The Future of Roads

Road agencies working with industry and universities to find innovative ways to prepare for future challenges

Sustainable Built Environment National Research Centre

Project Core Partners:

Project In-Kind Partners:

University Research Team

Program Leader

Prof. Peter Newman (Curtin)

Project Leaders

Charlie Hargroves (Curtin)

Cheryl Desha (QUT)

Research Team

Luke Whistler (Team Leader – QUT)

Annabel Farr (QUT)

Annie Matan (Curtin)

Leon Surawski (Curtin/MRWA)

Justine Beauson (Curtin)

Kimberley Wilson (QUT)

Rob Salter (Curtin)

Project Advisor

Prof. Arun Kumar (QUT)

Synopsis

Although road construction and use provides significant economic and social benefits, its environmental impact is of growing concern. Roads are one of the greatest greenhouse gas contributors, both directly through fossil energy consumed in mining, transporting, earthworks and paving work, and through the emissions from road use by vehicles. Further, according to the Australian Government, when combined with expected population growth and internal migration, expected changes in temperature and rainfall are expected to increase road maintenance costs. This discussion paper will outline opportunities within the Australian context for reducing environmental and carbon pressure from road building, and provide a framework for considering the potential pressures that will affect the resilience of roads to the impacts of climate change and oil vulnerability.

Acknowledgement

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Front cover: The Riverside Expressway in Brisbane.
Image: David Sparks.

Executive Summary

Australian road agencies have long been at the cutting edge of best practice on road planning, assessment, construction and management. Looking ahead, such practices will need to be supplemented with a number of new technologies and processes in order to respond to changing pressures. Indeed, as road agencies look into the coming decades they are increasingly finding that conditions that have shaped operations in the past are very different to those of the future. In particular, road network and transport infrastructure is facing increasing pressure from a range of factors, including population growth and urbanisation, changes to weather patterns, increases in energy and resource prices, road material resource shortages, and the changing usage and expectation of roads and transport. There is a growing imperative for road agencies to address such pressure with informed and transparent approaches. This project focuses on how road agencies, particularly in Western Australia and Queensland, are facing the future and dealing with these issues. There is now a wealth of evidence and precedent to show that road projects can improve sustainability outcomes through design, construction, maintenance, and operation. The project evolved in response to stakeholder interests, identified through early consultation in both states. The subsequent scope focused on three needs as summarised below, namely:

The need to reduce greenhouse gas emissions related to road construction

- Focusing on the construction phase, the most sizeable reductions in carbon intensity can be gained by considering materials used, including aggregates, asphalt, and concrete.
- A key opportunity is the use of alternative aggregates that require less mining and crushing energy and can be sourced closer to site in order to reduce hauling fuel consumption.
- Local pavement materials can be used, such as naturally-occurring weathered rocks, ridge gravels, stream gravels, sands and clays that are close to site and can be obtained and placed by readily available construction equipment.
- Other options for reducing greenhouse gas emissions include reducing automobile fuel consumption through road alignment design (vertical, horizontal), designing for multiple use of road space, reducing and avoiding fossil fuel use in hauling and onsite transport of materials and water, and reducing energy use in route and signal lighting.

The need to measure and report on the sustainability of roads

- The focus of agency reporting has broadened from ‘environmental reporting’, considering ecological impacts and disturbances of road construction, to ‘sustainability reporting’ more broadly. In addition, this reporting is increasingly adopting terminology around taking action rather than just observing.

- These broader sustainability considerations relate to resource availability; to the availability of, access to, and alternative sources of energy required; and to transport activities involved (including types of fuel used and greenhouse gas emitted). They include the effective use of recycled materials, ameliorating in-situ materials, and using industrial by-products.
- Agency reporting metrics are also being refined and augmented to monitor environmental (including carbon) performance across a number of factors.
- Much of the data required to fulfil the new generation of project reporting is already being collected across many, if not all, road construction projects. However this data is not systematically or transparently reported on in a way that encourages use.
- A number of rating schemes and tools, as well as assessment tools, are currently in use for a variety of objectives. These tools range from freely available resources to proprietary products, and from simple spreadsheets to complex software packages. One of the emerging sustainability tools is the AGIC '*Infrastructure Sustainability*' tool, and two of its fourteen trials have been undertaken in Western Australia. The trials showed how useful the tool could be if mainstreamed, especially if aligned to the tender stages of projects.
- Road agencies in both Western Australia and Queensland have committed to incorporating into existing reporting structures the use of AGIC and GRI.

The need to identify potential trends and future risks affecting roads

- This project has included the creation of a process to consider potential trends and future risks affecting roads, which was piloted with both state government road agencies.
- The level of consideration of future environmental, economic, and social *trends* associated with roads will have a significant impact on their associated *costs and impacts*. Through stakeholder consultation, the project considered a short list of 10 potential ***trends***, including:
  - Increases in the cost of road maintenance
  - Increases in extreme weather events
  - Oil based road surfacing becoming unfeasible
  - More walking, cycling and public transport trips
  - Shortages of aggregates
  - Increases in the size and number of freight vehicles
  - Funding constraints on new projects and on maintenance of existing infrastructure
  - Transport infrastructure reaching capacity
  - The mainstreaming of electric and alternative fuel vehicles
  - City planning requiring densification along rail lines and infill development.

Road maintenance costs continue to increase. Image: Queensland Department of Transport and Main Roads, 2012.

- It is important to consider how the intensity of these trends may change over time, through '*Trend Intensity Profiles*'. These provide a structure through which to consider the risks that the trends will present to road agencies, and they show how some trends may be affected by others. The project has considered a range of such potential profiles.

- The final stage of the process is the consideration of ***strategies*** through which transport agencies can prepare for the risks associated with the key trends, particularly those strategies that are able to address multiple trends. The project considered a short list of potential ***strategies***, including:

  - Road pricing mechanisms
  - Government action to support change
  - Investment in research and development
  - Analysing investment priorities
  - Incentivising preferred practices
  - Increasing the efficiency of existing infrastructure
  - Creating adaptable design standards
  - Sharing knowledge and building capacity
  - Investing in carbon management
  - Transit oriented development.

- These strategies highlight the changing roles of road agencies, and importantly, the structural shift that is occurring within them, which is leading them to focus less on new infrastructure and more on maintenance and enhancing the efficiency of existing roads.

Summary of Industry Benefits

Industry benefits from this project include: a better understanding of emerging options to reduce greenhouse gas emissions associated with road construction; improved strategic positioning; guidance in areas of specialisation; and a better understanding of market gaps and resultant business opportunities. Government benefits from the project's research include: more informed policy and management decisions for a resilient road network; greater insight into changing roles and leverage points for action; a scenario planning framework to stimulate responses; and more informed targeting of funding for future research. Both industry and government will need transparent and strategic reporting mechanisms to show how the new challenges for road delivery and operations are being addressed.

Summary of Recommendations

From these findings, the following recommendations are made with regard to actions for moving forward:

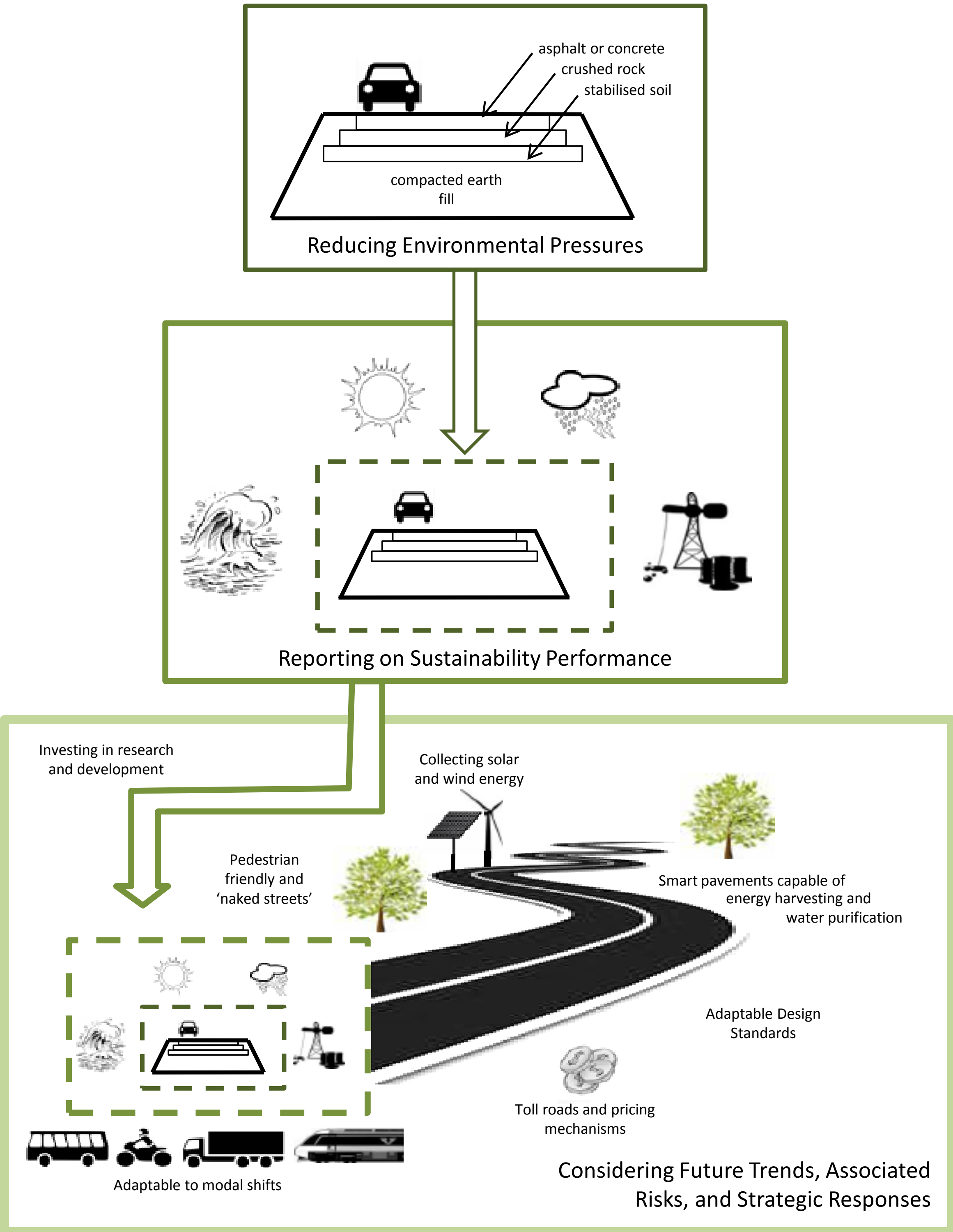
- The project findings can be used to identify 'low hanging fruit' actions that reduce greenhouse gas emissions during construction, design, maintenance and operation on existing and future road projects. In the next stage of the research a set of specific topics will be further explored, for instance, reducing energy demand from route and signal lighting using energy-efficient technologies and demand management.

- AGIC's new sustainability reporting tool should be used for significant trialling on road projects across Australia, and further research should be carried out to support road agencies and companies to interpret the tool and best prepare projects for strong results. Based on the outcomes of this project the next phase of the research will inform a process by the Global Reporting Initiative to explore topics in the transport sector to enhance their important organisational sustainability reporting process.

- Stakeholders can continue to participate in the process of risk and strategy analysis associated with current and future trends, further refining the knowledge being developed and creating a platform for informed and transparent decision-making.

About the Research Team:

Professor Peter Newman led an experienced research team from Curtin University and the Queensland University of Technology, which was managed by emerging sustainability authors Charlie Hargroves (Curtin University) and Dr Cheryl Desha (QUT). The research team has been mentored by Professor Arun Kumar, and includes outstanding sustainability researchers Luke Whistler, Annie Matan, Annabel Farr, Kimberley Wilson, and Leon Surawski. Professor Newman is the John Curtin Distinguished Professor and is the Director of the Curtin Sustainability Policy (CUSP) Institute. Newman is the co-author of nine books and over 200 papers on sustainability, is on the Board of Infrastructure Australia, and is the current Lead Author for Transport on the IPCC. As part of The Natural Edge Project, Hargroves and Desha have worked with a range of co-authors to publish four international books on sustainable development, selling over 80,000 copies in four languages. The books have received a Prime Minister's Banksia Award, and have been ranked 5th and 12th amongst the '*Top 40 Sustainability Books of 2010*' by the Cambridge University Sustainability Leadership Program.


asphalt or concrete
crushed rock
stabilised soil
compacted earth fill
Reducing Environmental Pressures
Reporting on Sustainability Performance
Investing in research and development
Collecting solar and wind energy
Pedestrian friendly and 'naked streets'
Smart pavements capable of energy harvesting and water purification
Adaptable Design Standards
Toll roads and pricing mechanisms
Adaptable to modal shifts
Considering Future Trends, Associated Risks, and Strategic Responses

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Introduction

Australia's road network and transport infrastructure is facing increasing pressure from a range of factors, including population growth and urbanisation, changes to weather patterns, increases in energy and resource prices, road material resource shortages, and the changing usage and expectation of roads and transport. On the one hand, reports suggest that in the developed world the use of cars has peaked, resulting in less need for roads and greater sharing of road space as demographic and digital change impacts on traditional movement patterns. On the other hand, the OECD reported in 2012 that Australia is suffering from an '*infrastructure deficit*', and is experiencing increased congestion in its transport infrastructure. There is a growing imperative for road agencies to be cognisant of these changing trends and pressures and to proceed with informed and transparent approaches to this rapidly changing world. Australian road agencies have always been at the cutting edge of best practice on road planning, assessment, building and management. Such practices will need to be supplemented with a number of new technologies and processes in response to the growing pressures on the *Future of Roads*. This project reports on how road agencies in Western Australia and Queensland are facing the future and dealing with these conflicting and challenging issues.

One of the most immediate pressures is the need to respond to climate change, and in particular the need to reduce carbon intensity through options such as:

- reducing automobile fuel consumption through the design of road alignments (vertical and horizontal),
- reducing embodied energy of aggregates, cement and asphalt,
- reducing and avoiding fossil fuel use in hauling and onsite transport of materials and water,
- reducing energy requirements of route and signal lighting.

A key aspect of the success of such efforts is the appropriate monitoring and reporting of progress to both cultivate best practice and comply with growing reporting requirements. Finally, as road agencies look into the future they are increasingly finding that the conditions that have shaped their operations over the last two decades will look very different to conditions in coming decades. Hence, this project has focused on responding to three key industry needs expressed by project stakeholders, namely:

1. The reduction of greenhouse gas emissions related to road construction,
2. Measuring and reporting on the sustainability of roads, and
3. Identification of potential trends and future risks affecting roads.

In the 22 September 2012 edition of the Economist a lead article examined the emerging global awareness that car use has peaked in the world's developed cities.[1] It quotes an Australian Government report examining the phenomenon, and speculates on what may be causing this and what it could mean for government policy, especially on roads. Factors considered to be significant were those impacting on other areas of the economy as well, including the use of digital communications instead of travel, internet shopping, changing demography with younger people favouring more urban living and less oriented to the attractions of the car, and increased fuel costs due to oil scarcity and climate policy. At the same time as road agencies are digesting what this means for their priorities and approaches to road building and management, they are under increased pressure to provide solutions to congestion due to the '*infrastructure deficit*' as outlined in a 2012 OECD report on Australia, and the political cycle of promised new roads.

How do road agencies deal with these conflicting approaches and demands? This report outlines the start of an approach developed by the Sustainable Built Environment National Research Centre working closely with the Western Australian and Queensland transport agencies. It shows how the issues are being examined through workshops that enable road agency staff to grapple with their agency's future. It suggests that this transparent and deliberative approach to road policy issues may enable Australian road agencies to maintain their global best practice edge. The first section begins by outlining one of the new challenges for road agencies – climate change.

Climate Change and Roads

Road building and management has always had to adapt to particular circumstances. However climate change is posing a range of new challenges as set out in Table 1. For instance, in the face of increasingly frequent natural disasters

[1] Economist (2012) The future of driving, Seeing the back of the car, In the rich world, people seem to be driving less than they used to, 22 September 2012.

Table 1: Impacts of Climate Change on Road Infrastructure

Issue	Implication for Roads
Costs of greenhouse gas emissions	• Reducing automobile fuel consumption through the design of road alignments (vertical and horizontal). • Reducing energy intensity of aggregates, cement and asphalt. • Reducing and avoiding fossil fuel use in hauling materials and water. • Reducing energy requirements of route and signal lighting.
Temperature increase and severe droughts	• Increased maintenance of surface cracking in roads due to changing landscape topography caused by evaporation. • Maintenance caused by increased wear and tear of road surfaces due to temperature increasing the fragility of the road surface. • Increased rehabilitation of road surfaces due to surface cracking, warping and asphalt bleeding (flushing).
Increased extreme rainfall events and flooding	• Increased amount of road maintenance caused by potholes created when water enters the road surface. • Increased road rehabilitation due to flooding events affecting large expanses of roadways. • Decreased ability for maintenance and rehabilitation to take place due to extreme wether events affecting construction days and access. • Road flooding putting pressure on road network and drainage systems.
Sea level rise	• Salt water corrosion of roads due to flooding increasing the water table and to sea level rise. • Increased storm surge and wave impact on coastal and low-lying coastal areas.
Increased cyclones	• Increased debris on roads causing road damage and traffic hazards.

such as floods, cyclones, and bushfires, roads become a nation's lifeline to affected communities and will need to be able to resist inundation, higher temperatures and a range of other impacts from such disasters.

Emissions from the mining, transport, earthworks and paving associated with road construction, as well as emissions from road users, makes roads one of the greatest contributors to climate change, responsible for some 22 per cent of global carbon dioxide emissions. Each kilometre of road constructed required large quantities of rock, concrete and asphalt to be sourced, transported and placed, and these activities account for some 95 percent of emissions from road construction. A typical two-lane bitumen road with an aggregate base can require up to 25,000 tonnes of material per kilometre, showing why aggregates are the most mined resource in the world. Just as the past decade has seen a focus on the footprint and alignment of roads to minimise ecological disturbance, coming decades will see a significant focus on responding to climate change, and in particular reductions in carbon intensity. For example, alternative road base materials may provide opportunities for sequestering carbon, roads may be designed to enable electricity generation through capturing solar or kinetic energy, and transport systems may be designed to encourage multi-modal usage and allow a reduction in the area of road needed, creating space for development and public green space.

Changing Priorities for Road Agencies

As well as pressures from climate change, transport agencies are facing predicted resource shortages, increased prices for energy and natural resources, increased costs related to greenhouse gas emissions, and changing usage and expectations of roads. Hence, transport agencies around the world are reconsidering their approach to the coming decades as the requirements will be much different to those of the last two decades. Figure 1 shows a stylistic representation of the changes that are likely to be experienced in transport agencies in the coming two decades. The figure shows two circles for each division within a typical transport agency, with the unbroken line indicating the baseline and the broken like indicating the level of additional focus that will be needed in this area in the coming decades. This project will provide valuable guidance in this process by, respectively, highlighting opportunities to reduce carbon intensity of roads, informing efforts to monitor and report on sustainability performance, and providing a structured approach to interrogating trends in order to identify risks and develop strategies.

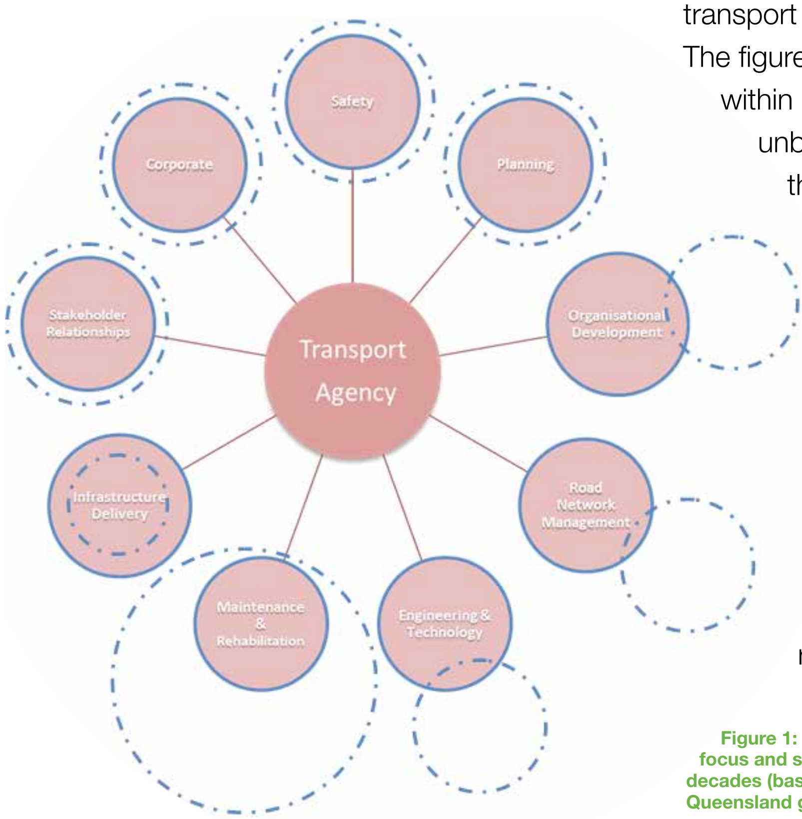


Figure 1: A stylistic representation of the potential changes in both focus and scope to the form of transport agencies in the coming decades (based on the structure of the Western Australian and Queensland government)

The Value of Investigating the Future of Roads

Industry Led Outcomes

As part of the Sustainable Built Environment National Research Centre's (SBEnrc) focus on industry-led research, two stakeholder workshops were held in the early stages of the project, and two more in the later stages, hosted by SBEnrc partners, Main Roads Western Australia in Perth (thanks to Menno Henneveld, Leo Coci, Rob Giles, Ed Nieman and Louis Bettini), and the Queensland Department of Main Roads and Transport (thanks to Ross Guppy, Jon Oxford, John Spathonis and Cameron Alexander). The initial workshops involved the research team presenting the findings of the literature review and working with some 20 key stakeholders to identify areas of interest for the project to develop. The result of the workshops was a project scope to investigate the key areas of interest identified by partners, areas that would provide clear benefits to industry and government. Following the initial workshops a series of meetings were held with SBEnrc partners to refine the scope in light of the findings of the research team. The three key challenges that were identified as important to consider in the scope of the research were:

- *The reduction of greenhouse gas emissions related to road construction*: Stakeholders expressed interest in finding out about leading options for reducing the carbon intensity of roads. The workshop participants were provided with a list of potential inclusions in such a study and were asked to provide feedback on the overall scope, highlight areas of interest, and identify areas not covered.
- *Measuring and reporting on the sustainability of roads*: Stakeholders expressed interest in finding out about ways to measure and report on the sustainability performance of roads, especially in a manner that aligns with national and international reporting frameworks. Workshop participants were divided into groups to discuss the potential for measurable indicators for road projects.
- *Identification of potential trends and future risks affecting roads*: Stakeholders expressed interest in finding out about a range of potential future trends related to sustainability and how to develop strategies to respond to the risks associated with them. Participants were asked to both describe probable future trends and identify strategies through which industry and government might respond to the associated risks.

The second stage of stakeholder workshops involved some 20 partners and stakeholders and focused on the third area above. It made use of a new methodology for undertaking trend assessments that will be the basis of the next stage of the project.

Based on the industry engagement the project focused on:

1. Providing a '*clear description*' of a range of options for reducing the carbon intensity of roads in the design and construction phases. Both workshops identified aggregates and asphalt as key areas of focus with concrete and road lighting also topics of interest.
2. Investigating how '*sustainability reporting*' applied to road projects and identifying relevant assessment and rating tools. This section focused mainly on understanding the level of sustainability reporting in road projects in Australia and internationally.
3. Developing a '*strategic process to consider future trends*', to provide both transport agencies and industry with a tool to consider future trends, consider the likely intensity of such trends over time, identify risks, identify interactions between trends and risks, and develop strategies that can minimise the risks and deliver multiple benefits across key trends.

Benefits to Industry of the 'Future of Roads' Project

Industry is shifting to assist governments to deliver transport networks that support economic growth while minimising or eliminating adverse environmental impacts. In such a competitive industry, firms are seeking to develop approaches that differentiate themselves from their competition, delivering cost-effective, innovative solutions addressing multiple objectives. With this in mind, it is important for industry to connect with research institutions to ensure that emergent areas for innovation are quickly investigated, understood and integrated into project offerings. This research project has sought to contribute to the conversation around 'sustainable road infrastructure', providing an extensively researched context to inform future innovation. Specifically, the outcomes of the 'Future of Roads' project provide industry with a number of benefits, including:

- *Understanding emerging options to reduce greenhouse gas emissions associated with road construction*: There is a growing awareness of a number of significant opportunities to build roads in ways that generate far fewer greenhouse gas emissions. The findings of the project provide industry with clear guidance on what these opportunities are and how they can be realised, with precedents from around the world.
- *Improving strategic positionin*g: The project provides insight into future areas for risk management with consideration of global population, resources and climate trends. Industry has the opportunity to capitalise on this information in building capacity to deliver services in these areas.
- *Providing guidance on areas of specialisation*: The project has grouped the identified opportunities for innovation into sector-specific areas of interest. These can be used by industry to focus resources into areas that will provide the largest reduction of environmental impacts during road construction.
- *Understanding market gaps and resultant business opportunities*: The project findings provide an opportunity for contractors and products to target new business opportunities in best practice sustainable construction, and strategic areas for research and development collaboration.

Benefits to Government of the 'Future of Roads' Project

The scope for this research project was defined in close consultation with government funding partners, to ensure that the findings provided relevant and timely contributions to departmental planning. This included creating a clear platform for considering emergent opportunities to address the environmental impact (focusing on carbon) of road construction, and providing advice on future risks to be addressed in managing road infrastructure in a changing climate. The subsequent benefits of the project's research to government are as follows:

- *Informing policy and management decisions for a resilient road network*: The project identifies a number of construction and maintenance innovations (construction materials, processes, and rating and assessment tools) that government can incorporate into road management planning, tenders and reporting. Precedents are provided from around the world, demonstrating the potential for lower infrastructure maintenance budgets, more adaptable infrastructure networks and overall improved resilience to natural disasters.
- *Providing insight into changing roles and leverage points for action*: The project highlights the changing role of road agencies, including the shift to focusing on maintenance and enhancing the efficiency of existing roads. The project presents key trends identified through stakeholder engagement in Western Australia and Queensland, highlighting potential strategies to address multiple issues over the coming years.
- *Providing a scenario planning framework to stimulate responses*: This project has developed a unique scenario planning methodology and workshop process to help road agencies to identify emerging trends that impact on the state road network, and strategic responses that enable road agencies to combat risks and build resilience. This aligns with the desire of both DTMR and MRWA to adopt a more holistic planning framework that accounts for social, economic and environmental drivers and outcomes.
- *Informing Further Research Areas*: This study provides a detailed understanding of further critical areas of applied research in which to invest government funding and resources. These include research into future scenarios and ways to engage government in planning for future climate and resource related risks. It also includes targeted research into design and technical solutions that could contribute to improved resilience of state road networks, in particular with regard to ongoing maintenance requirements and managing recovery from natural disasters.

The damage to roads caused by storms.
Image: Queensland Department of Transport and Main Roads, 2012.

Key Findings

Reducing the Environmental Pressure of Roads

Roads are vital to the Australian economy and cover more than 814,000 kilometres, with some 157,000 kilometres being state-controlled. Current practices are often very efficient and seek to minimise costs related to construction and maintenance, including balancing earthworks to optimise cut and fill, utilising local sources to minimise the import of materials, using stabilising additives to adapt local marginal materials, and optimising pavement thickness for anticipated conditions and loads. However the impact on such practices of a range of growing trends associated with environmental and social change are less clearly understood. Considering such risks will be a critical factor in the coming decades as the future of roads is faced with a series of new challenges. The roads of the future will be resilient and adaptable, be constructed with optimal alignment, achieve minimal environmental impact, and create minimal greenhouse gas emissions. Hence best practice in sustainable road construction is entering a new 'wave of innovation' centred on energy and resource efficient materials and methods.

There is now a wealth of evidence and precedent to show that road projects can improve sustainability outcomes through all phases, namely design, construction, maintenance, and operation. For instance, the design phase provides significant opportunity to design roads that dramatically reduce vehicular emissions through pavement smoothness and alignment, as the automobile sector moves from fossil fuel based vehicles to a range of lower carbon options. A particular challenge is that of reducing the generation of greenhouse gas emissions in road construction, a challenge heightened by likely increases in prices of traditional aggregates and pavement options due to resource shortages across Australia.

Within the construction phase the most sizeable reductions in carbon intensity can be gained by altering the materials used in road construction, including aggregates, asphalt, and concrete. An example of the breakdown of emissions in the construction phase is shown in Figure 2 for the Mickelham Road Duplication Project in Victoria.

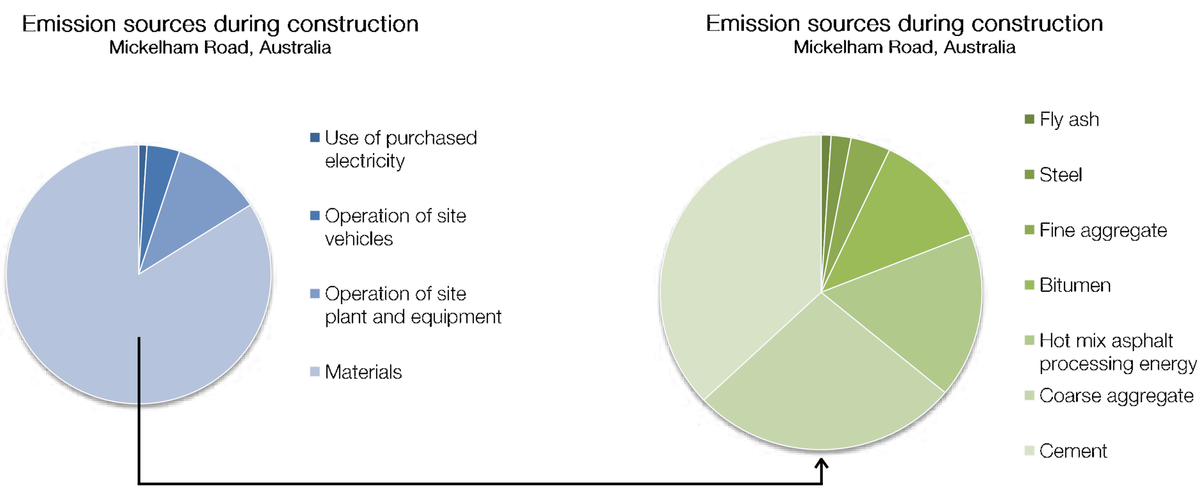


Figure 2: Relative greenhouse gas emissions sources during construction of the Mickelham Road Duplication Project in Victoria. Source: Humphrys, T. (2011)

A key area is the sourcing of alternative aggregates that require less mining and crushing energy and can be sourced closer to site to reduce hauling fuel consumption, such as a range of recycled and alternative products. A partnership between the Australian Road and Research Board (ARRB) and the Institute of Engineers Australia was formed to create '*guidelines for making better use of local materials*'. The guidelines investigate the performance of 50 soil types across Australia, using a national materials register developed by the Queensland road agency prior to 1991. Local pavement materials are typically naturally-occurring weathered rocks, ridge gravels, stream gravels, sands and clays which are close to site and can be obtained and placed by readily available construction equipment. The guidelines highlight that a '*variety of materials, loams, soft sandstones, natural gravel, decomposed rock and industrial residuals have been and are being successfully used where traffic is not too heavy*'. Guidance is given on how to treat a soil for particular use as a sub-base or base course, or as a wearing course in the case of unsealed roads.

In Australia, there are now a number of States with specifications and guidelines that regulate the use of recycled materials in roads, including:

- *Queensland*: The 2010 'MRS35 – Recycled Materials for Pavements' specifies stringent requirements that suppliers must consistently meet before providing recycled road base.
- *Western Australia*: The 2010/11 'Pavement Specification 501' specifies that alternative materials such as recycled materials and crushed glass must meet criteria equivalent to crushed rock.
- *New South Wales*: The 2001 'Specification for Supply of Recycled Materials for Pavements, Earthworks and Drainage' covers crushed concrete, brick and reclaimed asphalt blends.

Alternative materials may be used in road construction.
Image: Department of Transport and Main Roads, 2012.

- *Tasmania*: The 2011 Tasmanian road construction specifications include the use of recycled materials in the production of asphalt and for use as aggregates.
- *Victoria*: The 2011 'Sustainable Procurement Guidelines' from VicRoads specifies where recycled materials can be sourced from and the quality that is required.

As Figure 3 shows, with industry engagement the *Future of Roads* project has focused on five key areas in which roads can respond better to climate change, namely road design, aggregates, asphalt, concrete, and road lighting.

The literature review for this stage of the project has identified numerous examples of leadership in each of these areas, including:

- *Design*: Developed in 2006, JOULESAVE is a widely used European software that allows the road designer to rapidly quantify the energy requirements for all phases of road construction and to compare different options. To date, the software has shown that energy savings of up to 47 per cent in road construction, up to 20 per cent in

DESIGN

Route design
Pavement design
Material specifications
Alternative road users
Knowledge transfer

ASPHALT

Materials
The use of alternate materials such as rubber crumb and recycled asphalt.
Opportunities to innovate bitumen mix design.
Processes
The use of warm mix technologies.
The use of cold mix applications.
Innovations in methods and techniques for bitumen placement.

AGGREGATES

Placement
Saline or non-potable water stabilisation.
Non-potable water for dust control.
Alternative Materials
The use of waste products – concrete, tyres, glass, bauxite residue, and waste building materials.
Plant based bitumen alternatives.
The use of in-situ stabilisation techniques such as foamed bitumen to reduce the need for aggregate.

CONCRETE

Materials
Use of alternative aggregate material.
Use of cement alternatives including sulfo-aluminate, magnesium-phosphate, and alumino-silicate cements.
Processes
The potential to achieve carbon storage in concrete, in particular magnesium-phosphate cements.
Innovations in methods and techniques for cement placement.

LIGHTING AND SIGNALS

Potential to reduce consumption of electricity and associated greenhouse gas emissions through lighting choices, such as using energy efficient route lighting using LEDs, and demand management.

Figure 3: Options for reducing environmental pressures related to roads.

the operational life of a road, and up to 30 per cent in maintenance are possible in many road projects.

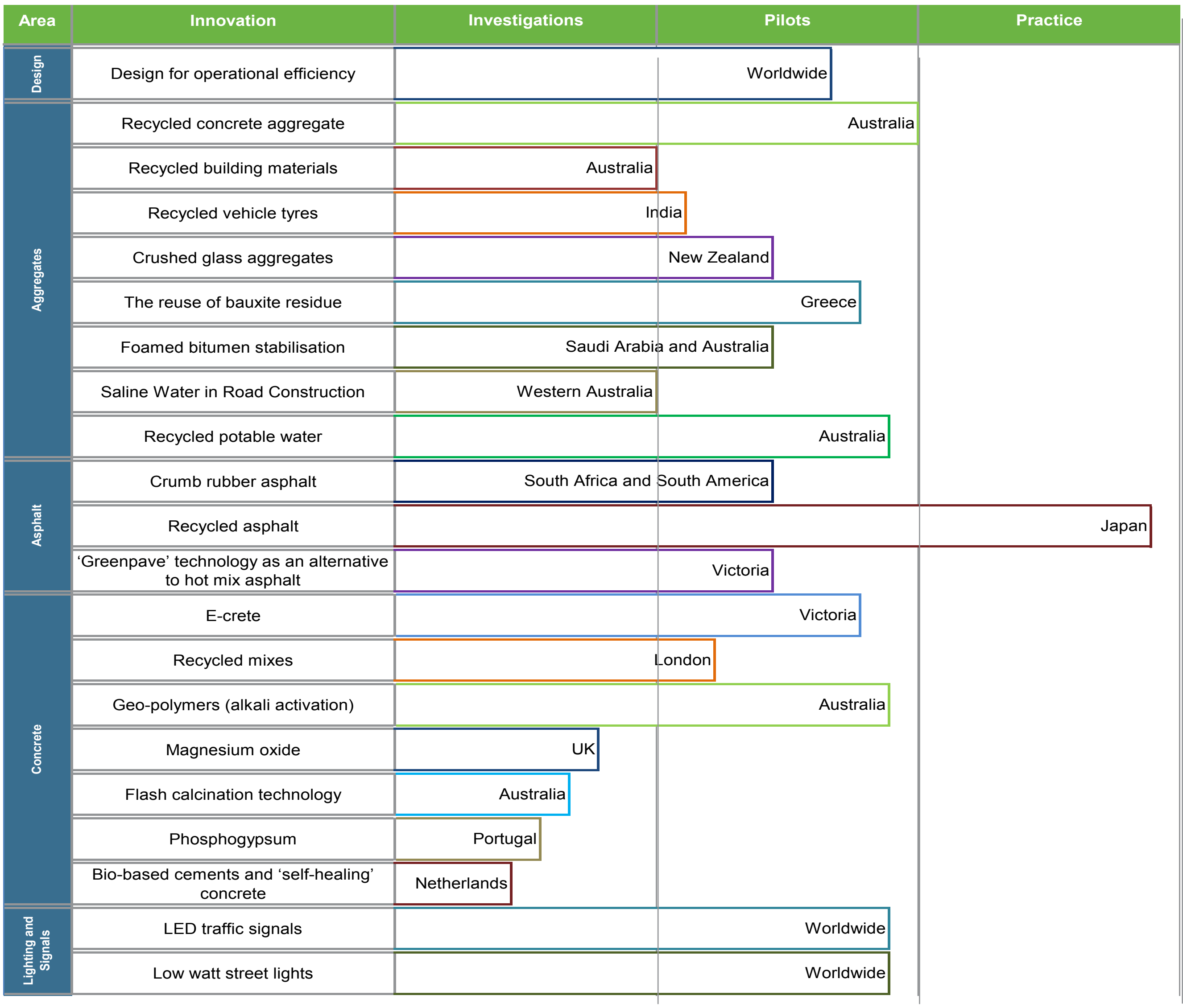
- *Aggregates*: Testing by the City of Kwinana and Main Roads Western Australia found that a one kilometre stretch of Gilmore Avenue constructed with recycled concrete aggregate performed better than a control road nearby made from non-recycled materials. This is supported by testing in Victoria by ARRB which found that on a particular project the life expectancy of the virgin rocks was 5 years and the strength was 270MPa, compared to recycled crushed concrete which had a life expectancy of 441 years and a strength of 3,500MPa.
- *Asphalt*: Bitumen is 100 per cent recyclable. Reduced need for virgin bitumen reduces the demand for extraction and transport of crude, the refining of oil, and the transport of bitumen to an asphalt plant. According to Australian Asphalt Pavement Association CEO John Lambert, industry in Australia should be aiming to recycle 100 per cent of all asphalt pavement produced. Japan has been recycling asphalt pavement since the 1970s, and has a recycling rate of over 98 per cent.
- *Concrete*: The Olympic Delivery Authority for the 2012 London Olympic Games stipulated in construction tenders that carbon footprint reductions would account for 25 per cent of the tender evaluation, resulting in a concrete with a 43 per cent lower carbon intensity being selected, the ‘2012 Mix’.
- *Lighting and Signals*: Between 2001 and 2009 the New York City Department of Transportation converted nearly all of its traffic signals to LED. This generated annual

energy savings of 81 per cent and energy and maintenance cost savings of approximately US$6.3 million a year. According to the Transport Authorities Greenhouse Group Australia and New Zealand, over a 50-year period, an intersection on an undivided road is estimated to consume 1,346,000kWh if incandescent lighting is used or 208,000kWh if LED lighting is used. This equates to 310–1,840t CO_2-e for incandescent lighting and 50–280t CO_2-e for LED lighting. Such advances are being achieved around the world with a growing number of innovative approaches being taken across the five areas, as shown in Figure 4.

Such efforts are creating a wealth of experience and knowledge about innovative approaches to road construction and maintenance, and these include road bases that reuse previous pavement layers, road surfaces using scrap tyres, plastic bags, and plant based bitumen alternatives, and lighting designs that achieve radical energy and cost reductions by implementing new lighting and signal technology. Leading examples include:

- *Using recycled building materials in road construction*: The City of Canning, WA, trialled an 860m stretch of Welshpool Road with different recycled material combinations, using materials from the existing road and compared

Figure 4: A stylistic indication of global best practices in innovative road construction methods



them to a control section of conventional road-base. The project established that high density foreign materials in the recycled concrete material are clay brick and tile, sand, milled asphalt, and crushed glass less than 4mm in size. The maximum percentage of high density foreign material is recommended as 20 per cent for low traffic base course, 30 per cent for sub-base and 40 per cent for select fill.

- *Crushed glass aggregates used in urban roads*: Fulton Hogan and Nelson City Council in New Zealand trialled the use of recycled crushed glass aggregate in a city street, and found that this reduced the cost of transporting the glass to landfill, used less virgin aggregate, improved environmental awareness and attitudes, and was economically feasible.
- *Foamed bitumen*: The Queensland Department of Transport and Main Roads used foamed bitumen on a 1.6 kilometre section of the Cunningham Highway and a 17 kilometre section of the New England Highway. The trial concluded that this use of foamed bitumen allowed traffic to use the road earlier than if conventional methods were used, and the long term use of foamed bitumen was deemed feasible.
- *Saline Water in Road Construction*: During the upgrade of the Great Northern Highway in Western Australia the use of saline water in the construction process was trialled. Preliminary inspection of the trial section showed no immediate road quality issues, and the section is still in operation.

Measuring and Reporting on the Sustainability of Roads

Road agencies in Australia are experiencing an increasing focus on reporting on the performance of projects, and this is rapidly evolving in scope. Beginning with a focus on '*environmental reporting*' on ecological impacts and disturbances of road construction, this has broadened to '*sustainability reporting'* (see Table 2). This broader focus has included attention to resource availability in assessing the road-building process; to the availability of, access to, and alternative sources of energy required; and to transport activities involved (including types of fuel used and greenhouse gases emitted). In support of greater levels of reporting, the Global Reporting Initiative argues that '*a Green Economy can only be achieved if organisational information on economic, social and environmental performance… is widely available to decision makers, including governments and private sector organisations*'.

The research team has identified that much of the data required to fulfil the new generation of project reporting is already being collected across many, if not all, road construction projects. However, it is clear that this data is not systematically or transparently reported on in a way that encourages use. The broadening of the reporting focus for road agencies has led to the emergence of an array of sustainability assessment frameworks, with varying purposes, report requirements and outcomes, as summarised below. For instance the Australian Green Infrastructure Council's 'IS Rating Tool' was used as part of the Eastern Busway project in Brisbane in 2009. The use of this tool led to a number of significant improvements in the sustainability performance of this project, including a reduction in busway grades to save fuel, the lifting of bus stations to prevent flooding damage, the incorporation of water sensitive urban design practices, and a significant reduction in lighting and operation costs due to improved design.

Environmental reporting can provide an impetus for improving performance, empowering decision makers with foresight to mitigate risk and deliver roads that are resilient to environmental and resource related challenges. The process of sustainability reporting can improve the performance of road projects in three main ways, namely:

1. It provides a clear and consistent structure and direction for departments and project teams to focus on, with elements such as baseline reporting areas.
2. It can include methods to measure environmental indicators, such as volumes of water, emissions and waste to landfill. These methods may consist of key performance indicators collected and reported across all departments, or a more rigorous requirement such as the use of an established rating scheme or tool, or the certification of projects.
3. Construction data can be collated across road projects to establish a benchmark to guide improvements to and the monitoring of the environmental impacts of road projects. This allows the measurement of improvements and the identification of performance targets so as to mitigate known risks, for example, aggregate shortages.

The range of environmental elements discussed in the annual reports for the Department of Transport and Main Roads Queensland (DTMR) and Main Roads Western Australia (MRWA) has evolved over the years. Notably, a change in language has been occurring whereby agencies have adopted active terminology – demonstrating an increasingly proactive commitment to sustainability and the associated reporting, as in Figure 5.

Figure 5: A shift to active language over the years in road agency annual reporting

Within the emergent industry of infrastructure performance evaluation, a number of terms are used to categorise the tools. For the purpose of this report, a *Rating Scheme* refers to a program that enables a third-party to conduct a verified 'rating' as a mechanism for performance evaluation. Within a rating scheme, one or more *rating tools* can be used for a self-evaluation in the form of a rating. In contrast, an *Assessment Tool* is designed to be used for self-evaluation in the form of a measurement, not necessarily linked to any scheme or rating. A number of rating schemes and tools and assessment tools are currently in use, spanning a variety of objectives. The tools also range from freely available resources to proprietary products, and from simple spreadsheets to complex software packages. A number of national and international tools are available, covering both general infrastructure and road specific projects, such as:

Australian tools:

- *INVEST (Integrated VicRoads Environmental Sustainability Tool)*: Developed by VicRoads as a road-specific self-assessable rating tool, it covers 11 lead indicators and 44 sub-indicators of performance. A number of them are specific to carbon management, including accounting for 'energy-related carbon emissions', 'purchase of carbon offsets' (using the national carbon offset standard), and 'future carbon reduction schemes'.
- *IS (Infrastructure Sustainability)*: Developed and administered by the Australian Green Infrastructure Council (AGIC), this tool uses a framework of 15 categories within six broad themes, developed in collaboration with industry. The categories 'Energy and

Carbon' and 'Materials' directly focus on carbon reporting and prioritise the reduction of greenhouse gas emissions and the minimisation of energy demand, by recognising the use of greenhouse gas emissions offsets, and by considering material life cycle impacts.

- *Carbon Gauge® Calculator*: Jointly funded by six road agencies across Australia and New Zealand, this road-specific assessment tool is entirely focused on carbon reporting, related to whole of life (50 year time horizon) greenhouse gas emissions from projects. These include emissions from planned construction, operation and maintenance activities, such as drainage, material transport, earthworks, street lighting and traffic signals.
- *eTool Life Cycle Assessment software*: Developed by eTool, this freely available, online assessment tool can be applied to a range of industries including those involved in residential, commercial, development and infrastructure projects. The software program enables analysis and comparison of several design concepts with regard to energy use and carbon output.
- *Bottom Line2 software*: Developed through the University of Sydney, this assessment tool uses existing organisational financial data to report across a wide range of social, economic and environmental sustainability indicators in any organisation.

International tools:

- *Global Reporting Initiative (GRI)*: Developed by the US non-profit organisations the Coalition for Environmentally Responsible Economies (CERES) and the Tellus Institute, this tool provides a comprehensive Sustainability Reporting Framework that is widely used around the world. The Framework enables all organisations to measure and report their economic, environmental, social and governance performance.
- *GreenLITES* (Green Leadership in Transportation Environmental Sustainability): Developed by the New York State Department of Transportation this road-specific self-assessment tool is intended for reviewing economic, social, and environmental sustainability practices undertaken in design, operations and maintenance phases of civil engineering works. Modelled on the building industry's LEED system, and initially developed to assess environmental issues, the tool has been augmented to become a triple bottom line approach to evaluation.
- *CEEQUAL*: Developed by the Institution of Civil Engineers (UK), this rating tool focuses on a range of economic, social and environmental sustainability criteria. It is most useful when applied as early as possible in the project as a planning aid for design and construction, but may also be used in retrospect as an assessment tool.
- *Greenroads Rating System*: Developed by the Greenroads not-for-profit foundation in the US, this road-specific rating tool is suitable for evaluating the social, economic and environmental sustainability of roadway and transport infrastructure projects during design and construction phases. Users address 11 mandatory project requirements and then use the rating tool to work through a broad range of categories.
- *Envision™ Rating System V2.0*: Developed through a collaboration between multiple organisations and Harvard University, this tool evaluates the economic, social, and environmental sustainability aspects of infrastructure projects of all types, sizes, complexities and locations. A self-assessment

checklist of five key areas and multiple sub-topics highlight a range of sustainability considerations including ecology and biodiversity, energy and carbon, and access and mobility. Also available is an optional stage two verification process, in which a rating is established based on stage one scoring and then verified by an independent third party for public recognition.

- *The Highway Sustainability Checklist:* Developed by Parsons Brinckerhoff, this road-specific planning tool comprises a spreadsheet that lists key environmental considerations across various phases of highway projects – from planning to design, through construction, operations, and maintenance.
- *Changer Greenhouse Gas Calculator*: Developed in Switzerland by the International Road Federation, this road-specific assessment tool requires input of information on the construction techniques and materials in order to calculate overall greenhouse gas emissions. The tool contains data from 188 countries and, within two main modules, pre-construction and pavement, emissions can be estimated from activities such as clearing and piling, materials transport and construction machines.

Environmental reporting at global, agency and project levels is inter-related and can be used collectively so as to not duplicate effort. By reporting on sustainability road agencies may enhance their overall performance according to the Global Reporting Institute:

*Sustainability reporting gauge[s] the quality of an organisation's governance processes and its long term strategy ... it creates **an impetus for improving performance** enabling companies to measure, monitor and manage their impact on society and the economy.*

Like every nation around the globe, Australia is faced with the necessity to upgrade, expand and maintain its road systems and infrastructure. From the literature review and stakeholder engagement undertaken as part of this project it is clear that there is an increasing focus on sustainability innovations. This includes identifying the effective use and implementation of recycled materials, ameliorating in-situ materials, and using industrial by-products. In addition, metrics are increasingly being used to monitor environmental and carbon performance across a number of factors.
Table 2 shows a sample of the results of a brainstorm by stakeholder workshop participants of potential metrics to assess the sustainability of road projects.


Building a highway. Image: Main Roads Western Australia, 2012.

The Great Eastern Highway Upgrade project in Western Australia used the AGIC Infrastructure Sustainability tool to improve sustainability outcomes. Image: Main Roads Western Australia, 2012.

Table 2: Sample metrics for the consideration of the sustainability of roads

Energy/Emissions

- The percentage of renewable energy used per kilometre of road constructed.
- The total amount of energy used in construction (direct and in-direct).
- Tonnes of CO_2e emitted during road construction (both direct and in-direct).
- Tonnes of air pollutants emitted during road construction (PM_{10}, VOC, NOx).
- The percentage of renewable energy used to maintain and operate roads.
- The revenue from energy generation, carbon sequestration per lane-km of road.
- Level of design for low carbon use (gradients, intersections, albedo).
- The level of noise generated by final road surface.
- Road surface characteristics post construction (roughness, temperature).
- Embodied energy in materials.
- Impact on urban heat island effect.
- Efforts to reduce heat island effect (such as increased tree canopy coverage, surface finishing and materials choice).

Biodiversity

- The creation or linking of wildlife corridors.
- The enhancement of existing wildlife corridors and biodiversity hotspots.
- Innovative practices to reduce negative biodiversity impacts.
- Percentage of capital cost invested in practices to reduce negative biodiversity impacts.
- Species count before and post construction.
- Efforts to reduce wildlife deaths from vehicles (including signage, roadspeed levels, fencing, sonic systems, and nature under or overpasses.)

Ecosystems

- Hectares of land revegetation as part of project.
- Hectares of land revegetated to offset construction footprint (such as replanting and ecosystem development).
- Percentage of land revegetation to total construction cost.
- Percentage of capital cost investment in erosion and sediment control measures.
- Percentage of unpaved area revegetated.
- Efforts to reduce potential impacts from noise and dust.
- Level of effective road alignment to avoid endangered environments.

Water

- Water efficiency during pavement material mixing and compaction (including trickle system vs flood mixing, additives in water, orange oil use, and Bomag mixing.)
- Distance to non-potable water supply suitable for construction purposes.
- Economic assessment of access to non-potable water vs potable water sources.
- Percentages of potable, bore, and sea water used.
- Risk of impact from sea level rise (measured in distance above sea level and distance from ocean).
- Economic assessment of the cost per day if road is inundated or damaged by salt water intrusion (road importance factor).
- Consideration of long term characteristics of road base when inundated with sea water.
- Consideration of flood resilience (measured in height above predicted design events).
- Level of innovation in drainage infrastructure (such as provision for animal habitat and access corridors, and the day-lighting of streams and natural water courses).
- Hectares of affected watercourse and wetlands.
- Hectares of watercourse and wetlands protected or enhanced to offset construction footprint.
- Percentage of watercourse restoration to total construction cost.
- Volume of runoff treated on-site via swales and other innovative practices.
- Level of retention of original flow patterns, overland flow, and watercourses.

Materials

- Distance imported aggregate travels per km of constructed road.
- Tonnes of materials imported to project.
- Percentage of alternative materials for road base (considering the longevity and security of supply).
- Percentage of materials recycled (both on and off project).
- Percentage of project specific raw material extraction (adaptive re-use).
- The use of adaptive re-use or rehabilitation options (considering cost and legacy).
- Lifespan of pavement (total years and maintenance programs).
- Impact on materials longevity from maintenance activities over life.
- Volume of bitumen used (considering potential exposure to oil price increases).
- Percentage of alternative materials for bitumen (considering the longevity and security of supply).
- The use of results of innovative trials in materials (in-situ stabilisation).
- The opportunity for innovative materials trials as part of project.
- The level of strategic risk taking on alternative materials.
- Rehabilitation (costs and community legacy).

Community

- Options to raise environmental and sustainability awareness both in local community and more widely as a result of the project.
- Number of ideas submitted and adopted through community engagement.
- Level of participation of community members in project team.
- Number of entry level labour positions (e.g. apprenticeships) in project team.
- Level of local knowledge (from professionals, elders, community leaders, etc) used in project.
- Level of satisfaction shown by community (during and post construction).
- Level of safety of constructed roads (number of 'black spots' per km of road).

Maintenance

- Population serviced per lane/km of road constructed.
- Average distance travelled per maintenance task.
- Level of strategic vs reactive maintenance.
- Total anticipated kilometres travelled for maintenance per lane.
- Cost comparison of the provision of public transport options vs road investment based on expected patronage.
- Considerations and methods to reduce and manage traffic congestion.
- Consideration of legacy and whole of life social costs and opportunities.

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Source: Drawing on the findings of SBEnrc Stakeholder Workshops, Hosted by 1) Main Roads Western Australia in Perth on 12 July 2011, and 2) Queensland Department of Transport and Main Roads in Brisbane on 9 September 2011, facilitated by Curtin University and QUT.

Identification of Potential Trends and Future Risks Affecting Roads

In the coming decades the design, construction, and maintenance of roads will face a range of new challenges – many that bear little resemblance to challenges previously faced – and as such will require a number of new approaches. Such challenges will result from a growing number of interconnected environmental, social, and economic pressures or trends, as highlighted in Table 3. For instance, environmental pressures will include the impacts of climate change on rainfall patterns and temperature profiles; economic pressure will include materials and resources shortages and predicted increases in energy and resource prices globally; and social trends will include a shift to lighter vehicles, reduced use of cars due to higher fuel costs, and political pressure to respond to climate change.

Given that roads typically have a design life of 20 to 40 years, with bridges being designed for up to 100 years, the level of consideration given today to future environmental, economic, and social trends associated with roads will have a significant impact on costs and impacts into the future. The project has considered a short list of trends, including:

- *Increases in the cost of road maintenance*: Road maintenance costs in Australia are estimated to be $5 billion per year and are expected to increase by over 30 per cent by 2100. Climate change will affect these costs through hotter temperatures that make bitumen more brittle and deteriorate seal binders, a wetter climate that causes more pavement deterioration, and extreme weather damage.
- *Increases in extreme weather events*: Temperature increases from climate change are causing established weather patterns to change and extreme weather events, such as flooding, storm surges, tropical cyclones, droughts and heat waves, to become more common. For instance the average number of days in which the temperature exceeds 35˚C is expected to increase by 10 to 100 per cent by 2030.
- *Oil based road surfacing becoming unfeasible*: Oil resources are becoming increasingly scarce and expensive. In economic terms the peak in production of conventional oil (oil which can be produced under around $65/barrel) occurred in 2005. The production of unconventional oil (deep water, remote and shale) is increasing, but this is very inefficient and expensive.
- *Increased trips by walking, cycling and public transport*: These result from a number of factors including the negative impacts of urban sprawl, negative impacts on human health, the rising cost of petrol, the adoption of sustainability or 'green' values, and a marked cultural shift with people moving to more urban locations that enable less car-dependent lifestyles.
- *Shortages of resources such as aggregate*: A typical two-lane bitumen road with an aggregate base can require up to 25,000 tonnes of material per kilometre. Greenhouse gas emissions from the mining, transportation, earthworks and paving associated with road construction, as well as vehicles, is one of the largest contributors to climate change, some 22 per cent of global carbon dioxide emissions.
- *Freight vehicle increases in size and number*: The freight task in Australia's eight capital cities is expected to grow by 50-70 per cent between 2003 and 2020, with 60 per cent

Table 3: A list of potential trends affecting the future of roads (drawn from stakeholder workshops)

Potential Trends Affecting Future Roads	
• Climate change*	• Modal shifts to rail and public transport
• Rising price of oil*	• Biodiversity degradation and collapse
• Increased community action*	• Loss of agricultural land
• Decreasing access to resources*	• Increased automation
• Population growth*	• Waste reduction and harnessing
• Increased freight*	• Growing middle class
• Maintenance costs*	• Peaking of food production
• Increased community expectations of transport network*	• Alternative fuel sources
• Employment and skill shortages*	• Changing world powers
• Global financial crisis*	• Pressure for intergenerational responsibility
• Water scarcity*	• The influence of the government
• A price on carbon	• Decentralisation
• Technology innovation, e.g. smart roads for driverless cars	• Congestion increases or decreases
• Rapid urbanization and densification	• Globalised tourism
• On-line shopping	• Health costs and impacts
• Increased use of social networking	• Changing lifestyles affecting mobility
• Increased use of smart phones and applications	• New transport paradigms
• Increased frequency and intensity of extreme weather events	• Short political cycles
• Growing environmental awareness and cooperation	• Methods of energy generation

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* Participants were asked to identify the most influential increasing pressures on the future of roads, listed first and designated by a star.

Source: Drawing on the findings of SBEnrc Stakeholder Workshops, Hosted by 1) Main Roads Western Australia in Perth on 12 July 2011, and 2) Queensland Department of Transport and Main Roads in Brisbane on 9 September 2011, facilitated by Curtin University and QUT.

of freight being moved by trucks. Hence the number and weight of freight vehicles is increasing with implications both for space and for road construction, maintenance, and longevity.

- *Funding constraints on new projects and on maintenance of existing infrastructure*: Government funding of road infrastructure projects, research and maintenance is decreasing. Main road authorities are less able to finance the innovation programs or the testing of innovations needed to combat the impacts of climate change.
- *Transport infrastructure at capacity*: In 2012, the OECD reported that Australia is suffering from an 'infrastructure deficit' and is experiencing increased congestion on roads and rail lines. For instance, a recent RAC survey reported that in the last year 43,000 more cars came onto Western Australian roads, with 400,000 more cars expected on Perth roads over the next 10 years.
- *Electric and alternative fuel vehicles mainstreamed*: Vehicles are increasingly being powered by alternative fuels and electricity, affecting their road design profile. Furthermore, advances in charging options such as fast charging stations, wireless charging stations, and charging strips embedded into roads will require changes to transport infrastructure and associated services.
- *City planning densification requirements along rail lines and for infill development*: All major metropolitan urban plans in Australia have set targets of 40 to 70 percent of residential development to be built in developed areas (infill development) or around existing infrastructure. These plans require compact urban development in appropriate locations such as close to public transport, along urban corridors and near existing retail and employment centres.

When addressing such trends it is important to consider how their intensity may change over time, and this can be done through the development of potential '*Trend Intensity Profiles*', as shown in Figure 6. The process of developing such profiles promotes investigation and discussion of possible ways the trend may progress over time. Once the intensity profile has been developed it provides a structure to consider the risks that the trend will present to road agencies over time. For instance for the trends shown in Figure 6 the associated risks from '*freight vehicles increasing in size and quantity*' may include increased costs of road construction and maintenance from increased numbers of 'restricted access vehicles', and risks associated with 'aggregate shortages' may include increased cost of aggregates.

Having considered the intensity of the trend over time and the potential associated risks it is important to consider how such trends may be affected by other trends, examples of which include:

- '*Increase in extreme weather events*' leading to increased damage of main roads and an '*increase in the cost of road maintenance*' in Queensland,
- '*Aggregate shortage*' leading to increased costs of aggregates and an '*increase in the cost of road maintenance*' in Queensland,
- '*Freight vehicles increase in size and quantity*' leading to increased design strength requirements for road base, contributing to '*aggregate shortages*' in Western Australia.

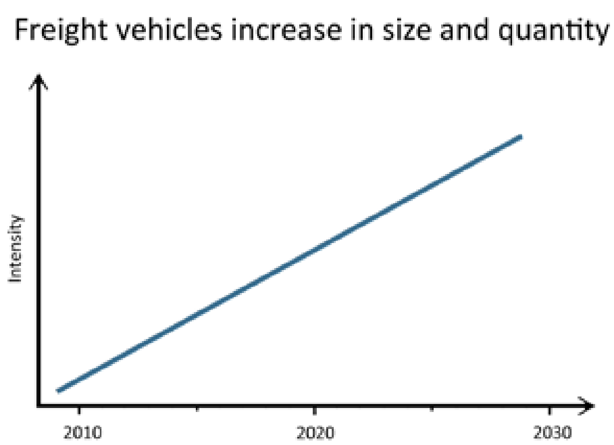
Trends that may reduce another trend's impact include:

- '*Trips by walking, cycling and public transport increase*' leading to reduced car ridership and reducing the impact from '*Transport infrastructure reaching capacity*' in Western Australia,
- '*Trips by walking, cycling and public transport increase*' leading to reduced car ridership and reducing the impact from '*increase in the cost of road maintenance*' in Queensland.

The final stage of the process is the consideration of strategies that can assist transport agencies to prepare for future risks associated with key trends, including strategies that can address multiple trends, as shown in Table 4.

These strategies highlight the changing role of road agencies, and importantly, the structural shift that is occurring within organisations and leading them to focus less on new infrastructure and more on maintenance and enhancing the efficiency of existing roads.

- *Road Pricing Mechanisms*: A road pricing mechanism can both generate revenue to adapt and maintain assets, and influence road user behaviour, for example, encouraging alternative modes and reducing congestion.



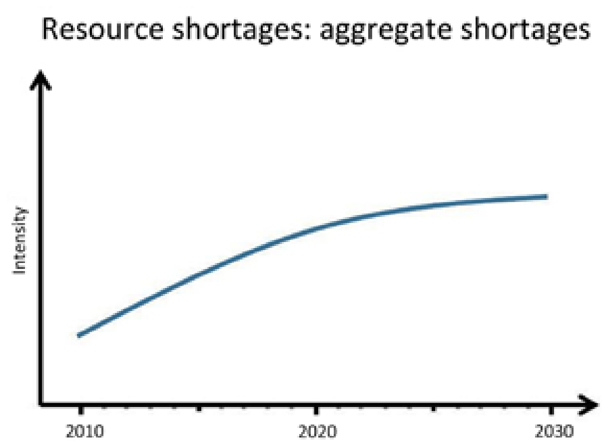


Figure 6: Example of trend intensity profiles from stakeholder workshops

Table 4: Strategies identified by workshop participants mapped across selected trends

	Potential Future Trends impacting Main Roads							
	Resource shortages: aggregate		Trips by walking, cycling and public transport increase		Increase in extreme weather events	Increase in the cost of road maintenance	Transport infrastructure reaches capacity	Freight vehicles increase in size and quantity
Clustered Mechanisms	QLD	WA	QLD	WA	QLD	QLD	WA	WA
Road pricing mechanisms	•	•		•	•	•	•	
Government action to support change	•	•	•	•		•	•	•
Investment in research and development	•	•	•		•	•		•
Analysing investment priorities		•	•	•	•		•	
Incentivising preferred practices	•	•	•		•	•		
Increasing the efficiency of existing infrastructure	•			•			•	•
Adaptable design standards	•	•	•		•			
Knowledge sharing and capacity building	•		•			•		
Investment in carbon management				•	•			
Transit oriented developments				•			•	

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Source: Drawing on the findings of SBEnrc Stakeholder Workshops, Hosted by 1) Main Roads Western Australia in Perth on 27 April 2012, and 2) Queensland Department of Transport and Main Roads in Brisbane on 13 April 2012, facilitated by Curtin University and QUT.

Road pricing may be implemented in a number of ways, including as a tax added to the fuel price, as increased costs of vehicle registration and insurance, as higher freight charges, or as a direct charge for use of specific roads at specific times of day.

- *Government Action to Support Change*: Change can be facilitated through new policies, including those that make more economically competitive the actions required to prepare for the risks of future trends. This can be achieved by lessening the fallout from failures in this area, improving integration across agencies involved with transport, and mandating the inclusion of preferred materials or practices (e.g. recycled materials in road projects).
- *Investment in Research and Development*: Funding and investing in targeted research and development is critical to identifying and evaluating alternative road building materials, new design methods, and enhanced transport planning processes. This may be achieved by funding industry collaborative applied research in the area, and investing in targeted research programs to develop key innovation areas (e.g. stabilisation techniques, alternative and recycled road materials, mode integration, and efficient use of local and marginal materials).
- *Analysing Investment Priorities*: To determine the best areas for investment in road and transport infrastructure, there should be collaborative network planning across transport modes. This may be achieved by the use of low-cost high-impact scale for investment analysis, and building the resilience of primary networks by prioritising maintenance and investment for specific routes.

- *Promoting Preferred Practices*: This may be achieved by the inclusion of specific performance requirements in tenders, the provision of financial incentives for particular project practices, and the alignment of procurement practices to prefer products and services that support efforts to prepare for future trends.
- *Increasing the Efficiency of Existing Infrastructure*: Improving the efficiency of existing infrastructure can dramatically reduce the need for new infrastructure, reducing pressures on resources and capital. This may be achieved by creating additional intermodal transit hubs to harness existing road infrastructure (such as truck to train freight, and bus to passenger train), by using operative intelligent transport systems (ITS), and by having managed lanes (such as those for high occupancy vehicles and public transport vehicles). It can also be achieved by encouraging decentralised operations to harness existing infrastructure in satellite or regional locations, and by supporting flexible work hours to spread out peak traffic loads.
- *Adaptable Design Standards*: Standards need to be adaptable and site specific to allow optimum use of resources and money for a specific site. This can be achieved by providing material specifications that are flexible for different areas, and by using and allowing site specific technologies and solutions.
- *Knowledge Sharing and Capacity Building*: Rapid uptake of tested innovative technologies and practices can be facilitated through awareness raising and capacity building, for example, by funding research projects to create educational and capacity building materials, by incorporating a 'lessons learned' requirement in project reporting, by improving regional communication, and by providing targeted skills training to address the shifting roles of road agencies.
- *Investment in Carbon Management*: Carbon emissions can be reduced by removing barriers to cleaner technology and shifting to low carbon fuels and energy. This may be achieved by carbon measurement and reporting of road projects, by the provision of enabling infrastructure (e.g. electric car charging stations), by preferring low carbon cars in government and industry fleets, by requiring low carbon options in tendering, and by the disclosure of the carbon liability of projects.
- *Transit Oriented Developments*: Road networks need to be coordinated with urban planning, in order to promote compact urban development in close proximity to urban corridors and existing retail and employment centres. This can be achieved through urban planning and infrastructure provision that allows for a decentralised, hub-and-spoke model of development.

This analysis shows that there are a number of strategies applicable across multiple trends, such as '*road pricing mechanisms*', '*government action to support change*', and '*investment in research and development*', and these may provide powerful leverage points to prepare for the future trends selected. For example, road pricing has the potential to simultaneously reduce congestion and user pressures on roads while generating revenue to invest in road maintenance and the provision of low carbon alternatives to car use. The implementation of road pricing is being trialled and used in a number of countries around the world and its use will involve consideration of a range of political, social, and economic issues and opportunities.

Conclusion

Roads will always be a focus for any city or region due to their economic and social importance. Perhaps for the first time in a century there may be a confluence of factors that are causing road agencies to fundamentally rethink how roads are made, how they are shared, and how they are managed. It will be important for the agencies to maintain a transparent and innovative approach to these emerging global and local trends, and the results so far suggest that road agencies in Australia are up to the challenge.

Future Work

The work undertaken in this project is proposed to be extended in two new research projects:

1. an ARC Linkage proposal (*The investigation of key emerging trends related to sustainable development to identify associated risks and inform strategic responses by Australian road agencies*)
2. an SBEnrc Foundation Project.

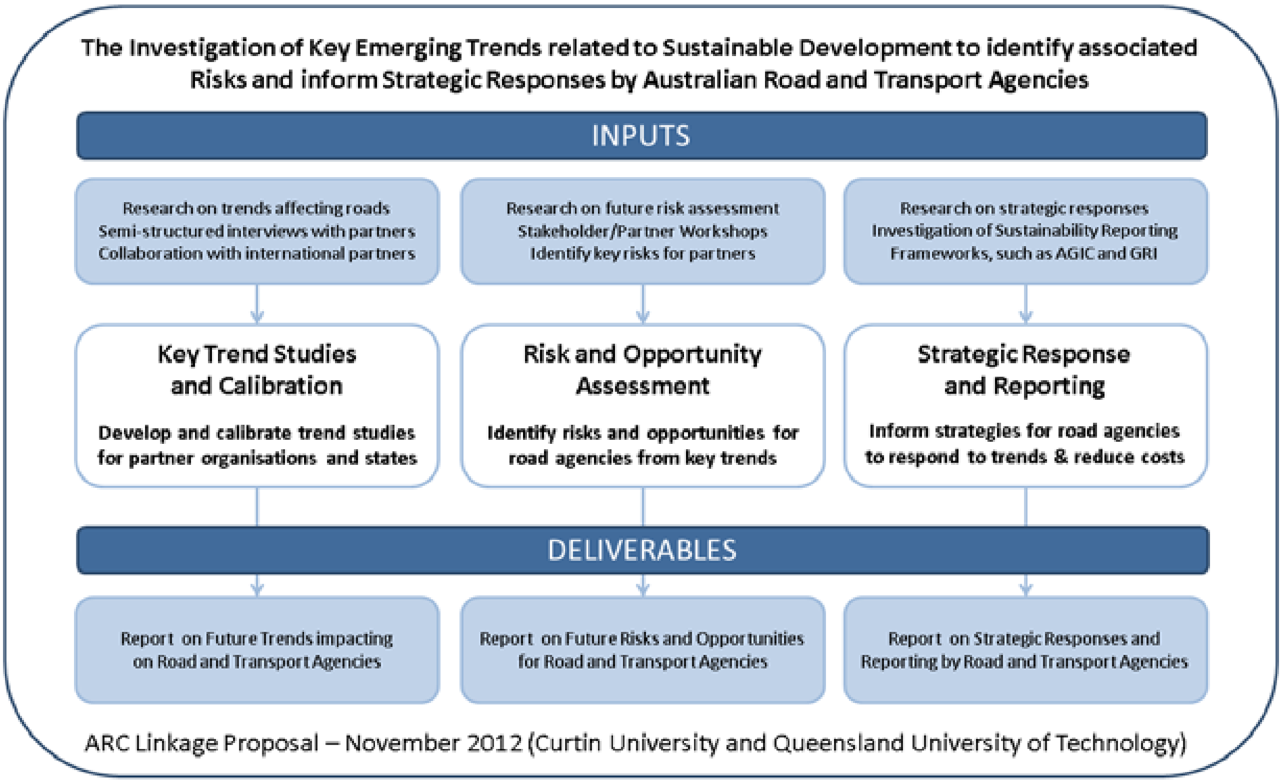
These projects are outlined on the following pages.

Road maintenance being carried out in a rural area. Image: Main Roads Western Australia, 2012.

ARC Linkage Project on Trends, Risks and Opportunities for Road Agencies

The ARC Linkage proposal seeks to address a number of key issues facing road and transport agencies throughout Australia related to climate change, resource availability, and the changing use and expectations of roads. This will be addressed through 3 key areas of investigation: (i) Trend Studies (through a literature review, targeted research, and stakeholder engagement) (ii) Risk Assessment (including the development of a process for road agencies to identify risks and opportunities associated with trends), and (iii) Strategic Responses and Reporting (to consider a suite of tangible strategies and reporting tools that can prepare agencies for the oncoming trends and reduce associated costs). This project will provide value to road agencies by working closely with them to identify key risks and opportunities associated with sustainable development, which may then inform a strategic responses. It is intended that this research also inform the Australian Green Infrastructure Council and the Global Reporting Initiative (with Professor Newman invited by GRI to contribute to the development of a transport related sector supplement).

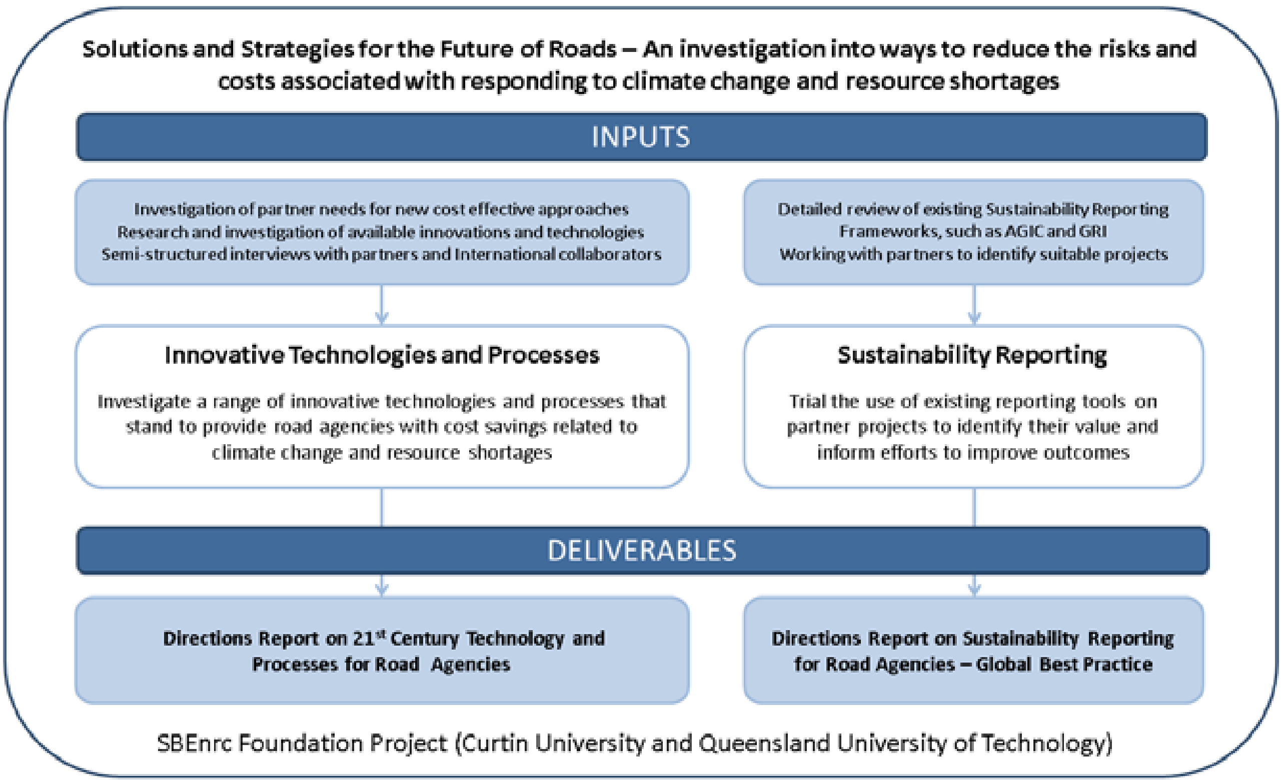
The project is important as road infrastructure and road transport will be faced with many challenges over the coming decades, including extreme weather events, predicted increases in energy and resource prices, road freight requirements, deteriorating assets, predicted resource shortages and the changing use and expectations of roads. With emerging issues related to environmental impacts and carbon legislation, economic risks and social demands, long-term planning and resilience-building is urgently required to provide reliable and extensive road networks in future. Considering the magnitude of our public infrastructure, the future environmental impacts, economic risks, and social trends associated with roads will have a significant impact on long term costs and service for citizens. Australian road authorities are being called upon to investigate the pressures facing the future of roads and consider how a strategic response can be informed.



SBEnrc Foundation Project on Solutions and Strategies for the Future of Roads

This research proposal seeks to work closely with government and industry to address two key areas facing Australian road and transport agencies, namely sustainability innovations and technologies that can deliver cost savings as part of a response to climate change and resource shortages, and sustainability reporting tools that can be used to deliver value to projects. The research will comprise two parts: (i) The investigation of a range of innovative technologies and processes that stand to provide road agencies with cost savings related to climate change and resource shortages, and (ii) The trial of existing reporting tools on partner projects to identify value and inform efforts to improve outcomes. This project will provide value to road agencies with clear guidance on specific technologies and processes that can both response to climate change and resource shortages and reduce costs. Further the project will provide clear guidance on how to best gain value from the use of sustainability reporting.

This project is important as road agencies face growing pressure to respond to future issues related to climate change and resource shortages, and must find cost effective ways to do so. A key part of this response will be reducing energy demand of the transport infrastructure through strategies such as 'Electricity Neutral' projects that consider opportunities for innovations and new technologies to provide cost savings in road construction, route and signal lighting, managing tunnel exhaust, and to generate energy onsite. Given the rapid change in such innovation areas, it is important to ensure rigorous investigation is undertaken prior to incorporation in tenders and projects. Another key area will be the use of sustainability reporting tools to streamline such activities and provide structure and benchmarking. The new AGIC tool also advises agencies on how to best prepare projects and tenders to support strong performance as measured by the tool.



Sustainable Built Environment National Research Centre

The Sustainable Built Environment National Research Centre (SBEnrc) is the successor to Australia's CRC for Construction Innovation. Established on 1 January 2010, the SBEnrc is a key research broker between industry, government and research organisations for the built environment industry.

The SBEnrc is continuing to build an enduring value-adding national research and development centre in sustainable infrastructure and building with significant support from public and private partners around Australia and internationally.

Benefits from SBEnrc activities are realised through national, industry and firm-level competitive advantages; market premiums through engagement in the collaborative research and development process; and early adoption of Centre outputs. The Centre integrates research across the environmental, social and economic sustainability areas in programs respectively titled Greening the Built Environment; Developing Innovation and Safety Cultures; and Driving Productivity through Procurement.

Among the SBEnrc's objectives is to collaborate across organisational, state and national boundaries to develop a strong and enduring network of built environment research stakeholders and to build value-adding collaborative industry research teams.

SBEnrc Core Partners:

Government of Western Australia
Queensland Government
Parsons Brinckerhoff
John Holland
Curtin University
QUT
Swinburne University of Technology

For further information:

Professor Peter Newman (Program Leader)
Professor of Sustainability
Curtin University Sustainability Policy (CUSP) Institute
P.Newman@curtin.edu.au

Charlie Hargroves (Project Co-Leader)
Senior Research Fellow
Curtin University Sustainability Policy (CUSP) Institute
charlie.hargroves@curtin.edu.au

Dr Cheryl Desha (Project Co-Leader)
Senior Lecturer in Sustainable Development
QUT Science and Engineering Faculty
cheryl.desha@qut.edu.au