Reducing Environmental Pressures of Road Building

A Sustainable Built Environment National Research Centre (SBEnrc) Discussion Paper by Curtin University and the Queensland University of Technology

University Research Team
Program Leader: Prof. Peter Newman (Curtin)
Project Leaders: Charlie Hargroves (Curtin) and Cheryl Desha (QUT)
Academic Advisor: Prof. Arun Kumar (QUT)
Research Team: Luke Whistler (Team Leader - QUT), Annabel Farr (QUT), Justine Beauson (Curtin), and Leon Surawski (Curtin)

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, along with in-direct emissions from road use by vehicles. This discussion paper will outline opportunities within the Australian context for reducing environmental pressure in road building and consider the future environmental impacts of road projects.

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1. Why focus on reducing the environmental pressures of roads?

Roads and road infrastructure will be faced with many challenges over the coming decades. These include the considerable number of rapidly expanding economies around the world, significant changes to weather patterns and extreme weather events, and predicted increases in energy and resource prices.[1] Leading efforts around the world are now showing how such challenges can now be met with creativity and innovation across many aspects of roads.[2,3,4]

The dominant message from these institutions is that the opportunity exists to transform the way road infrastructure is conceived and harnessed, to assist society to respond to climate change and reduce a range of environmental pressures.

A particular interest in the future of roads has been expressed by both the Queensland and Western Australian governments, due to the potential to inform and enable sustainable transport strategies to reduce both greenhouse gas emissions and the associated financial costs anticipated in a carbon constrained economy. This paper draws on the early activities and findings of the first stage of 'The Future of Roads' project,[5] to be completed in September 2012, and focused on exploring such opportunities for road infrastructure design, construction, maintenance and operation. Within this context, the paper highlights the literature review findings regarding opportunities for reducing the environmental pressures of road building. The project team invites feedback to further inform the findings and ongoing research.

It is important to consider the direct environmental impact of roads because of their role in our society and the scale of the infrastructure we have built to date. It is also important, but more challenging, to consider the indirect environmental impact of roads through their end-use as transportation corridors, and how this might be addressed through strategic directions in road building. For example, roads support an automobile industry that employs millions of people and sells a copy of its product every 1.5 seconds.[6] Road infrastructure also supports vehicles that combust 310,000 barrels of oil every day in Australia and emit 17 percent of Australia's greenhouse gases in turn threatening global climatic stability, local ecology and agriculture industries.[7]

Recent history clearly shows that roads are a cornerstone to economic activity in a capital market. For example, improved road transport and economic liberalisation has resulted in 6 percent per annum global economic growth over the past 50 years. This is demonstrated simply by the fact that a single cup of coffee can use some 29 different transport related activities in its lifecycle. While the economic benefits of road construction and use is well known, the environmental impact and associated future economic impacts is underestimated. The past decade has seen a focus on the footprint and alignment of roads to minimise ecological disturbance. The coming decade will see a focus on the resources required to build and maintain roads.

For example, each kilometre of road constructed required large quantities of rock, concrete, asphalt and steel to be sources, transported and placed. 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. The emissions from the mining, transportation, earthworks and paving associated with road construction, as well as emissions from road users makes it one of the greatest contributors to climate change, some 22 percent of global carbon dioxide emissions.[8]

2. How can the environmental pressures from roads be reduced?

With this context in mind, the literature was reviewed for ways to reduce environmental pressures of road building. The following paragraphs highlight the opportunities that are emerging associated with road construction and maintenance in Australia. From the literature review it is clear that across government and industry, momentum is increasing to achieve meaningful reductions in the environmental pressures during road building. There are a number of opportunities throughout the various stages of road and infrastructure development that allow a reduction in environmental pressures, as outlined in Table 1.

Table 1: *Example options for reducing environmental pressures related to roads**

Aggregates Processes	Aggregate Materials Selection
Extraction – *Increased fuel efficiency and fuel switching in extractive equipment and plant* Crushing – *Increased energy efficiency of crushing equipment and techniques, such as considering cutting angles* Transportation – *Increased fuel efficiency in transportation and distribution vehicles* – *Options to shift transportation modes, such as from trucks to rail* – *Consideration of the moisture content of aggregate materials to reduce haul weights* Placement – *The potential to use saline or non-potable water in road base stabilisation* – *The use of non-potable water for dust control*	Alternative Materials – *The potential to redirect waste products to replace extracted aggregates, such as:* – Glass – Plastic – Flyash – Recycled road materials – Tyre rubber – *The potential for aggregate replacement through in-situ stabilisation, such as:* – Foamed bitumen – Cement blends – Geopolymers – Red sand – Quick lime – Lime, slag and flyash triple blend – Alkali activation
Bitumen	**Concrete**
Materials – *Opportunities for the use of alternate*	Materials – *Opportunities for the use of alternative*

aggregate materials – *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*	*aggregate materials* – *The use of cement alternatives including sulfo-aluminate cement, magnesium-phosphate cement, and alumino-silicate (Geopolimer) cement* Processes – *The potential to achieve carbon storage in concrete, in particular magnesium-phosphate cements* – *Innovations in methods and techniques for cement placement*

** Note: Information, recommendations and opinions expressed are not intended to address the specific circumstances of any particular individual or entity. This table has been produced for general information only and does not represent a statement of the policy of the participants of the stakeholder workshop, the SBEnrc, or the SBEnrc partner organisations.*

In addition there are a number of emerging innovations that are promising significant reductions in environmental pressures, such as:

– Technological advances at asphalt plants create a 'half-warm mix'[9] involving reducing emissions and toxic fumes for personnel and construction staff respectively. Innovations in rock crushing techniques are beginning to reduce the energy required to produce suitable aggregates for pavements and bases.[10,11]

– In-situ stabilisation has been recognised as a key innovation trend to economically reducing the raw aggregate and energy requirements of new roads especially in regional areas. Current industry examples of this emerging field are foamed bitumen (with a trial undertaken by Qld DTMR[12]), and the use of geopolymers, including bauxite and alkali activation technology.[13,1415]

– The industry for recycling of aggregates and concrete continues to grow,[16].with State authorities beginning to amend raw aggregate specifications to encourage and support innovative products. The recently released Queensland Main Roads Specification MRS35 – Recycled Materials for Pavements, highlights the growing awareness amongst design professionals in this field and is a positive sign of innovation moving beyond small scale trials and into mainstream industrial applications.[17]

– A joint research initiative with Curtin University and Alcoa has resulted in the creation of a specification detailing the use of residues (from the production of bauxite) as a practical road base material.[18],[19] The investigation also revealed a successful project in Europe demonstrating the re-use potential of bauxite in embankment construction.[20]

Innovations that sequester carbon are also beginning to emerge with prototype solutions for concrete and aggregates.[21] For example, the Queensland-developed bio-composite material Carbonlock™ is intended to improve the sustainability of construction materials by using polymers from waste streams that can store carbon. Other innovative trials include the use of waste plastic and glass, supported by the Packaging Stewardship Forum and NSW's Road Traffic Authority (RTA).[22] The calculation of greenhouse gas emissions tools and energy consumption for road construction is also gaining popularity, on projects in Australia by VicRoads[23] and in Europe[24] respectively. For example the Mickleham Project calculated their emissions in order to offset their carbon footprint by planting 7500 trees to offset 2002 tonnes of GHG for a cost of approximately $25,000.

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 first round of stakeholder engagement (with the second to be undertaken in Brisbane), it is clear that there is an increasing focus on sustainability innovations including 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 the environmental performance across a number of factors. Table 2 shows the results of a brainstorm by participants of the stakeholder workshop of potential metrics to consider the future sustainability of road projects. This list will be enhanced by the workshop in Brisbane to be investigated by the research team to support the development of an assessment framework, the '*Sustainability Assessment Framework for Road Infrastructure*' (SAFRI).

Table 2: *Possible metrics for the consideration of the future 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 CO2 emitted during road construction (both direct and in-direct). – The percentage of renewable energy used to maintain and operate roads. – The revenue from energy generation per lane-km of road.	– Energy efficiency improvements in vehicles from the roughness of final road surface. – The level of noise generated by final road surface. – Road temperatures post construction.. – Impact on urban heat island effect. – Efforts to reduce heat island effect (such as increased tree canopy, surface finishing and materials choice.).
Biodiversity	**Ecosystems**
– 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.)	– 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. – Options to raise environmental and sustainability awareness in both local community and wider as a result of the project.
Water	
– Water efficiency during pavement material	– Consideration of flood resilience

mixing and compaction (including trickle system vs flood mixing, additives in water, 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 the use 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. – Consideration of long term characteristics of road base when inundated with sea water.	(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 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 innovative practices. – Level of retention of original flow patterns, overland flow, and water courses.
Materials	
– Distance imported aggregate travels per kilometre 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. – The use of adaptive re-use or rehabilitation options (considering cost and legacy). – Lifespan of pavement.	– 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. – The opportunity for innovative materials trials as part of project. – The level of strategic risk taking on alternative materials.
Community	**Maintenance**
– Number of ideas submitted through community engagement. – Percentage of ideas adapted from community engagement. – Level of participation of community members in project team. – Number of entry level labour (ie apprenticeships) in project team. – Level of local knowledge (including professionals, elders, community leaders, etc) used in project. – Level of community satisfaction shown by community (during and post construction). – Consideration of legacy and whole of life social costs and opportunities.	– Population serviced per lane/km of road constructed. – Average distance travelled per maintenance task. – Level of strategic vs. reactive maintenance. – Total anticipated km's travelled for maintenance/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.

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Source: SBEnrc Stakeholder Workshop, Hosted by Western Australian Main Roads, Facilitated by Curtin University and QUT, 12 July 2011, Perth.

The literature review to date has found that projects and trials on reducing the environmental pressures during construction are now beginning to be documented and published into the public domain. The literature review has found that a number of barriers to implementation still remain and that these barriers are complex in their interactions. Such barriers are complicated by the impacts of changes to construction techniques such as delays, educational requirements, cost shifting and the use of options with short history of application. It is the purpose of the 'Future of Roads' project to explore such options and provide strategic guidance to the industry and the governments that are tasked with planning the future of our roads.

3. What is the focus of the '*Future of Roads*' project?

As part of the first stage of the project, through till September 2012, the research team intends to develop a number of key outcomes supported by undertaking a review of literature, publications and case studies, that will be complimented by selected semi-structured interviews and stakeholder workshops, in order to:

(a) **Investigate ways to reduce environmental pressures from road building**, and the project aims to identify best practices related to:

- road materials (*including the extraction, crushing, transportation and placement of traditional and alternate materials and aggregate replacement options*);
- the use of concrete (*including aggregate alternatives, cement alternatives, placement and carbon storage options*);
- the use of bitumen (*including raw aggregates, mix design, warm and cold mix technologies and placement*); and
- impacts on watersheds and biodiversity (*including toxicity, leachate, runoff pollutants and groundwater pollutants, erosion issues, changes to hydrology, changing stability of road and surrounds, and changing porosity of road and surrounds*).

(b) **Investigate the potential for adaptation to future pressures such as climate change and peak oil**, and the project aims to develop of a base framework for a '*Sustainability Assessment Framework for Road Infrastructure*' (SAFRI) model. The new model will be used to undertake a preliminary comparison of current national practices to identify opportunities for improvement. Project partners will be invited to nominate projects implement the assessment framework as part of its development. The framework will tie in closely with the AGIC framework.

As part of the second stage of the project beginning in October 2012 the research team intends to expand SAFRI and undertake a comprehensive comparison of current national practices to identify opportunities for improvement to inform recommendations as to potential legislative and policy adjustments and to investigate potential impacts and benefits of such adjustments.

(c) **Investigate the opportunity for utilising road areas to contribute to the mitigation of climate change and strengthening infrastructure and economic resilience**, and the project aims to develop an '*Innovative Scenarios for Sustainable Road Infrastructure*' (ISSRI) scenario planning methodology. Using the ISSRI scenario planning methodology will be used to interrogate a range of innovative scenarios to consider the availability, reliability and cost of existing and emerging options, considering the likelihood of adoption and appropriateness of each scenario in the context of various socio-economic and environmental conditions.

As part of the second stage of the project beginning in October 2012 the research team intends to expand ISSRI to consider a wider range of potential scenarios in collaboration with partners.

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