bats, gaps in walls for reptiles, birds, and bats to nest and roost and culverts with ledges to help reduce otter mortality from traffic.

Several areas of floristically rich meadow and woodland were translocated to prevent their loss, whilst the construction team protected other habitats, including a Site of Special Scientific Interest and many areas of woodland/upland soils. The Afon Lledr fea-

Environmental Benefits (cont.)

tured constantly in early discussions on construction methodology, due to the need to protect its water quality and associated aquatic flora and fauna.

The team further developed the contract's ecological requirements during construction. The bat hibernaculum - known as the 'bat hotel' on site - was redesigned to improve its bat 'attractiveness' as well as facilitating easier and cheaper construction, whilst a more cost-effective way to translocate the floristically-rich topsoils was developed with the Countryside Council for Wales. This was a particularly significant success in its first year of new growth

Monitoring and Feedback

Key to the effective delivery of the project was the Environmental Management System (EMS), of which a major part was the Environmental Action a Plan (EAP) that detailed the project's commitments to environmental mitigation measures. All sections of the plan were targeted and monitored daily, with formal audits conducted for compliance with the EMS, and continual improvements implemented on site. The EMS was overseen by an Environmental Co-ordinator with a dedicated deputy stationed permanently on site to ensure all EAP commitments were implemented and appropriate mitigation measures provided.

Throughout construction, Arup's ecological specialists regularly surveyed and monitored the nature conservation in the Lledr Valley. Trees that might contain bats were only felled following detailed inspections and, if necessary, obtaining the appropriate protected species licences. Sites were cleared and walls/buildings demolished only after extensive review of the area for nesting birds, bats, or hibernating reptiles.

The effectiveness of the wildlife measures will be monitored for five years beyond project completion and comprehensive reports prepared to inform future trunk road schemes in Wales as part of the Assembly's commitment to continuous improvement.

Areas of land disturbed by the scheme but not planted/seeded or covered by hard engineering works will be allowed to regenerate naturally, particularly in the most upland sections. This should ensure an appropriate mix of natural flora, benefiting local biodiversity and integrating the scheme into the wider landscape.

Feedback

The sensitive environment, the design and build form of contract, and the demanding timescale - not to mention the weather - made the A470 Lledr Valley Improvement a difficult challenge. However, the scheme has been a success, with a lot of positive feedback.

The British media in particular has described the route as 'possibly the "greenest" road in Britain'. The project was delivered to the client five months early and within budget. It has achieved its objectives of providing a safer and more reliable route for the travelling public and other users, whilst minimizing its environmental impact.

Monitoring and Feedback (cont.)	It has received industry acclaim and won a portfolio of awards including: • Conwy Valley Civic Society 2004 – 2005 • ICE George Gibby Award 2005 (Highly Commended) • CEEQual 2005 (Excellent) • Landscape Institute 2007 (Highly Commended) • British Construction Industry Awards 2005: Civil Engineering Finalist and Conservation Finalist • Prime Minister's Better Public Building: Finalist (2005) • Considerate Constructors Award: Silver (2005)
Lessons Learned	Lessons were learnt in respect of the need to give appropriate emphasis and resources to the implementation of the site Environmental Action Plan from day one, and to ensure all project staff was aware of its content. Establishing good relationships with stakeholders from the outset proved advantageous as design changes from the consented scheme were approved quickly.
Credits and Thanks	Credits and thanks go to our partnership team comprising: Main client: Welsh Assembly Government Contractor: Laing O'Rourke Clients Agent: Halcrow and White Young Green Environmental

Case Study B: NH-1A Tunnel Design (India)

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Aspect	Elements
Project Title	NH-1A Tunnel Design, India
Project Description / Summary	The case study has been structured to capture the key components of designing the tunnel and lessons learned with reference to sustainability of infrastructure.
Project Development	The existing road, NH-1A, is a 2-lane road traversing through Pir Panjal ranges covering a distance of approximately 32 km through 2.4 km long Jawahar tunnel, which is approx. 2050 m above mean sea level and has two tubes one in each direction. The road serves as a critical route throughout the year for the movement of the paramilitary forces, other food products and medicines. Above all, this is the only road for maintaining connectivity to rest of the country from Srinagar. It is a highly eco-sensitive area with 32 identified landslips zone and 15 snow avalanches zone, steep gradients, sharp curves and poor road geometrics in the alignment. The existing 2-lane road cannot be widened to 4-lane requirement without hill cutting, as it will accelerate the process of landslips, which is common in the area of the present alignment. There are frequent closures of the road during winter season due to heavy snowfall. The necessity is to maintain an all-weather flow on NH-1A and to design the road as per latest Indian Road Congress (IRC) Standards and Specifications. The present road has outlived its capacity and there is urgent need to upgrade it to 4-lane alignment. Therefore, the overall challenge was to meet the environmental safeguards, apply sound design principles and comply with the rules and policies of Government. The proposed alignment, a new 4-lane road has a total length of 15.250 km. The road traverses through Doda and Anantnag district of Jammu and Kashmir and comprises two tunnels of 8.45 km and 0.865 km, 2.42 km length of over-bridge and viaducts and balance road of 3.515 km on ground. Applying these principles resulted in lower design speeds for the carriageway alignment as appropriate and reduced verge widths. Nevertheless, the improved carriageway width is generally 7.3m.

Environmental Benefits

The proposed Project will result in substantial environmental benefits. There will be less Greenhouse Gas emissions because of reduction in travelling time, distance, and smooth flow of traffic in the following pattern (ref. Table 1).

Table 1: Projection of Reduction in Green House Gas Emissions

Year	2015	2020	2025	2030	2034
CO (in tons)	0.79	1.09	1.48	1.93	2.34

Particulate Matter, NOX, HC will decrease (ref. Table 2) in the area as vehicles will be travelling at uniform speed without any acceleration or deceleration for going up and down the hill and for less distance resulting in less emissions compared to existing alignment.

Table 2: Projection of Reduction in PM, NOX and HC

Year	2015	2020	2025	2030
HC	0.05	0.07	0.10	0.13
NOX	0.24	0.34	0.46	0.61
PM	0.03	0.04	0.05	0.69

All values are in tons. HC: hydro carbon; NOX: oxides of nitrogen; PM: particulate matter

The widening of existing road will accelerate the process of landslips. However, the proposed alignment will avoid all such areas and will result in enhancement of Natural Habitat as the existing alignment is passing through Chakore Conservation Reserve and Notified Forest, resulting in fragmentation of Natural Habitat, whereas the proposed alignment is passing beneath these areas. The area through which existing road is passing is rich in biodiversity and has well-developed roadside plantation. The new alignment is passing beneath the area so biodiversity will be least affected.

Noise Levels in the area will be reduced due to the uninterrupted flow of traffic, as the new alignment is passing underground and the vehicles will not need to go up and down the hill and hence generate more noise. Also, the socio-economic profile of the people of Kashmir will improve due to all weather flow connectivity between Kashmir and rest of India. All-weather traffic flow will be maintained between Jammu and Srinagar, as the new proposed alignment will avoid the 38 landslide areas and 15 Snow Avalanche zones. The traveling distance will be reduced by 15.40 km and climbing up and down the hill will be avoided, as the long tunnel north portal is almost at the level of entrance to the valley. The Vehicles will be able to travel at a speed of 70 km / hr, which is currently restricted to 15 km /hr. In addition, savings in travel time will also lead to reduced fuel consumption.

Monitoring and Feedback

The intent of the Environmental Monitoring Programme is to ensure the effective implementation of Environmental Management Plan and desired benefits for the target population. The broad objectives of monitoring and feedback are: (i) To evaluate the performance of mitigation measures proposed in the EMP; (ii) To evaluate the adequacy of Environment Impact Assessment (EIA); (iii) To suggest improvements in management plan, if required; (iv) To enhance environmental quality; and (v) To satisfy the legal and community obligations. Various physical, biological and social components identified as of particular significance, affecting the environment at critical locations in various stages of the project have been suggested as Performance Indicators (PIs) which shall be the focus for monitoring. These include (i) Air quality w.r.t SPM, RSPM and CO; (ii) Surface water quality w.r.t BOD and pH (iii) Ground Water quality w.r.t pH, DO, and Coliform count; (iv) Noise levels (Leq and Maximum Noise level) around sensitive locations; (v) Replantation success / survival rate; (vi) Muck disposal; (vii) Road Safety in operation stage; and (vii) Greenhouse gas emissions.
For each of the environmental components, the monitoring plan specifies the parameters to be monitored, the location of monitoring sites and the frequency and duration of monitoring. The monitoring plan also specifies the applicable standards, implementation and supervising responsibilities.

The monitoring mechanism includes a reporting system starting with the Contractor submitting a monthly compliance report to the Supervision Consultant. The Supervision Consultant will undertake monitoring activities on its own and also review the monthly reports submitted by the Contractor, based on field visits and interaction. The Supervision Consultant shall submit the Quarterly Monitoring Report, presenting the compliances of Environment Monitoring Programme and improvements required thereof. The Supervision Consultant will conduct workshops in adjacent villages with stakeholders, in which information about progress of the project and implementation of EMP (Environment Management Plan) will be disseminated to the people to take their feedback. The Supervision Consultants will compile the suggestions and feedback received and will prepare and submit the Action Taken Report / Recommendations to the Client.

Lessons Learned

The tunnel designing process with environmental assessment and mitigation as the key focus provided a major learning experience for the multi-disciplinary team. A major challenge is appropriate disposal of the estimated quantity of Excavated Material (Debris) which is 1,565,000 m3.

Preparation of EIA and EMP plans has been crucial, which contributed significantly to the designing process. The study also includes the required safety features in tunnel construction and operation. The project signifies unique features, being an eco-sensitive zone, located on a hilly terrain, the only channel of connectivity to rest of the country which gets disconnected during landslides and snow avalanches. The project stresses the designing principles of the tunnel, as to how it has utilized the EIA and addressed the negative impacts of the environment in the EMP, representing a climate-proof infrastructure and proving it to be a beneficial exercise for the society.

As environment concerns are given due weighting during the design stage, the anticipated adverse impacts shall be turned into potential environmental benefits as the project will help in reducing the Greenhouse Gas emissions, enhance the natural habitats, and brings down the pollutants, apart from providing all weather connectivity to the Kashmir region from rest of India.

2.3 General Lessons Learned and Advice on Design

Environmental Action Plan (EAP)

The need to give appropriate emphasis and resources to the implementation of the site Environmental Action Plan is inherent from Day One. Also, establishing good relationships with stakeholders from the outset is advantageous, so that design changes can be approved quickly.

Landscape Improvement

It is a necessity to mitigate the environmental impacts of road infrastructure projects. This is why landscape improvements should be included in all road construction and rehabilitation plans. Historical, cultural and community values should be respected during the process. Furthermore, visual quality improvements should be made, whenever possible, on already existing road networks.
To mitigate environmental impacts of infrastructure projects, landscape improvements should be a necessity of every road construction project. It should recognise and respect all of the areas cultural, historical and community values. It should also be important to develop the visual quality of the road networks when possible.

Tunnel Design

During the design stage of a tunnel, there are many issues that need to be considered so as to reduce environmental impacts of the project. Appropriate disposal of the estimated quantity of Excavated Material (Debris) is a key consideration, along with preparation of EIA and EMP plans, in order to design a climate-proof infrastructure. Finally, it is important to list and quantify (as much as possible) the anticipated adverse impacts against potential environmental benefits (such as reduction of Greenhouse Gas emissions, enhancement of natural habitats, reduction of pollutants and provision of all-weather-connectivity between different cities, etc).

For IRF, some additional lessons learned would include:

Impacts Assessment: Tools that determine the Carbon footprint of road traffic and infrastructure

Mitigation: (i) Noise pollution, (ii) Water pollution, and (iii) Monitoring of environmental impacts of the infrastructure in general.

3.1 Introduction

The construction phase of a road is considered critical in the process of sustainable road provision and a few case-studies could hardly do justice to such a diverse topic. Further discourse and documented cases are definitely required to further this aim.

The SEA and EIA form crucial inputs to the development of a construction programme in that it should serve as a guide to both process and substance in execution of the contract. Before looking at concrete case studies, we will provide an in depth analysis of the process and practice of road construction.

3.2 Process – Road Construction

1. Management and execution framework /programme

An important step is the integration of environmental and quality management into the construction programme. This could mean the employment of dedicated resources to oversee the respective action plans developed for these key activities. The plans should ideally also identify the various stakeholders and the specific roles each are to play throughout the project period.

2. Codes of practice and Guidelines

While engineering codes should not easily be waivered, there would be instances where innovation without relaxation of standards would be appropriate. An example would be the use of local material for minor retentions or barriers which would blend in with the natural environment.

3. Stakeholder engagement

The EIA process should ideally have identified areas considered sensitive to various stakeholders. This initial consultative process should be taken further by keeping interested parties informed through regular communication or liaison sessions. A stance of inclusion invariably results in a better end product and could mitigate against potential delays resulting from opposition to the development as it progresses.

4. Partnering

The areas of environmental, quality, and safety management have developed into highly specialised fields and due consideration should be given to partner with such experts where appropriate. Such partnering should ideally achieve outcomes that improve on existing practices without an increase in costs.

3.3 Practice - Road Construction

To construct a road pavement that meets all performance standards with minimum impact on the environment, the following elements are important considerations:

1. Energy consumption and greenhouse gas emissions

• *Paving products produced at lower temperature and energy consumption*

Numerous studies conclude that the production of paving material is the most energy intensive activity in producing a pavement.

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1. Energy consumption and greenhouse gas emissions

• *Paving products produced at lower temperature and energy consumption*

Numerous studies conclude that the production of paving material is the most energy intensive activity in producing a pavement. In the quest to minimise GHG emission, it's therefore imperative to reduce energy consumption.

• *Recycling or re-use to reduce the use of virgin materials and minimise waste*

The benefits of such action are self-evident. Whilst reducing the pressure on waste-disposal sites, recycled or reused material mean less extraction of virgin material. Not only is this cost-effective, but also environmentally astute.

• *Optimised production plants which should result in more efficient energy usage*

Not only should plant machinery be fine-tuned for optimal combustion, but also the quality and state of the raw material used should be such that energy consumption is minimised. Reduction of the moisture content of the raw material prior to production through undercover storage, illustrate this point. Selecting the type of fuel most suitable for the plant could also positively influence consumption with similar consequences for emissions.

2. Water consumption

During road construction, water is used during compaction of granular pavement layers, to suppress dust and to regenerate vegetation. On large-scale projects, significant quantities of water are used, which could make water-saving through rain-water harvesting and the use of treated-water effluent from manufacturing processes in the proximity options to consider.

3. Ecosystem disruption

- Adopting construction techniques and practices that afford minimal disruption and or quick rehabilitation to unique flora and fauna would be the aim. Minimal landscape impacts where cuts are treated to take on natural appearances is an example. Such steps ensure that the character of natural surrounds is protected or enhanced.
- As roads can cut through and eventually become part of vibrant echo systems, consideration should be given to construction methods that would foster the living habitat of the various species in the area. As an example, the appropriate use of natural material that leaves cracks and openings would assist in the attraction of smaller species like rodents, reptiles and birds for breeding purposes.
- Where disruption to the Indigenous plants and trees has taken place, this should be remedied with the replanting of similar species. Also, rare flora could also be removed from the road reserve prior to the commencement of construction, put in safekeeping and replanted on cut and fill slopes.

4. Occupational health

Worker health could be at risk with continuous exposure to potentially harmful substances like dust, hydrocarbons and organic compounds. Reduction of this risk through product innovation (like warm mix asphalt) and appropriate personal protection equipment are ideal mitigation measures.

Most mechanised construction equipment produce noise at levels which could result in hearing impairment with unprotected continuous exposure. Whereas personal protection equipment might suffice for certain tasks, the ideal would be to introduce noise control measures such as noise barriers and enclosures, as this would as well benefit to the broader neighbourhood of the construction project.

5. Traffic management and road safety
Upgrading existing road networks brings with it the complexity of accommodating significant traffic flows within the work zone, which makes traffic management an essential element of such a project. Both worker and road user safety should be considered in the traffic management plans that would be drawn up in conjunction with traffic law enforcement organisations. Keeping road users informed through ITS or similar measures should assist in neutralising incidents.

6. Waste Management
This involves the implementation of a waste management system, in order to prevent or reduce the amount of construction waste that might end up in landfill sites through re-use and recycling.

7. Lessons Learned
That process and practice should receive equal attention in undertaking a road construction contract.
A contract management programme and framework should be developed with all output objectives (including environmental) in mind.

There can never be enough communication with stakeholders and pro-actively involving interested parties could counter potential delays resulting from those opposed to the development. Partnering with specialists should deliver cost effective results.

In addressing occupational health, exposure risks that cannot be eliminated, should be carefully managed. With proper planning and execution, developing a road can deliver socio and environmental benefits over the long term. More case studies are required to enhance road construction practices.

(References: Including landscape in road design, construction and mitigation; M. Boden & K. Rowe Sustainable practice in road construction; Jo Moss, Claire O'Keefe & Damien Wagner)

3.4 Case Studies

Case Study A: Warm Mix Asphalt (South Africa)

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Aspect	Elements
Project Title	Warm Mix Asphalt
Project Description / Summary	Brackenhill Road & Leicester Road - Durban South Africa
Project Development	The first trial section of Warm Mix Asphalt (WMA) was constructed in South Africa in November 2008. The aim of this trial was to verify the results obtained by other countries in producing, paving and compacting asphalt mixes at temperatures at least 20oC below those of conventional hot-mixed asphalt. The trials, in which a specialised WMA technology enabled the mixes to meet this goal, included “warm” mixes containing 10% reclaimed asphalt (RA). A second trial, in which a second WMA technology and 10% RA were used, confirmed the findings of the original trial. The trials each used a quantity of approximately 2,000 tons of mix, the mix for the first trial being produced using a continuous drum type mixing plant and the second using a batch-type mixing plant. A template was developed after the first trials incorporating all the lessons learnt. The template was strictly applied through the second trial, from initial laboratory mix design, through full-scale plant and paving designs, to the trials themselves. Temperature limits of maximum 140°C, minimum 120°C after manufacture at the mixing plant and on arrival at the paving site were implemented. Useful information was obtained from the extensive use of thermal imagery. Compaction versus temperature as well as number of roller passes required to achieve density was monitored along the full extent of the trials. Both trials include control sections where asphalt with similar grading and with unmodified bitumen was manufactured and paved at conventional temperatures.

Picture from Beidermann

Environmental Benefits

Picture added from Solomons

The benefits include environmental issues such as lower emissions at the mixing plant and better working conditions at the paving site, as well as reduced consumption of burner fuel. The addition of RA (Rubberized asphalt) goes hand-in-hand with WMA in improvements to sustainability.

The principle aim of producing "Warm Mix Asphalt" containing 10% RA, at temperatures at least 20°C below those of conventional asphalt mixes, was achieved in these trials.

The trials showed that asphalt mixes containing 10% RA manufactured in the batch-type mixing plant at both normal mixing temperatures and at the reduced "warm mix" temperatures could be produced with acceptable moisture contents, well below the usual maximum 0.5% moisture content requirement.

During the Leicester Road trials the "warm" mix temperatures were achieved by reducing the fuel flow to the burner while maintaining the same production rate as that for normal asphalt. However no distinct trend was found between the burner fuel consumption figures of the control mixes and the "warm" mixes. This is contrary to the finding from the Brackenhill WMA trials as well as the general trend of a minimum saving of 15% as reported from other international projects. It is recommended that closer attention be paid to the calibration of the instrumentation on this plant and utility measurement if it is going to be used in any future WMA work.

Monitoring and Feedback

The trials show that "warm" asphalt mixes can be successfully produced using the local aggregates and reclaimed asphalt, as well as bitumen modified with either SASOBIT or REDISET WMA technologies.

With the success of these trials, further trials using other WMA technologies are being planned. In the meantime draft specifications have been prepared and it is planned to utilise WMA in projects within the Durban Metro to gain more experience before rolling it out on a national basis in 2010.

The full array of tests undertaken in these trials shows the quality of the WMA to be at least as good as that of the conventional asphalt mixes, while monitoring of compaction shows that WMA requires similar or even slightly less energy to compact to the required density compared to the conventional asphalt mix. The trials also give indications of significant reductions in burner fuel consumption. All six trial sections were successfully compacted to achieve the required minimum 92% MTRD level of compaction. There is some indication that, in general, the WMA mixes required fewer roller passes to reach density than the control Type D mix.

No significant trends in the amount of energy required to produce the different mixes were obvious from amp readings taken during the manufacture of the six mixes. The significance of this finding is that the reduced viscosity binders of the warm mixes, and

Monitoring and Feedback (cont.)	their resultant lower resistance to flow, yielded equi-viscosities at a temperature 30°C lower than their hot mix (control) counterpart. The trials showed that asphalt mixes containing 10% RA manufactured in the batch-type mixing plant at both normal mixing temperatures and at the reduced "warm mix" temperatures could be produced with acceptable moisture contents, well below the usual maximum 0.5% moisture content requirement. The principle aim of producing "Warm Mix Asphalt" containing RA, at temperatures at least 20°C below those of conventional asphalt mixes, was achieved in these trials.
Lessons Learned	The template especially developed for the manufacture, paving and compaction of WMA proved invaluable, and is used as a yardstick in drawing up specifications for the full implementation of this process. With a number of different WMA technologies available, careful evaluation is necessary to gain experience with their individual characteristics before they can be used in wide-scale production.

Case Study B: Development of Road Energy System (Netherlands)

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Aspect	Elements
Project Title	Development of Road Energy System
Project Description / Summary	Development and installation of a system to extract and use heat from asphalt pavements. Asphalt can get very hot in summer. A system has been developed to extract this heat and store it in underground aquifers during the summer period. During the winter the heat is used to warm buildings. So far, 13 projects have been completed with the system.
Project Development	• Because of the extensive asphalt paved road network in Europe there is a huge potential of energy in the form of heat which could be a significant contribution to reaching the Kyoto protocol goals. • System has been derived from systems used in the floor heating business. Pipes and fixation system had to be completely redesigned for application in asphalt pavements. This included material testing, mechanical modelling and also full scale testing. Furthermore a specific type of asphalt needed to be designed. • For the aquifer development a geo-hydrological design needed to be performed. • From the heating installation part several redesigns from conventional systems needed to be made • The system needed to replace a conventional system completely and accordingly energy collection models were developed to calculate the heat gain of a square metre of asphalt given the climatic condition. • Because of the large number of technology fields and the large number of stakeholders involved a holistic management approach is required to complete this kind of project successfully.

Environmental Benefits	• Reduction of housing and commercial energy consumption so far as a complete replacement of conventional (natural gas fuel) heating systems. • Estimated reduction on annual basis with current products 1,600 ton CO_2
Monitoring and Feedback	System is monitored constantly trough effectiveness of heating system and now a dynamic simulation model of the system is being developed on the data fro one of the systems.
Lessons Learned	It has been a long process but in the end successful. Getting all stakeholder at the same level of thinking is sometimes difficult and needs to be managed actively.




Case Study C: Low temperature asphalt (Switzerland)

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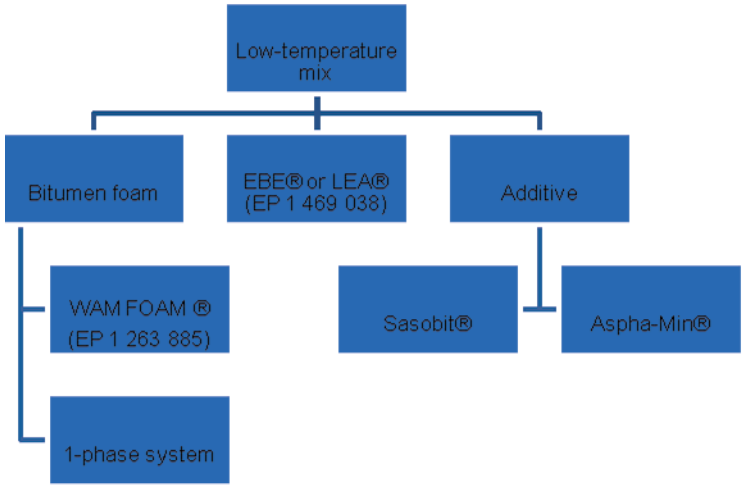
Aspect	**Elements**
Project Title	Low temperature asphalt – another step towards 'green roads'
Project Description / Summary	CO_2 accounts for the majority of man-made greenhouse gas production, with a share of 80%. Asphalt mixing plants used in asphalt road construction are a major source of CO_2 emissions, as the majority of energy is used to dry and heat the aggregate. This energy stems from fossil fuels. The two key aspects of a "greener" asphalt industry are lower production temperatures and the use of as much recycled asphalt as possible. Lower asphalt mixing temperatures lead to reductions in all kinds of emissions. That is why the industry is introducing what is known as "warm-mix asphalt". This asphalt is produced and laid at about 100°C, instead of the usual temperatures of about 160°C. The following flowchart details the low temperature asphalt process.



Project Development	Viscosity measures a fluid's internal resistance to flow. In order to modify viscosity at relatively low temperatures, so that the bitumen can mix well with the granular aggregate, cold water at high pressure is sprayed into the heated bitumen through nozzles. The bitumen is gently cooled and foamed at the same time, making it more fluid. As this happens, its volume is increased more than ten times over. This ratio is known as the expansion factor. The foam that is generated in this way soon subsides again; the half-life is used to quantify the time taken for this to happen. The problem here is this: the better a bitumen can be foamed, the faster it will usually subside. The objective is to find an ideal combination of expansion ratio and half-life time for the production of asphalt. The benefits of bitumen foam are evident when it comes to re-using recycled asphalt granulate that contains harmful substances such as tar. Thanks to the low temperature of the bitumen foam, these harmful substances are not dissolved and released as emissions, which can become a problem in the hot-mix process. The granular aggregate must also have specific properties so that it can be processed to make foamed bitumen asphalt.
Environmental Benefits	• Energy is saved; • Costs are cut; • Chimney emissions are reduced (CO_2, CO, NO_x, VOC); • Blue smoke is reduced on site; • Working conditions are improved; • Odour pollution is reduced;
Monitoring and Feedback	• Lower consumption of fuel; a major reduction in emissions (gases and smoke) from the plant • Significantly improved site working conditions for employees, machine operators and people living in the vicinity
Lessons Learned	Various methods of producing low-temperature asphalt are available; they include, for instance, the use of additives, foams, special types of binding agents, or a combination of these methods. It is usually possible to lower the mixing temperature by at least 20°C and sometimes by as much as 70°C. Various technologies are used, depending on the plant operator and the conditions on the construction site. The better a bitumen can be foamed, the faster it will usually subside. The objective is to find an ideal combination of expansion ratio and half-life time for the production of asphalt. Some parameters relating to the properties of asphalt produced from bitumen foam vary slightly from those of conventionally manufactured asphalt, although this cannot generally be described as either an increase or a reduction in quality.
Other Info	Joint project between the Ammann Group, Switzerland, and Belagswerk Hasle AG BLH

Case Study D: North Kiama Bypass (Australia)

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roads australia

Aspect	Elements
Project Title	North Kiama Bypass, NSW, Australia Re-use of quarried materials slag materials
Project Description/ Summary	• The Princes Highway is the major north-south transport spine connecting the south coast of NSW with Victoria and the major connector road for the local suburbs of Kiama, Kiama Downs, Gainsborough and Minnamurra in the Kiama area. The growing traffic volume associated with population growth in both the south coast and the urban area in North Kiama has resulted in increasing conflicts of through traffic with local traffic. • Population growth trends for the area indicated that the local region is expected to experience high population growth in the next 25 years. This requires a high standard road corridor to properly serve the growing demands of commuter, tourist and freight traffic. The RTA commenced construction of a 7.6 kilometre high standard four lane carriageway to bypass the northern Kiama area in 2001. The bypass was completed and opened to traffic in November 2005.
Project Development	• The design of the bypass included a major cutting through some high-quality basalt within a quarry precinct, which had not been previously extracted due to the proximity of local residences. • Whilst the material could have been crushed and used in the works, the quantity available was far in excess of that needed for the project, and the efficiency of mobile crushers is such that it would not have been economically viable to do so. • A decision was made during the design phase to make this valuable surplus material available for higher value re-use. The basalt material was used for reconstruction of an entrance road located at Lake Illawarra and was stockpiled for the construction of a marina at nearby Shell Cove. A significant quantity was also taken by the RailCorp for the manufacture of ballast for maintenance of State Rail infrastructure. High quality basalt was also exported to nearby quarries.

Project Development (cont.)	• In total, approximately 1,000,000 tonnes of high quality basalt was exported from the project. • There were three basalt quarries adjacent to the bypass – and two of these quarries had large stockpiles of minus 5 mm material. This material is the very fine dust that is produced by the crushing process and it has a very limited market and thus is effectively a waste product from the quarry industry. • The construction of the bypass was able to utilise this material for the construction of embankments, and as select fill for the construction of reinforced soil walls. Testing also revealed that it was suitable for use in the select material zone, the bottom layer of the pavement. The original design utilised material which required mixing with lime to achieve the specified material properties, but the quarry material did not require stabilisation, saving approximately 2000 tonnes of lime. Approximately 165,000 tonnes of this waste material was used in the select material zone, 90,000 tonnes for reinforced soil wall fill and 200,000 tonnes in embankment fill. • The pavement design called for a crushed slag pavement supporting an asphaltic concrete surface. Slag is a waste product from the steel making process and is readily available from the steelworks at Port Kembla, approximately 35 km from the project. Approximately 170,000 tonnes of crushed slag was used in the pavement. • The geotechnical investigations revealed that one of the cuttings was very wet and required a drainage layer. Again slag was chosen, this time as uncrushed spalls approximately 150 mm in size. Approximately 90,000 tonnes of slag spalls were used in the drainage layer. • Slag aggregate can also be used in asphaltic concrete, and this was also specified for the work as its skid resistance properties are superior to basalt, the most commonly used aggregate. Approximately 70,000 tonnes of slag aggregate was used in the asphaltic concrete.
Environmental Benefits	In total, the construction of the North Kiama Bypass recycled approximately three quarters of a million tonnes of waste materials and exported approximately a million tonnes of high quality basalt for other uses.
Monitoring and Feedback	Not applicable
Lessons Learned	Strategic assessment of availability of local recovered materials suitable for road construction during the early planning phases is critical to achieving a reduction in the use of virgin excavated materials. As important is the need to identify users of excess useable material early in the planning stages to avoid potentially costly alternative disposal options.

3.5 General Lessons Learned and Advice on Construction

1. Green Technologies

With the number of different and new "green" technologies available, careful evaluation is necessary to gain experience with their individual characteristics before they can be used in wide-scale production. Furthermore, within the procurement procedures, distinguished value could gradually be given to the 'green' processes and products that were established by the private sector.

2. Stakeholders

Getting all stakeholders at the same level of thinking is sometimes difficult and needs to be managed actively, but is essential for the successful implementation of new methods of construction.

3. Materials

Strategic assessment of availability of local recovered materials suitable for road construction during the early planning phases is critical to achieving a reduction in the use of virgin excavated materials. As important is the need to identify users of excess useable material early in the planning stages to avoid potentially costly alternative disposal options. Material life-cycle costs should be considered and life-cycle-analysis methodologies should be adopted.

4. Guidelines

In order to stimulate the application of best practices, guidelines and green rating systems need to be introduced. These will enhance environmentally-effective road constructions. Another important element could be to motivate the development of environmentally-friendly products and processes and recognize them in the procurement procedures independent of whether they were developed by private or public sector.

4.1 Introduction

Most roads follow historical routes connecting people with food, water, resources and each other. Consequently, maintenance is a reflection of the transport corridors' continuing value to society. Environmental aspects of present-day road maintenance largely depend on location-specific activities, including the following:

- Culverts and drains should be inspected for blockage and scouring, as well as their ability to allow fish passage to spawning habitat.
- Weeds and noxious plants are frequently treated with biocides. Spray drift onto nearby agricultural land or residences must be avoided, although this can be difficult due to changing wind and weather conditions.
- Truck accidents may involve chemical spills. Once the accident has been attended to, residues should be cleaned up, before waterways become polluted or they are soaked into the ground.
- Resurfacing technologies use high-energy grinding or water cutting techniques. Frequently, night is the only time available for these works and the resulting noise is hard to control and causes sleep deprivation to nearby residents. Noise-sensitive households should be temporarily moved if necessary.
- High-traffic urban areas may need regular cleaning and sweeping. Road-derived sediments contain high levels of zinc from tyre wear which is inhibitory to plant life and toxic to aquatic organisms. Disposal should be in a controlled and permitted facility.
- Locally-significant animals may cross the road during diurnal or seasonal migration. Provision for passage should be considered for both animal welfare and traffic safety. This may require fences, underpass or overpass for tree inhabitants.
- Old structures like bridges and tunnels may be culturally important and require historical authority approvals during refurbishment. Minor works requiring excavation may uncover artefacts.
- Equipment operators should be aware of accidental discovery protocols. Minor earthworks should have appropriate erosion and sediment controls in place.
- In unstable geography, strategic stockpiles of rock and gravel are needed for timely road repair.
- Approvals should be obtained from property owners, if required.
- Litter and refuse is most commonly found within several kilometres of small towns or from adjacent residents. Rubbish control and litter removal are complex social issues that are difficult to address.
- Roads passing through national parks need clear agreements with park authorities for the vegetation removal.
- Winter weather requires removal of ice and application of grit and chemicals. Ice reduction salts should be of the lowest toxicity. For example, calcium magnesium acetate. More extreme conditions may warrant calcium chloride but this should only be used when necessary.
- Noise mitigation may require the retrofit of barrier walls. Measurements must be taken before-hand to both ensure their effectiveness and quell concerns of noise reflection onto nearby properties.
- The removal of road side vegetation for safety requirements is commonly followed by noise complaints. Although vegetation has secondary noise reduction properties, people tend to perceive more noise when they can see the traffic.

In conclusion, each maintenance area should develop an Environmental Management Plan that maps sensitive receiving environments, clarifies Standard Operating Procedures and clearly delineates roles and responsibilities in order to ensure environmental aspects are adequately managed.

4.2 Case Studies

Case Study A: Environmental Performance Assessment of Network Maintenance Contracts
Strategic Environmental Assessment for the Norwich Area Transportation Strategy (New Zealand)

Aspect	Elements
Project Title	Environmental Performance Assessment of Network Maintenance Contracts
Project Description/ Summary  **Waipoua forest, NZ**	The focus of this project is on environmental management of New Zealand Transport Association (NZTA) network operation and maintenance activities. The project aimed to gain a level of understanding of current environmental management and compliance on the Northland network. The project sought to capture whether the processes were in place to enable good environmental management and compliance and to identify potential opportunities to improve environmental performance both locally and nationally.
Project Development	Candidate sites (3) were selected across a variety of geographic locations and contract types. Key steps in the delivery of this project are: • Project meetings and coordination – a start-up meeting (video conference) between project team members was held to ensure there was a shared understanding about project objectives, lines of communication and all participants were committed to the delivery of the project. Fortnightly project progress reports and regular telephone discussions were held between project team members. • Contact with local network operators – the project team contacted key individuals involved in the operation of the network to outline the project objectives and invite local participation in the assessment. • Activity register - a register of key activities undertaken on the network and the potential environmental impacts associated with those activities was developed in

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WAKA KOTAHI

Project Development (cont.)

Kamo, NZ.

collaboration with network operators.

- Selection of key activities – a selection of key activities was identified for inclusion in the environmental performance assessment based on their environmental impacts and relevance to the network.
- Planning assessment – network activities were assessed against the applicable district and regional plan criteria, to determine regulatory thresholds and requirements for undertaking identified activities.
- Resource consents – a review of known resource consents for the network was undertaken and four selected for inclusion in the environmental performance assessment.
- Questionnaire development – the environmental performance assessment questionnaire was developed in consultation with NZTA staff and informed by discussions with network operators and the outcome of the network activity, planning and consent reviews.
- Interviews – interviewees were identified from across all levels and organisations involved in the operation of the network.
- Analysis and reporting – interview results were analysed, outcomes summarised in a report and recommendations on opportunities for improvement provided.

Environmental Benefits

Wild flower planting, NZ

The NZTA is seeking to improve environmental performance and compliance of network operation and maintenance activities. The purpose of this project has been to review the current level of environmental performance of the Northland state highway network to identify good practice and recommend opportunities for improvement. The outcomes of this report are intended to inform both local networks and the NZTA in improving environmental management practices and delivering the NZTA's environmental objectives.

Monitoring and Feedback

The Northland state highway network comprises of approximately 752 kilometres of state highway with approximately 952 million vehicle kilometres travelled on it annually. Parts of the network are remote from significant population centres, and whilst the region is undergoing significant growth particularly in eastern coastal areas, it remains a relatively poor and isolated region of New Zealand (Northland Regional Council, 2008). Severe flooding and weak underlying soil structures provide significant challenges to the ongoing maintenance of the Northland state highway network.

Monitoring and Feedback (cont.)

The operation of the network is covered by PSMC Contract 002. Contract organisations include DownerEDi Works Ltd, MWH NZ Ltd and VK Consulting Environmental Engineers Ltd. These features and contract arrangements provide both challenges and opportunities for environmental management in Northland. A suite of NZTA national environmental policies, plans and guidelines provide an overview of potential environmental impacts of motorway activities and detail proposed approaches to minimising and managing these impacts.

Onewa pond, NZ

Regional and District Plans and resource consents provide further guidance on environmental management requirements associated with specific network activities. Local network operators were committed to improving environmental performance and were seeking guidance from the NZTA in terms of clarification of expectations for environmental management and support in identifying and responding to key environmental issues. Extensive lists of recommendations to enhance existing strengths and formalise processes will better enable efficient and effective environmental management of network operations have been proposed. Responsibility for implementation of the recommendations has been suggested to lie with local networks or the NZTA. Recommendations have been presented in a table from the Asset Management Plan guidance document with the intention that actions can be prioritised and easily transferred into plans for network improvements.

Lessons Learned

- Lack of specialised environmental support for network activities not requiring resource consents.
- Mixed perceptions about roles and responsibilities for environmental management.
- Lack of clarity in relation to contract requirements for environmental management.
- Lack of vision/understanding of how the corridor interacts with surrounding environments in relation to environmental management.
- Quarterly liaison meetings with Local Planning Authorities do not cover environmental management.
- Incomplete list of environmental issues and actions identified in Asset Management Plan.
- Increasing national regulatory requirements for environmental management.
- Consent conditions are vague and difficult to interpret.
- Consent information is not easily accessible by all people contributing to network operations.
- Reliance on personal knowledge and experience of individuals to guide environmental management including regulatory compliance.
- Reporting on environmental management is based on noncompliance only.
- Lack of consultation with network operators by capital project teams to consider maintenance requirements in new asset design.
- Project Management Control Plans are key documents for communicating environmental management and regulatory requirements to teams undertaking planned projects.

Lessons Learned (cont.)

Grafton gully, NZ

- Limited opportunity to learn from experiences of other networks in addressing common environmental issues.
- Environmental Management Plan (EMP) is not seen as a working document or used regularly to inform on the ground practices.
- Lack of clarity about who is responsible for implementing the network EMP.
- Need for a dedicated resource to manage or address environmental issues.
- Lack of clarity on EMP's by NZTA.
- Lack of training on network EMP.
- Lack of records of culture and heritage sites available to network contractors undertaking permitted activity work.
- No records of contaminated sites on or near the network.
- Lack of investment in adapting to climate change.
- Lack of guidance relating to potential contaminants in some materials – e.g. bitumen from water cutting and waste from material used to absorb road spills.
- Lack of available dumpsites throughout the region to receive soil overburden from slips and other associated activities.
- Lack of direction on minimum client requirements and prioritisation of environmental issues – what issues are the most important?
- Lack of transparency on the evaluation of non-price attributes during tender evaluation process.
- Lack of information to better manage challenging en issues such as coastal and stream bank erosion.
- Variable level of guidance required for day to day operational activity.
- Funding weighted towards areas with higher traffic volumes.

Case Study B: Sustainable Pavement Rehabilitation at the Isle of Man Airport (UK)

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Aspect	Elements
Project Title	Sustainable Pavement Rehabilitation at the Isle of Man Airport
Project Description/ Summary	Pavement rehabilitation was needed at the Isle of Man Airport to carry future traffic loading. An alternative pavement option to the conventional asphalt reconstruction (using cold in-situ recycling to meet the technical and financial requirements) was used for the taxiway strengthening. The design and construction process consider the UK government's Waste and Resources Action Programme (WRAP) Halving Waste to Landfill Initiative and achieved the waste hierarchy of Reduce, Reuse, Recycle to improve sustainability and optimise the project cost and its impact on the environment. The recycling option delivered a sustainable solution with substantial reductions in cost (40%), energy consumption (44%) and carbon dioxide emissions (32%), when compared against the conventional design.
Project Development	In December 2008, the airport authority commissioned Colas to investigate the pavement condition and develop rehabilitation proposals that satisfied financial, technical and sustainability requirements. Colas appointed Scott Wilson to perform the site investigation, pavement strengthening designs and construction monitoring, however, the rehabilitation works were carried out by Colas. An alternative option to the conventional asphalt reconstruction using cold in-situ recycling was used for the taxiway strengthening. The rehabilitation design considered the UK government's Waste and Resources Action Programme (WRAP) Halving Waste to Landfill Initiative and negated the need to dispose hazardous tar bound materials found during the pavement investigation.

Project Development (cont.)

Pavement strengthening designs included both conventional and recycling options were prepared. Recycling options (using cold mix hydraulically bound recycled materials) were presented in order to:

- Promote sustainable and environmental engineering solutions, in accordance with the principles of WRAP.
- Reduce the amount of excavated material going to landfill in accordance with the Halving Waste to Landfill initiative.
- Reuse excavated pavement materials to reduce energy and material consumption, as endorsed by Defence Estates.
- Prevent the costly removal of the tar bound materials, which would otherwise need to be shipped to the UK mainland for safe disposal.
- Reduce carbon dioxide emissions and minimise damage to the environment.

Conventional treatment comprised of removal and disposal of 160mm of existing pavement materials and replacing them with new 160mm asphalt surface and base over unbound granular sub-base. The alternative options comprised of 265mm of cold mix hydraulically bound recycled existing pavement materials with 100mm asphalt surfacing. A Repave option was proposed on taxiways where only a small strength increase or no structural treatment was required. The Repave process includes reheating the pavement surface before overlaying with 30mm of asphalt surfacing, to remove all surface defects, restore the correct surface characteristics and create a homogenous fully bonded layer.

The main priority in planning and programming the construction works was ensuring airport operation was not compromised at any time. In order to ensure drainage continuity, the new pavement construction needed to be tied into the edge drains, which ran adjacent to the taxiways. As a result of this level restraint, there was a surplus of excavated tar bound material, since the design required a total thickness of 100mm new surfacing material on top of the recycled base layer. Instead of removing the surplus tar bound material to landfill, it was used to reconstruct and reshape taxiway Charlie South. This operation used up all the surplus material. Recycled Asphalt Planings (RAP) were incorporated into the new hotmix binder course, further increasing the sustainable credentials of the project.

Project Development (cont.)

The whole works were carried out during a daytime, night time and weekend possession, allowing the airport to operate normally throughout. The estimated cost saving associated with the recycling design was 40%, compared to the conventional design.

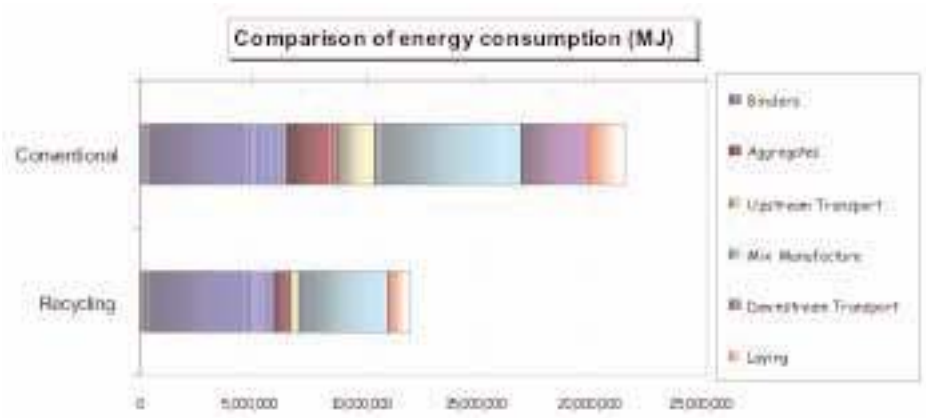
Environmental Benefits

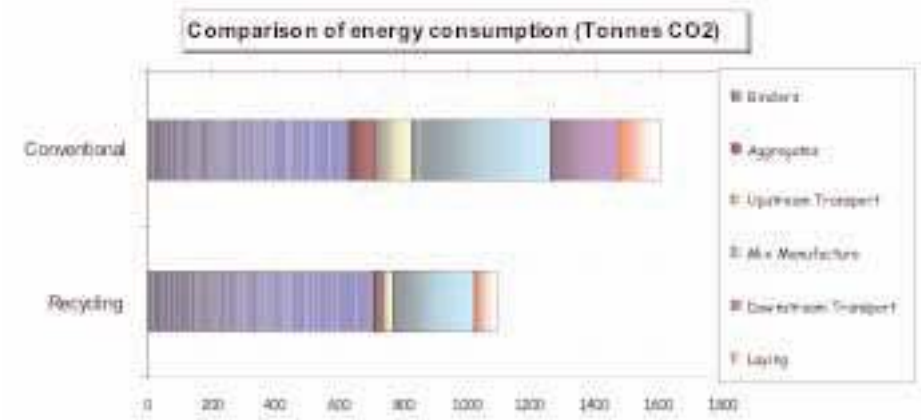
A comparison between the estimated quantity of material that would have been sent to landfill, new imported materials and number of vehicle movements had the conventional design been chosen against the actual quantities during the recycling works is shown below

	Conventional Design (Estimated)	Recycling Design (Actual)
	Waste to landfill (m^3)	
Asphalt Planings	9179	167
Tar-bound Material	3701	0
Subbase Material	8583	0
	Importing new materials (m^3)	
Asphalt	8301	5276
Subbase Material	8583	0
Topsoil	2586	40
	Total vehicle movements	
Asphalt Material	1453	923
Planings	1606	29
Tar-bound Material	648	0
Subbase Material	3004	0
Topsoil	296	5
Drainage	15	3

The energy consumption and Carbon Dioxide emissions were calculated using Colas's Carbon Calculator "Ecologiciel" and presented below.

Environmental Benefits





Monitoring and Feedback	The alternative pavement rehabilitation using cold mix recycling has resulted in a more sustainable, cost effective solution with the following benefits: The recycling works reduced the amount of excavated material going to landfill by an estimated 99% (compared to a conventional pavement design), in accordance with the Halving Waste to Landfill initiative. The excavated pavement materials were reused to reduce energy use and material consumption. The recycling works reduced the amount of new material imported to site by an estimated 73% (compared to a conventional pavement design). The recycling prevented the costly removal of the tar bound materials, which would otherwise need to be shipped to the UK mainland for safe disposal. The recycling reduced energy consumption by 44% and carbon dioxide emissions by 32%, therefore minimising damage to the environment. Approximately 6062 vehicle movements were saved by opting for a recycling design (compared to a conventional pavement design). Finally, the estimated cost saving associated with the recycling design was 40%, compared to the conventional design.
Lessons Learned	Recycling for airfield pavements has been identified as a substantial opportunity for furthering the objectives of sustainability in order to minimise damage to the environment. However, the technique has not been considerably used on airfield pavements due to the limited site trials and lack of long term performance. Therefore, providing a sound engineering design to ensure future performance to reduce the risk of maintenance and associated users cost due to operational restriction is essential.

4.3 General Lessons Learned and Advice on Maintenance and Rehabilitation

Project Management Control Plans
Project Management Control Plans are key documents for communicating environmental management and regulatory requirements to teams undertaking planned projects.

Design
A sound engineering design to ensure future performance and reduce the risk of maintenance and associated users' cost due to operational restriction is essential.

4.4 Obstacles observed

- Mixed perceptions about roles and responsibilities for environmental management.
- Quarterly liaison meetings with Local Planning Authorities do not cover environmental management.
- Reliance on personal knowledge and experience of individuals to guide environmental management including regulatory compliance
- Reporting on environmental management is based on non-compliance only.
- Lack of training.
- Lack of records of culture and heritage, of contaminated sites, or suitable dumpsites available to network contractors undertaking permitted activity work.
- Lack of guidance relating to potential contaminants in some materials – e.g. bitumen from water cutting and waste from material used to absorb road spills.

5.1 Introduction

As demonstrated in the previous chapters, protection of the environment from the impacts of a new or an existing road is crucial and can be undertaken in all stages of a road's life, from planning and design to construction and operation/maintenance. The primary obligation of an operating company is to ensure that traffic is kept moving and safety is maintained at high levels. However, operation of a road cannot be taken out of the equation towards environmental protection and mitigation. After all, no matter how prudent one has been during the previous stages, it is during operation that many parameters may change, leading to the necessity of immediate and effective actions to reduce any relevant environmental impacts. The best was to determine whether the designs and constructions environmental considerations were successful is to conduct detailed monitoring during the operational period. This is the time when improvements can be made in problems are encountered.

Environmental protection during the operation stage of a road is a continuous process, requiring constant monitoring of various parameters and implementing direct or indirect measures to ensure that the environment and quality of life are not compromised. The various environmental aspects that need to be monitored and protected during the operation of a road are analysed below.

1. Air Quality

As far as transportation is concerned, as vehicle technology had greatly improved with respect to emissions, one would expect air quality to have improved, too. However, this is not the case, as people travel more and further. Air quality deterioration is the most direct effect that road travel has on the environment and it is essential for a road operator to monitor it against the various standards set by national or international organizations, to protect human life and the life of the environment. After all, air quality is not only a local issue; it is also a trans-boundary one. The transmission of emitted air pollutants can harm the environment and human health far away from where the release actually occurred. Apart from monitoring air quality, operators must be prepared to take immediate action to reduce pollution within the acceptable limits, in case of pollution events. Keeping up with available techniques and technologies to reduce air pollution is essential in these cases.

2. Biodiversity and Landscape

Biodiversity is the variety of life forms (flora and fauna) within a given ecosystem. Biodiversity can be threatened directly or indirectly by human activities relating to transportation, in terms of air pollution or habitat fragmentation and needs to be closely monitored during the operation phase of a road, to ensure that provisions made during the design and construction phases are valid and effective. Local flora should be protected and re-planted, where needed, and local fauna should be allowed to cross the motorway without any danger to its life, through appropriate animal crossings.

Landscape encompasses the whole of our external environment, and for many people their main experience of the wider landscape of their country is from a moving vehicle. The development of the landscape the driver experiences is mainly carried out during the design and construction phase, however, during operation, great care must be taken to maintain and continuously improve it. Landscaped areas should be maintained within the highway boundaries so as to contribute to the local character, screen sensitive areas and support the local wildlife.

3. Cultural Heritage

Historic buildings, historic landscape and archaeological remains are all parts of cultural heritage. They show the connection between humans and the environment while providing us with physical proof of the story of mankind.

It is important to minimise the effect a road project has on the built and natural environment. Avoiding severe impacts on cultural heritage assets -whether these are known when designing the project or whether these turn up upon construction- are extremely important. Cultural heritage, much like biodiversity, can be affected directly or indirectly by transportation, as it can be affected by air and noise vibrations, too.

4. Water and Soil

As far as water is concerned, both in terms of surface water and the receiving waters, it is essential that the design, construction and operation of roads pay attention to flood risk and pollution from highway discharges. Road drainage needs to be well maintained by the operator, so as to avoid the negative environmental impact in the receiving water environment. Besides protecting the water environment from pollutants, road safety would also increase by speedy removal of surface water or hazardous spills, which would also extend the life span of road surface and associated infrastructure. Environmental Impacts from road operation may also affect the soil quality of the surrounding areas, mainly through airborne pollution and spray. Hence, water and air quality management also affect soil quality and by monitoring the first two, one can ensure the quality of the latter.

5. Stormwater

Storm water runoff from roads can cause adverse environmental impacts when excessive quantity or poor quality enters sensitive receiving environments. Impermeable surfaces like pavement exacerbate the impact of runoff causing erosion, scouring and flushing. Detention basins or ponds reduce the impact. Their design should consider the catchment and sub catchments in order to be effective. Whole-of-life operation and maintenance must be considered including access for sediment removal, inspections and safety. A well-designed storm water pond can be used for erosion and sediment control during construction, and also as a positive legacy for the nearby community. Low impact designs using open channels and swales are preferable over hard engineered piped drainage. Considerations must be given at the early planning stages for property acquisition to ensure sufficient and suitable land is available.

Notwithstanding erosion and sediment controls during construction, the main source of water quality degradation is zinc and copper, typically found in the ratio of 5:1. The source of zinc is worn tires, as it is used to control the vulcanization process during manufacture. Copper is shed from brake pads. Consequently, higher concentrations are found where driving is aggressive like hills, corners, intersections and congested start-stop traffic. Pollutant run-off levels also are affected by frequency and duration of rain events, pavement type, drainage and traffic volume and distribution between passenger cars and trucks.

Exhaustive studies have only been able to correlate about 30% of the pollutants with environmental factors. Under more controlled conditions, taking into account natural sedimentation rates, this improved to nearly 80%. As a result, it is very difficult to predict emission factors for a given stretch of road. A very general principle is that adverse effects are probably not found with traffic levels below 30,000 vehicles per day.

However, more than 100,000 vehicles increase the likelyhood. Nevertheless, simple treatment systems, such as grassed swales vegetated drainage channels, effectively remove both copper and zinc, while ponds are much less effective. Despite swale removal efficiencies of 60%, sufficient copper and zinc can be discharged into sensitive receiving environments at concentrations exceeding internationally acceptable limits.

6. Noise

Road traffic is a widespread source of environmental noise and can adversely affect community health and well-being. The World Health Organisation identified noise related (community noise, traffic noise) health effects. Some of these are:

- hearing impairment from noise,
- speech communication interference,
- problems with rest/sleep and
- mental health, physiological and performance effects.

There are two main sources of traffic noise:

- mechanical noise, such as engine and exhaust noise and
- rolling noise, resulting from the interaction between vehicle tires and the road surface.

Traffic noise may be continuous; for example, noise from a busy urban motorway or arterial road, or may be intermittent, like truck noise from a rural road at night. The level of traffic noise audible in a particular location will depend on a range of factors, including:

- traffic composition (vehicle noise standards, type and age of vehicles) and conditions (speed and traffic flow);
- road surface (texture and porosity) and grade (degree of incline);
- driver behaviour (acceleration and braking); and
- surrounding topography (built and natural environment, as well as environmental sensitivity).

Construction noise is associated with works to build new or upgrade existing highways, whilst maintenance noise is associated with works to maintain the standard of or repair existing highways. Both the type of equipment and techniques employed to undertake construction and maintenance works can generate noise. Noise issues associated with construction and maintenance activities on the highway network can be particularly intrusive and disturbing, especially when undertaken at night. To avoid the impacts on communities and individuals, these noise sources need to be managed effectively.

Noise assessments should be performed on new or altered highways likely to be affected by traffic noise. In consultation with local authorities, reasonable noise level criteria generally form legally binding requirements. Design methods to achieve the criteria rely on a number of approaches and will be dependent on local conditions. Methods include physical mitigation measures, such as low-noise road surfaces, noise barriers, walls and fences, as well as landscaped earth bunds. In addition, road geometric design approaches, such as design speed, road grade and intersection layout, can be used to influence traffic noise levels.

7. Waste

Waste reduction and management is an inseparable aspect of the construction, but also of the operation of a road project. The operating company is responsible for managing and removing appropriately tons of waste, produced either by the users for the road or by the operating personnel itself. Waste does not only include paper, metal or plastic, which are more straight-forward in their processing, but also more complicated materials, such as batteries, refrigerator fluids, oils, tyres etc.

All the issues presented above can assist a road operator in tackling any environmental problems that may arise. They are direct ways in which the operating company can protect the environment or mitigate any environmental issues. It is important to stress, however, that there are other, indirect ways that a road operator can protect the environment and that should be considered in addition to the aforementioned direct methods. One important indirect method of protecting the environment is the application of Traffic Management techniques and relevant ITS. As mentioned previously, the operator's main target is to ensure the smooth and safe flow of traffic. Ensuring this, though, also ensures that air emissions are kept to a minimum. As emissions per vehicle of most pollutants greatly increase as vehicle speeds fall (and vehicle speeds fall during congestion conditions), ensuring that vehicles flow smoothly, with less start-stop etc, will also contribute to the air quality itself.

Also, it is important to stress the significance of education of drivers and people with respect to the environment. An operator that invests in informing its users about eco-driving or recycling, for example, will enjoy the indirect effects of this change of behaviour, with less waste, less emissions, more constant speeds and safer driving. It is crucial to think about the bigger picture, when it comes to the environment, as there are so many direct and indirect things that one can do to protect it.

5.2 Case Studies

Case Study A: Innovative and environmentally-friendly tires

Aspect	Elements
Project Title	Michelin's commitments to sustainable mobility through innovative and environmentally-friendly tires
Project Description/ Summary	Michelin has committed to contribute to a smarter and better mobility for tomorrow's world by developing innovative products, low rolling resistance tyres, while improving the key tyre performances (better grip and handling , longer wear life) and reducing external noise contribute to a smarter and better mobility for tomorrow's world
Project Development	In order to move toward more sustainable mobility, assessing the various impacts of tyres was essential before taking action. Michelin has identified several ways to lower tyres' environmental impacts: • enhancing tyres' fuel efficiency to reduce CO_2 emissions • improving tyre longevity • reducing tyres' contribution to external noise The transport of goods and people is a key factor for economic development. Since the arrival of the car, road transport has represented an ever-increasing share and today accounts for more than 80% of transportation of people throughout the world. As a result, most countries face a range of important challenges such as growing transportation needs, environmental pollution, road safety and urban congestion. They have to meet the challenge of constraining CO_2 emissions to a peak by 2015 and then dividing by two global emissions, in a context where both the total number of vehicles and miles covered worldwide will more than double within the three or four decades to come. Since 1992, Michelin has launched various "green tyres" to limit fuel consumption and CO_2 emissions, "green tyres" owe their name to their energy efficiency that reduces environmental impact. Michelin is pursuing research to further improve the energy efficiency of its products, both for passenger cars and trucks.

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Project Development (cont.)

1. tyres are not the only source of noise: the choice of road surface has a major impact on noise emitted by tyres. It is the main source of excitation for a tyre which is greatly affected by the macro and the micro roughness of the road and/or the non continuities of the road surface. Many other things affect traffic noise. These include the traffic density, the driver's behaviour, the power train, the type of encapsulation in the vehicle, vehicle speeds, weather conditions, etc.
2. tyres play a major role in road safety. Reducing noise does not mean reducing overall tyre performance, such as tyre grip and handling, braking distance. Yet, overall tyre performance is determined by many characteristics, of which rolling sound is only one. When reducing noise, it is essential to maintain a correct equilibrium between all the different performance characteristics to put safe, reliable, harmonious and environmentally responsible tyres on the market.

What measures were undertaken to overcome these issues?

Michelin supported the EU proposal to reduce rolling sound emissions of tyres achieved through the approval of Regulation (EC) 661/2009. The objective is to reduce rolling sound emissions for all tyres from 2 to 4 dB beginning in 2012. While reducing rolling sound emissions of its tyres, through innovation Michelin has simultaneously improved fuel economy, increased tyre longevity and attained better grip and handling.

In addition, Michelin continues to work with road construction manufacturers to promote the concept of quiet roads, road noise grading and the use of innovative road surfaces such as rubber asphalt and other technologies that can help to reduce road noise. Indeed, an integrated approach to the issue of traffic noise is needed. A tyre that does not come in contact with the road makes no noise at all. And the type of road it comes in contact with will determine how much noise it makes. New types of porous pavements have been developed over the last few years to absorb noise. Further research needs to be done.

Environmental Benefits

Environmental benefits were key to trigger Michelin's commitments to manufacture environmentally-friendly tyres while improving the key tyre performances. As far as fuel economy is concerned, low rolling resistance tyres provide an economy of fuel ranging from 2 to 6%.

Monitoring and Feedback

Since 2007, Michelin has sought to quantify the contribution of its green energy through a meter which shows :

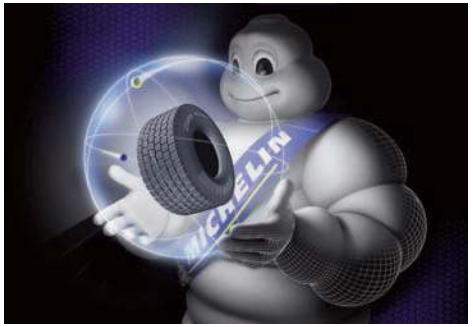
- the amount of fuel saved since the market launch of Michelin green energy saving tires in 1992,
- the amount of CO_2 not released into the atmosphere over the same period.

As of today, worldwide fuel savings attributable to Michelin green energy saving tires compared to conventional tires on the road since 1992 amount to 17,000,000,000 litres.

Lessons Learned

The amount of CO_2 not released into the atmosphere since the introduction in 1992 of Michelin green energy saving tires amounts to 43 million of tons.

Innovation is key to reconcile environmental protection, safety and road performance. Michelin, which allocates nearly 4 percent of its annual net sales to research and development, is responding to the challenge of designing tyres that help to reduce both fuel consumption and rolling sound emissions of tyres while improving performance levels in other areas: fuel savings and rolling sound emissions of tyres are now combined with superior grip and safety, as well as the best total mileage in the market.



Case Study B: Attica Tollway-Environmental Post-monitoring for Urban Motorways (Greece)

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ATTIKES DIADROMES

Aspect	Elements
Project Title	Attica Tollway: Environmental Post-monitoring for Urban Motorways
Project Description/ Summary	Attica Tollway, is a fully access-controlled Tollway within the metropolitan area of Athens, Greece. The 65 kilometre – long Tollway consists of 3 traffic lanes and an emergency lane in each direction, while a high speed rail runs along its central strip. As the motorway is in the metropolitan capital of Athens, its environmental performance relies greatly on post-monitoring techniques, such as air quality and noise level monitoring.
Project Development	Attica Tollway faced significant difficulties because of the complexity of constructing a motorway in a dense urban area, within a limited room for expropriation and an already congested road network. Design and construction of the new motorway was carried out following all relevant Greek and European legislation, to ensure the greatest degree of environmental impact alleviation and to ensure the protection of the Athenians' quality of life. Various environmental aspects (storm water management, animal crossings, local flora, planted areas to reduce thermal effect of motorway, recycling, etc.) have been taken into consideration from the design phase of the project and, as a result, Attica Tollway has been established as one of the most environmentally-friendly motorways in Europe and Attica Tollway Operations Authority was awarded the first prize for 2008 in the IRF GRAA competition in the category of Environmental Mitigation. Life in the metropolitan area of Athens was characterized by poor air quality and noise, as a direct result of the already congested network, and so, as far as air quality and traffic noise levels are concerned, the Tollway carries out continuous environmental post-monitoring of the prevailing levels during operation, in order to measure the impacts of the Tollway to the surrounding environment and to take special measures, when and where necessary.

Environmental Benefits

By monitoring air quality and traffic noise levels during the operation of the motorway, the quality of life of the people using and living close to the motorway is protected and the effects to the environment are monitored, with respect to the prevailing acceptable standards. When either air quality or traffic noise values exceed acceptable levels, the operator has the ability to intervene so as to reinstate conditions that do not jeopardize public health or the environment.

Monitoring and Feedback

The levels of air pollution and noise are monitored constantly by eight (8) noise and air-pollution measurement stations, located at key locations along the motorway, Reports are issued every quarter and submitted to the Ministry of Environment, showing levels and trends of air and noise pollution. For noise monitoring, apart from the permanent measuring stations, 24-hour acoustic measurements are carried out in 200 different locations every year using mobile measuring stations.

As far as air quality is concerned, the following emission levels are measured:
Carbon monoxide – CO
Nitrogen monoxide – NO
Nitrogen Dioxide – NO_2
Total volatile organic combinations – TVOC/Dust (PM10).

Attica Tollway has also started measuring PM2,5 to be compliant with the European Directive 2008/50/EK and by 11 June 2010 and will be incorporating the measurement of benzol, as well.

The various noise levels measured are:
L10(18h)
LA_{eq}(08.00-20.00) & LA_{eq}(24h)
L_{day} (07.00-19.00), $L_{evening}$ (19.00-23.00), L_{night} (23.00-07.00) & L_{den}.

Apart from monitoring the noise and pollution levels along the motorway, noise, pollution and vibration levels are also measured regularly at the toll stations, to ensure a safe working environment for the toll collectors, in accordance with the prevailing Occupational Health and Safety legislation.

Despite current traffic levels, the operation of the Tollway does not give rise to emission levels that exceed those internationally accepted, as all values of pollutants relating to air quality never exceed the values stated by the European union legislation. In any case, the stringent air quality monitoring system provides direct feedback on the effects of traffic on air quality, and in case of rise of emissions beyond acceptable levels, appropriate actions can be taken to directly mitigate the problem, using traffic management techniques, etc.

Monitoring and Feedback (cont.)	As far as noise measurements are concerned, measurements generally fall below the limits of the relevant legislation. However, a series of noise-protection measures are taken whenever and wherever the need arises, such as the installation of noise barriers (with a length currently exceeding 18km), as well as the construction of buffer zones and the planting of slopes and embankments (in addition to the already extensive landscaping actions for the Tollway. In addition, when notified about areas where there are complaints regarding noise, the company proceeds with mobile noise measurements, to ensure that the quality of life and the health of the people living near the motorway is not compromised. The same holds for measurements at the Toll Stations. By monitoring air quality, noise and vibration levels, the company ensures health and safety at work for its employees.
Lessons Learned	A new road, and certainly an urban road such as Attica Tollway, will always have an impact on noise and air emissions, but with constant monitoring, it is important to ensure that living conditions, health and quality of life are not compromised. Technology and research offer a great variety of solutions (noise barriers, pollution-repellent paints, planting etc.); it is a matter of investigating and finding the solution that is most appropriate.

Case Study C: Transport Noise Interactive Site (New Zealand)

Aspect	**Elements**
Project Title	Transport Noise Interactive Site
Project Description/ Summary	This web site is intended to provide a range of information and tools to help ensure that transport noise is managed in an effective and efficient manner. The material is likely to be of interest to land use and transport planners, road designers, traffic engineers, urban designers, environmental managers as well as acousticians and the general public.

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Management and Operation

Project Development

The site was launched with a single tool to predict noise levels from road traffic, and has since been expanded to include construction noise. Future tools will address traffic and construction vibration. Guidance will also be provided on noise management and mitigation measures, and recommended noise measurement and computer modelling procedures.

Environmental Benefits

The New Zealand government wishes to see a reduction in the environmental effects arising from land transport. Transport noise is one such effect that can cause a range of impacts on people and communities from general interference with everyday activities to more significant effects such as sleep disturbance.

Monitoring and Feedback

An electronic ‘contact us’ means is provided on the website.

Lessons Learned

Vivian St, NZ

The website is still too new to provide a guidance for lessons learned.

Case Study D: LED Traffic Signal Replacement (Australia)

Aspect	Elements
Project Title	Roads and Traffic Authority (RTA) Australia LED Traffic Signal Replacement
Project Description/ Summary	• Replacement of incandescent traffic signal lamps with light emitting diode (LED) technology.
Project Development	• The RTA is committed to reduce energy use and greenhouse gas emissions from its operations. • Prior to 2005, approximately 30 per cent of the 3,500 traffic signal sets in the state were fitted with energy inefficient 240 volt incandescent lamps. • In December 2005 a successful trial into the use of LED technology was completed by the RTA and demonstrated that significant energy and maintenance cost savings could be achieved through the use of LED technology. • The RTA an obtained $18 million loan from the NSW Government's Energy Efficiency Loan Scheme to replace all the incandescent traffic signal lamps across the state with LED technology. This loan scheme provides state agencies with access to low interest capital to fund energy efficiency upgrades. • The full lamp replacement project commenced in 2006 and was completed in 2008 and resulted in more than 50,000 incandescent globes being replaced with LED technology. • The upgraded traffic lights use just 11 per cent of the energy previously required to power the incandescent globes. • The LED technology produces further savings through reduced maintenance requirements because LEDs have a lifespan of around seven years, compared to around 12 months for incandescent globes. • There are also safety benefits as the new lights are more visible in sunny conditions and they are easier to see among street lights and shop signs and from a distance. • The remaining 70 per cent of the state's traffic lights, equipped with quartz halogen technology lanterns, are being progressively replaced over the next 10 years as these lights reach their planned replacement date.

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roads australia

Environmental Benefits	The LED replacement project has resulted in savings of : • more than 10 gigawatt hours of power per year. • approximately 10,000 tonnes of greenhouse gas emissions per year (the same as emissions from about 760 average Australian homes). • approximately $1 million a year in energy costs.
Monitoring and Feedback	• Consumption of energy use from the operation of RTA's traffic signal network is reported internally every three months and annually to the State Government.
Lessons Learned	Good analysis of historical energy data trends is required to identify where to initially focus attention for energy efficiency projects. In this case, data analysis showed that the largest reductions in energy consumption would be achieved by targeting the 30 per cent of traffic signals fitted with incandescent lamps. Access to energy efficiency funding schemes provided by the State Government provided an alternative method of funding this project which may have otherwise not proceeded. The RTA will complete repayment of the loan within 8 years of the project through energy and maintenance savings.

Case Study E: The Environmental Management System in Egnatia Odos motorway (Greece)

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Aspect	**Elements**
Project Title	The Environmental Management System in Egnatia Odos motorway
Project Description/ Summary	The Egnatia Motorway constitutes one of the priority projects of the Trans-European Transport Network and is the communication link spanning Northern Greece, from its western to its eastern border. Being a collector axis of the Pan-European Corridors leading from North to South, it is of great geostrategic importance for both the Balkans and South-Eastern Europe. It is one of the first large-scale public works to apply a system of environmental management, which organises and implements environmental protection and mitigation measures in the design, construction, maintenance and operation stages of the project. Egnatia Odos S.A. aims at designing, constructing, maintaining and operating the motorway, while at the same time is making an effort to minimise or even prevent the impact on the environment. For this reason the company introduces an environmental strategy and a new perception of highway construction, maintenance and operation and also protection of the natural and manmade environment, by investing on environmental purposes a significant percentage of the total budget. The company's strategy is based on the Greek and European Community legislations on environmental protection, the international standards, and the principles of sustainable development.
	Management of cultural Heritage The alignment of the Egnatia Motorway follows the traces of the ancient Roman Via Egnatia and along its route and within a 1000m wide zone, 270 sites of historical interest have been identified. A Memorandum of Cooperation was signed between Egnatia Odos S.A. and the Greek Ministry of Culture, for the effective management of archaeological excavations and the protection and enhancement of archaeological finds.

Project Development (cont.)

The company, being the agent responsible for the design, construction, maintenance and operation of the project, proceeded to actions aiming at the protection and preservation of the cultural heritage of Greece, as well as at its enhancement, when this was feasible. In several cases, the alignment was either changed or improved at a cost of approximately €80 mn. Up to date more than 50 archaeological excavations have been financed along the motorway axis at a cost amounting to €14 mn. The findings unearthed are important and date back to different historical eras.

Environmental Benefits

- Protection of more than sixty (60) archaeological sites
- Protection of fauna and flora species along the motorway's axis
- Protection of more than eighty (80) settlements, at the motorways vicinity, by monitoring noise, water and air quality on a regular basis and by undertaking certain measures if considered necessary (i.e noise barriers)
- Preservation of best air quality inside tunnels for the protection of drivers health
- Protection of surface and ground water quality by installing Pollution Control Units (PCU) along the Egnatia motorway
- 5% of the total annual cost of the motorway's maintenance budget spend in waste collection and disposal.
- Limitation of energy consumption

Monitoring and Feedback

Monitoring and Protection of the Biodiversity

Egnatia Odos S.A completed the motorway in an "environment-friendly" manner, constructing several structures, such as tunnels, bridges, overpasses and underpasses, as well as a Green Bridge, ensuring the protection of fauna.

With the aim of constructing major infrastructure projects for the benefit of the affected area's development, deeply respecting the environment, the citizens' and the country's wellbeing, has worked like only a few European bodies have done so far, substantially contributing to the scientific research for big mammals. The company puts every possible effort in ensuring the necessary resources-credits, in order to take the necessary protection measures, required both for the road users and fauna (bears).

Egnatia Odos SA has prepared, assigned and financed monitoring programmes for the effects of the axis construction on the brown bear population, in cooperation with NGOs and Universities. The projects involved among others the use of special collars on mammals, so as to confirm the corridors used by the animals' population, with the aim of ensuring the fauna passages' appropriateness.

During maintenance and operation, the company monitors fauna mortality, caused by collisions with the passing vehicles, and takes several measures in order to eliminate traffic accidents.

Project Development (cont.)

- Reinforced fencing has been placed along the major part of section “Panagia- Grevena”, to prevent big animals from entering the highway
- Permanent electronic informative signs have been placed, marking the bears’ habitat at section “Panagia- Grevena”.
- A reinforced high fencing was placed at section “Siatista- Koromilia” of Vertical Axis 45, as a result of various traffic accidents involving bears, even though the area had not been previously characterized as a brown bear habitat by NGO.
- Leaflets have been periodically distributed at Toll Stations to the drivers passing from the areas indicated as brown bear’s habitat, warning them about the brown bears and advising them to reduce their speed, while crossing these areas.
- Informative signs were installed at section “Siatista- Koromilia”, with the aim of informing the drivers about the possibility of encountering bears, in order to reduce speed at sections where such a possibility is common.

Additionally, Egnatia Odos S.A for the restoration of disturbed surfaces such as borrow pits, disposal areas and work sites, the company established the Landscape Guidelines, which now constitutes a contractual document for design and construction, supplementary to the Environmental Terms. Additionally, plant nurseries were created for native flora species in order to be used for the motorway slope restoration. Furthermore, the company controls the quantity of salt used for the snow ploughing of the motorway and insists on the regular cleaning and maintenance of culverts and wildlife passages throughout the motorway.

Monitoring and Mapping of Road Traffic Noise

Egnatia Odos S.A aims to minimize the noise disturbance caused by the motorway’s operation. To this effect, a program of monitoring and mapping the Road Traffic Noise (according to 211773/27.04.2012 Joint Ministerial Decision) is set up in residential districts, having as main criteria the distance of the settlements from the motorway, the traffic volume, the composition of vehicles’ flow, the vehicles’ speed, the technical characteristics of the motorway, the meteorological conditions, the existing Environmental Terms of the project and the citizens complaints.

Numerous noise measurements were performed in settlements on both sides of the Egnatia Motorway, ensuring the observance of environmental noise indicators.
The whole program is performed with respect to the European Guideline 2002/49/EU “concerning the evaluation and management of environmental noise” of the Council dated 25.6.2002 and the relevant Greek Joint Ministerial Decision 13586/724 (GG B´384 28.3.2006) concerning the “definition of measures, terms and methods of evaluating and managing noise in the environment”. Furthermore, Strategic noise maps (SNM) including noise action plans (NAP) and evaluation of the population's exposure to road traffic noise are executed for all the network sections, with over 6.000.000 vehicles per year, in proximity with urban settlements along the road axis.

Project Development (cont.)

In areas where, in accordance to the current legislation, taking of measures relative to Noise Protection is considered necessary, the efficiency of all noise protection measures are examined (noise barriers, special bituminous carpets, special planting, etc), for the selection of the most viable solution.

Monitoring of air quality

Air quality management is one of Egnatia Odos S.A. targets, connected with the life quality of the inhabitants of adjacent to Egnatia motorway settlements and also with the policy against global heating (Kyoto Protocol).

To draw conclusions concerning the pollution rates caused by the operation of Egnatia motorway, programs of measuring several gas pollutants are carried out, with particular emphasis on sections with high road traffic volume, as well as those going through areas of sensitive ecosystems. The parameters measured are Carbon Monoxide (CO), Nitrogen Dioxide (NO2), Sulfur Dioxide (SO2), Ozone (O3), Benzene, Lead (Pb), Particles (PM10-PM2,5-PM1), Toluene, Ethylbenzene and Xylene.

Additionally, most of Egnatia motorway tunnels are equipped with CO and NO meters, constantly measuring the levels of the specific pollutants, in order to preserve the air quality in the tunnels. Additional measurements of gas pollutants are carried out in the tunnels of Egnatia motorway, particularly in those longer than 500 meters.

Furthermore, Egnatia Odos SA has been equipped with a mobile laboratory to carry out environmental measurements within the project Environmental Highway Observatory (E-Highway), of the cross-border cooperation program INTERREG Greece - FYROM IPA 2007-2013. Through the mobile laboratory equipment, key environmental indicators such as air pollution, water pollution, noise pollution can be monitored, according to the project's requirements, but also according to the Joint Ministerial Decisions on the approval of Environmental Terms.

Monitoring of motorway's run-off waters – Protection of water quality

The company in order to protect surface and groundwater runs a program for the monitoring and assessment of the motorway's run-off water quality at the points of discharge to the adjacent receivers (i.e. rivers, lakes). The pollution parameters presenting greater interest, which are directly related to the motorway's operation, are: COD, Total Solids, Fats and Oils, Heavy Metals, etc.

The selection of the areas and points for carrying out the measurements is based on the Environmental Terms and the sensitivity of each eco-system. Additionally, pollution control units were and are constructed along the axis of Egnatia Odos motorway.

Project Development (cont.)

Moreover, treatment plants, called Pollution Control Units (PCUs) are constructed along the motorway. Those units treat the pollutants carried by runoff waters during rainfalls and they collect and isolate waste leaks after accidents in the highway. The operation and maintenance of the PCUs is of great importance, it is considered essential for the environmental protection along the motorway and it deals with specific health and safety risks, such as confined spaces, toxicity, slips, trips and falls, manual handling, weather, transport of hazardous waste.

Waste management

The pollution of the motorway caused by its users can have multiple negative results, such as pollution of the adjacent waters and grounds, creation of an inelegant image of the motorway and dangers for drivers and passengers.

All kinds of waste are gathered from the road surface and the central reserves. The management and the final disposal of waste are based on the Environmental Terms and the existent legislation. The annual cost of cleaning is about 1.000.000€, which amounts to 5% of the total annual cost of the motorway maintenance.

Moreover, the company monitors and registers in a database the amounts and types of waste gathered from the motorway. Significant amounts of paper, glass, plastic, wood, metal and other materials are collected, so the company has decided to run a recycling program. Finally, the company recycles large amounts of damaged steel safety barriers and lighting masts of the motorway.

Management of energy consumption

Egnatia Odos S.A. in order to limit the energy consumption of the motorway takes certain actions, such as:

- Program of lighting measurements in tunnels
- Regular maintenance program of E/M installations
- Time-schedule of lighting
- Energy management program in the tunnels
- Limitation of the electricity consumption based on the timely detection of damages, the optimization of the road lighting operation and the limitation of possible unnecessary operations
- Investigates the use of new lighting technology of low energy consumption, the use of renewable energy sources to substitute base load in tunnels and the reduction of the energy profile of the highway's building infrastructure.

Lessons Learned

Egnatia Odos S.A. introduces a different approach and a new strategy in the construction, maintenance and operation of major road axes in Greece, by implementing the preservation and protection of the natural and man-made environment.

According to the company, the environmental protection during a project, now, more than ever, constitutes a significant factor equally important to the technical and financial factors. Furthermore, all three factors should be involved in the process, in such a way so as to result in a technically complete and environmentally acceptable project.

5.3 General Lessons Learned and Advice on Road Management and Operation

One important thing to keep in mind when addressing the subject of road operation and environmental impacts is that there is not one particular "recipe" for success. Each road is unique and will require different environmental protection/mitigation techniques. Maybe some of the ones mentioned above, maybe all. An urban road will have different requirements than a rural road; a road crossing virgin land with great biodiversity will require different mitigation techniques than one built within an already developed environment, etc. This chapter only serves as general guidance and the case studies presented represent exactly that: each road and each situation requires different considerations. One should always be aware of all the fields that need to be considered in road operation and to identify the issues that are relevant to a particular road project.

1. Noise and Air Quality monitoring

As far as noise level monitoring is concerned in an urban road, crossing a busy city centre, it is essential to use both stationary and mobile measuring stations. Stationary stations provide a basis for comparisons, while mobile measuring stations deal with individual cases, especially as real estate development expands along the length of the motorway. The same holds for air-pollution monitoring stations.

2. Noise and emission reduction

As an indirect method of reducing road traffic noise and emissions, appropriate choice of tyres for vehicles has proven to be very effective. By enhancing tyres' fuel efficiency, CO_2 emissions san be reduced, while the tyres' contribution to external noise can also be reduced, even though they are not the primary source of traffic noise. Tyres are mainly related to safety, however, educating the public with respect to the new types of tyres that are safer, quieter and are associated with less CO_2 emissions can indirectly benefit the environment and the effects from transportation.

3. Energy data trends

Good analysis of historical energy data trends is required to identify where to initially focus attention for energy efficiency projects.

4. Funding schemes

Access to energy efficiency funding schemes provided by the State can provide an alternative method of funding projects, which may have otherwise not proceeded.

Conclusion

The purpose of this publication has been to illustrate - through different case studies - how sustainability can be incorporated in road infrastructure projects. The projects examined have made provisions for sustainability at all stages of the life of road infrastructure (Road Planning, Design, Construction, Maintenance and Rehabilitation, Management and Operation).

The case studies presented are diverse by nature and geographical span, thus providing a solid basis for a thorough reflection on how to ensure that we design, construct and maintain more sustainable roads. The value of the knowledge shared in this publication, in terms of lessons learned and obstacles observed, is what we hope the reader will appreciate and use.

In a nutshell, and in an attempt to summarise the key findings for each of the stages identified in the life-cycle of a road infrastructure project, the following should be taken into consideration:

1. Road planning:

- Strategic Environmental Assessment should be a fundamental component of road-network planning, as it can help in ensuring the following:
    - o Legislation and consistency
    - o Understanding environmental impacts at the strategic level
    - o Improved collaboration and efficiency in decision-making
    - o Positive effects on subsequent project assessments
    - o Transparency and public participation.
- Efficient land-use planning is an essential pre-requisite for determining the optimum interfaces between the environment, roads and users. 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.
- During the planning stage, common obstacles include lack of expertise, lack of communication and lack of collaboration at the institutional level. These, along with additional bureaucracy, can greatly affect the progress of a new road project.

2. Design:

- In order to support the design process and maintain a clear, structured approach to project development, experience demonstrates the value of setting environmental design objectives that respond to the need for a balance between engineering, environment, cost and safety.
- 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 recognizes 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.
- The use of tools to determine the carbon footprint of road infrastructure should be encouraged. These tools can be used to assess and reduce the environmental impact considering alternative solutions.
- Cost-benefit analysis is crucial to ensure that resources are used and managed in the most effective way.

3. Construction:

- In order to stimulate the application of best practices, guidelines and green rating systems need to be introduced. These will enhance environmentally-effective road construction.
- Materials and energy are key finite resources, and must be used in a manner that recognizes, 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.
- Strategic assessment of availability of local recovered materials suitable for road construction during the early planning phases is critical to achieving a reduction in the use of virgin excavated materials.
- The development and use of environmentally-friendly products and processes should be encouraged and recognised in the procurement procedures.

4. Maintenance and Rehabilitation:

- Each maintenance area should develop an Environmental Management Plan that maps sensitive receiving environments, clarifies Standard Operating Procedures and clearly delineates roles and responsibilities in order to ensure environmental aspects are adequately managed. In fact, the main obstacles that can be usually encountered include:
    - o Mixed perceptions about roles and responsibilities for environmental management.
    - o Reliance on personal knowledge and experience of individuals to guide environmental management including regulatory compliance.
    - o Lack of training.
- 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.
- Life-cycle-analysis methodologies should be adopted as a guiding principle for the assessment and selection of materials and technologies.

5. Road Management and Operation:

- 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.
- 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.
- Noise pollution and air quality monitoring must be addressed as part of an integrated approach.

When addressing the subject of a road project’s impacts on the environment, there is not one single method to achieve success. Each road project is unique and will require a unique blend of different environmental protection/mitigation techniques and measures. 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.

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