

Navigating the future of roads – considering potential impacts of environmental and social trends on road infrastructure

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Abstract

Providing mobility corridors for communities, enabling freight networks to transport goods and services, and a pathway for emergency services and disaster relief operations, roads are a vital component of our societal system. In the coming decades, a number of modern issues will face road agencies as a result of climate change, resource scarcity and energy related challenges that will have implications for society. To date, these issues have been discussed on a case by case basis, leading to a fragmented approach by state and federal agencies in considering the future of roads – with potentially significant cost and risk implications. Within this context, this paper summarises part of a research project undertaken within the ‘Greening the Built Environment’ program of the Sustainable Built Environment National Research Centre (SBEnc, Australia), which identified key factors or ‘trends’ affecting the future of roads and key strategies to ensure that road agencies can continue to deliver road infrastructure that meets societal needs in an environmentally appropriate manner. The research was conducted over two years, including a review of academic and state agency literature, four stakeholder workshops in Western Australia and Queensland, and industry consultation. The project was supported financially and through peer review and contribution, by Main Roads Western Australia, QLD Department of Transport and Main Roads, Parsons Brinckerhoff, John Holland Group, and the Australian Green Infrastructure Council (AGIC). The project highlighted several potential trends that are expected to affect road agencies in the future, including predicted resource and materials shortages, increases in energy and natural resources prices, increased costs related to greenhouse gas emissions, changing use and expectations of roads, and changes in the frequency and intensity of weather events. Exploring the implications of these

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potential futures, the study then developed a number of strategies in order to prepare transport agencies for the associated risks that such trends may present. An unintended outcome of the project was the development of a process for enquiring into future scenarios, which will be explored further in Stage 2 of the project (2013-2014). The study concluded that regardless of the type and scale of response by the agency, strategies must be holistic in approach, and remain dynamic and flexible.

Keywords: road, future, trend, strategy, transport

1. Introduction

A range of factors are placing an increased amount of pressure on Australia's road network such as changes to weather patterns, road material resource shortages, the changing usage and expectation of roads and transport, population growth and urbanisation, and increases in energy and resource prices. The Organisation for Economic Co-operation and Development's (OECD) Economic Survey (2010) described Australia's increased congestion in its transport infrastructure as an 'infrastructure deficit'. While on the other hand, research suggests that in the developed world the use of cars has peaked and demographic and digital change are impacting traditional movement patterns, resulting in a lesser need for road network expansion and rather a greater sharing of existing road space (Brookings Institution Metropolitan Program, 2008; Newman & Newman, 2006; Newman & Kenworthy, 2011). These ever-changing trends and pressures demand that road agencies be mindful of this rapidly changing world and proceed with informed and transparent approaches. A number of new technologies and processes may need to be adopted in order for Australian road agencies to respond to the pressures associated with the future of roads and remain at the cutting edge of best practice on road planning, assessment, building and management.

Long-term planning and resilience-building is urgently required in response to emerging issues related to environmental impacts, carbon legislation, economic risks and social demands, to provide reliable and effective road networks into the future. Particularly relevant in Australia, where 814,000 kilometres of road network spans a wide range of geographic areas (see Figure 1), the cost of road construction in Australia is estimated to be in the order of \$17.5 billion per year (Bureau of Infrastructure, Transport and Regional Economics, 2009). The road maintenance cost is estimated to be in the order of \$5 billion per year and rising. This rising maintenance task, in which the cost is estimated to be in the order of \$5 billion per year and rising (BIS Shrapnel, n.d.), was made clear by the forensic work of BIS Shrapnel in 2012 who revealed that for every \$100 of net assets in Australia, we are only spending \$1.44 on maintenance (Hart, 2012), which has resulted in years of under spending in maintenance on roads, public rail.



Figure 1: Major Australian road networks

It is critical to understand 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, and 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 for transport infrastructure. For example, roads support an automobile industry that employs millions of people and sells a copy of its product every 1.5 seconds (Worldmeters.info, n.d.). 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 agricultural industries (Australian Bureau of Statistics, 2010).

The use of roads has become a core part of an economies activity, for example a cup of coffee can be based on nearly 30 different transport related activities. However, while the economic benefits of road construction and use are well known, the environmental impact and associated future economic impacts are typically underestimated. For example, each kilometre of road constructed, and associated infrastructure, requires large quantities of aggregates, concrete, asphalt and steel to be sourced, 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 (InterAcademy, 2007).

2. Method Summary

This report outlines the commencement of an approach developed by the SBEnrc working closely with the Western Australian and Queensland road agencies. It outlines findings on a number of key trends affecting the future of roads and will highlight the potential impacts on social well-being. It will begin an exploration into developing strategies to ensure that roads continue to deliver social needs and that a transparent and deliberative approach to road policy issues may enable Australian road agencies to maintain their global best practice edge.

This project presents the findings of a research project as part of the Sustainable Built Environment National Research Centre (SBEnrc) in Australia. The research has included findings from a global literature review, four stakeholder workshops, and extensive research based collaboration with industry. The project is supported by Main Roads Western Australia, QLD Department of Transport and Main Roads, Parsons Brinckerhoff, John Holland Group, and the Australian Green Infrastructure Council (AGIC).

Table and diagrams shown in this paper were sourced from the findings of SBEnrc stakeholder workshops, hosted by Main Roads Western Australian in Perth on 12 July 2011, and Queensland Department of Transport and Main Roads in Brisbane on 9 September 2011, facilitated by Curtin University and Queensland University of Technology. The second series of stakeholder workshops was held in each respective city on 27 April 2012 and 13

April 2012. Of the 75 participants, Government employees were well represented on behalf of the project partners while a range of industry associations, private, public and academic professionals contributed towards the breadth of analysis and range of discussions.

The 2011 workshops were aimed at learning from the experiences of participants, identifying a range of challenges the research team must consider, and gaining a strong understanding of how the research can directly support and enhance industry and government practices and policies. Hence, the workshops were a valuable opportunity for the research teams to engage with the project partners and experts in the field to ensure that the projects are well informed and guided towards tangible outcomes.

The 2012 workshops were structured around a new methodology developed by the research team to explore future trends related to roads and sustainability in order to consider a range of possible strategic responses. The process has been succinctly summarised below in Figure 2, based on an inverted triangle to demonstrate the progression of the process, starting with a highly complex idea or goal (i.e. planning for the future of roads) and narrowing down to tangible outcomes (i.e. identifying strategies to respond to specific future risks). Each stage of the process was designed to deliver specific outputs for the research investigations and industry partners.

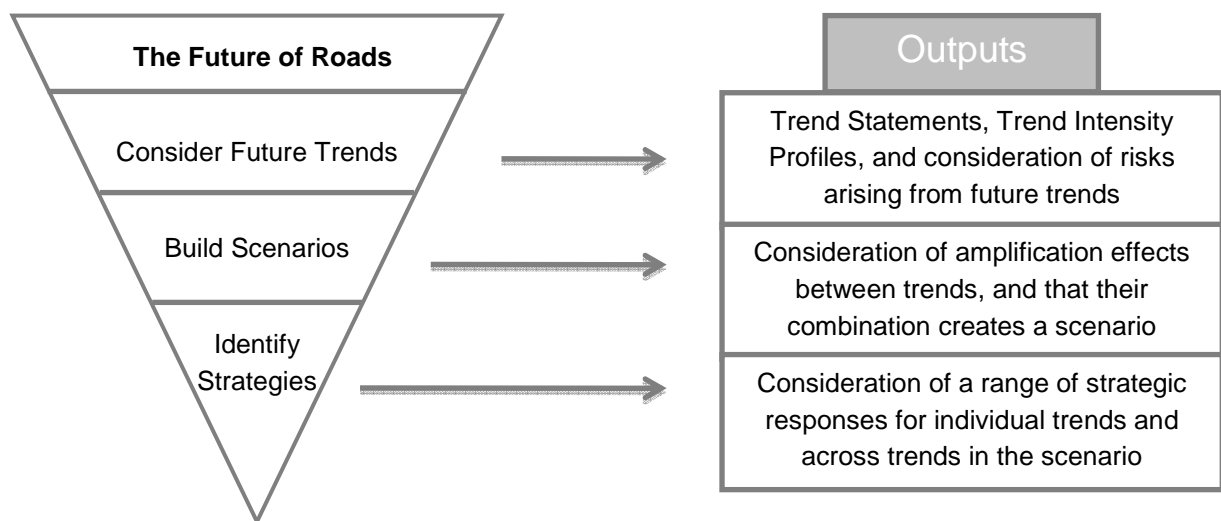


Figure 2: Workshop process for considering the future of roads

3. Discussion – Trends

A new range of complex social, economic and environmental pressures will face road agencies and the transport network, presenting challenging implications for society. Global trends are emerging that can inform the context of these issues and allow further investigation for agencies. An early understanding of the social, economic and environmental trends affecting the future of roads will enable the development of strategies to ensure that road agencies can continue to deliver road infrastructure that meets societal needs in an environmentally appropriate manner. The following section uncover the global

emerging trends and investigate findings from road industry workshops and proposes some of the key trends and processes for addressing their impacts.

3.1 Emerging global trends

A lead article in the September 2012 edition of the Economist examined an emerging global trend revealing the term 'peak car'. It describes the concept of car use peaking in the world's developed nations (Economist, 2012) and reflects on an Australian Government report examining the phenomenon and the effect on government road and transport policy. Factors considered to be significant were underpinned by social influences, including the use of digital mediums instead of travel, online shopping, changes in demography with a preference towards more urban living and the reduced attraction of automobiles, and other factors including increased fuel costs and climate policy. Meanwhile road agencies are absorbing what this means for the road network and their approach to road building, operations and maintenance, as they attempt to resolve increasing congestion due to the 'infrastructure deficit' outlined in a 2010 OECD report on Australia, and the political cycle of new public infrastructure.

The dominant global perspective illustrates that an opportunity exists to transform the way road infrastructure is conceived and harnessed, to assist society to respond to a range of environmental and social pressures. Innovations in the construction, road use and management in order to manage these changes can now be seen. The most provoking global trends are those developing from new influences of technology, vehicle ownership patterns and maturing network expectations of informed citizens. Emerging global trends identified during the literature research are listed below in more detail:

- Community expectations regarding road space and use are changing. A US study described that 75% of youths would rather own a smart phone than a car reinforcing we have moved from the age of ownership to the age of access. Car ownership is declining while public transport use, walking and cycling is increasing and people are moving to higher density locations which support reduced car dependence. This is reflected in metropolitan areas across the globe where there is a move towards citizens reclaiming space that was for cars and car parking (see Figure 3);



Figure 3: The reclamation of space in New York's Times Square

- Vehicle design including the size, shape and fuel use is evolving, with manufacturers changing the power source of vehicles away from fossil fuel and the subsequential implications of roadside infrastructure to service these changes;
- Roads have the potential to generate and also provide electricity with commercial businesses exploring the solar potential of roadways, harnessing of the energy produced by the motion of traffic and using magnetic energy to charge electric vehicles while they are driving;
- Existing transport infrastructure can be used more efficiently. Many innovations look at how existing road infrastructure could be used more efficiently, exploring behaviour change policies, parking restriction policies, different technological innovations, such as driverless vehicles to assist congested traffic flow, managed lanes, innovative congestion or road user charging and prioritising public transport within established road corridors; and
- Raw aggregate alternatives for use in pavement construction are emerging to reduce increased extraction and transport costs due to the poor accessibility of quarries and strict aggregate quality guidelines. Wastes are increasingly being repurposed for use in road construction, evident in India whereby the incorporation of recycled plastic bags have been shown to improve performance under excessive solar heating. Furthermore, roads are being used as repositories for carbon, and insitu-stabilisation techniques (like using natural rubber additives) are gaining credit for its adaptable sustainability solutions.

3.2 Emerging trends for Australian road agencies

In the coming decades the design, construction, operation and maintenance of roads will face a range of new challenges. Many of these will bear little resemblance to challenges previously faced - a result of a growing number of interconnected environmental, social, and economic pressures or trends. For instance, environmental pressures will include the impacts of climate change on rainfall patterns, temperature profiles and accelerated maintenance cycles; economic pressure will include greater road freight demand, resource shortages (aggregates and water) and predicted increases in energy prices globally; and social trends will include a shift to lighter vehicles, smart phone technology influences on mobility, population pressures, and political pressure to adapt to climate change.

Drawing on the findings of SBEnc Stakeholder Workshops in 2011 hosted by the partner road agencies and facilitated by Curtin University and QUT, Table 1 below shows the results of an exploration potential global trends. Participants identified both positive and negative changes in order to conceive the future global environment for the road industry. Participants were asked to identify the most influential increasing pressures, listed first and highlighted with an asterisk.

Table 1: Proposed list of both positive and negative changes used to conceive the future global environment for the road industry (drawn from stakeholder workshops)

Potential trends affecting the future of roads (drawn from stakeholder workshops)	
<ul style="list-style-type: none"> - *Climate change - *Rising price of oil - *Increased community action - *Decreasing access to resources (aggregates) - *Population growth - *Increased freight - *Maintenance costs - *Increased community expectations of transport network - *Employment and skill shortages - *Global financial crisis - *Water scarcity - A price on carbon - Technology innovation, e.g. smart roads for driverless cars - Rapid urbanization and densification - On-line shopping - Increased use of social networking - Increased use of smart phones and applications - Increased frequency and intensity of extreme weather events 	<ul style="list-style-type: none"> - Growing environmental awareness and cooperation - Modal shifts to rail and public transport - Biodiversity degradation and collapse - Loss of agricultural land - Increased automation - Waste reduction and harnessing - Growing middle class - Peaking of food production - Alternative fuel sources - Changing world powers - Pressure for intergenerational responsibility - The influence of the government - Decentralisation - Congestion increases or decreases - Globalised tourism - Health costs and impacts - Changing lifestyles affecting mobility - New transport paradigms - Short political cycles - Methods of energy generation

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.

The list revealed distinct trends emerging in the form of overarching themes. The themes common to both workshops were climate change leading to extreme weather events, the rising price of fossil fuels, water scarcity and the increased importance of the community as a key stakeholder. Participants of the Queensland workshop identified population growth and the changing influence of the governments as particularly important, which reflect specific pressures to Queensland. Interestingly, Western Australian (WA) stakeholders identified resource shortages as a key global change, whereas Brisbane participants listed accessibility issues leading to the shortage of aggregate resources rather than a decreasing supply. It is proposed that this reflect on the state's long history of resource shortages and changing outlooks within the road construction industry on the long-term viability of resource use in Western Australia.

3.3 Identification of potential trends by stakeholders

In consultation with road agency partners, the above list was developed into ten trends for further exploration. The research team investigated each trend to establish a series of 'trend statements', which analysed information about the trend profile, timeframe and risks. The list of ten trends is as follows:

1. Roads require more frequent and costly maintenance
2. More extreme weather events and sea level rise require a more resilient road network
3. Oil based road surfacing becoming unfeasible
4. Demand for new infrastructure due to an increase in active and public transport
5. Aggregate shortages
6. Road freight increases in size & quantity
7. Funding constraints on new projects & on maintenance of existing infrastructure
8. Road and public transport infrastructure reaches capacity
9. Electric & alternative fuel vehicles mainstreamed
10. City planning densification requirements along rail lines & for infill development
11. Information technology and smart phones influence transport and mobility patterns

It is understood that this list is not conclusive; however it serves as a useful base from which to analyse the impacts to road agencies, consider the amplification of trends when combined, and make preliminary steps into scenario planning. Within the professional experience of the practitioners present in the 2012 workshop series, the stakeholders confirmed the trends as suitable representations, alongside reaching a consensus for the addition of technology, smart phones and intelligent transport systems (ITS) as being influential to road agency roles in the coming decades.

Drawing on the findings of 2012 series of SBEnc stakeholder workshops road industry representatives from the public and private sector, along with academic and industry associations considered a short list of emerging trends and its effect on state roads in the coming two decades. The agreed top four in each state are shown in Figure 4.

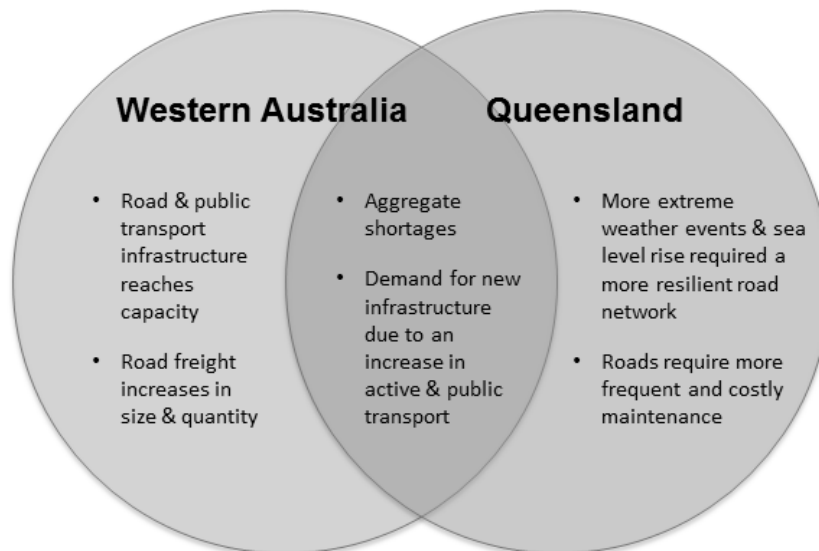


Figure 4: Future trends selected for consideration by SBEnc partners and stakeholders as part of the 'Future of Roads' workshops in Brisbane and Perth, 2012

Reflecting on the trends selected the research team suggest that there are some key reasons why particular trends are important to each state. Both Queensland and Western Australia are experiencing increased infrastructure demands as a results of mining booms, putting enormous pressure on natural resources to service these requirements, evidenced by the 'aggregate shortage' trend being selected with the most votes in both states. A changing social culture, population growth, and growing congestion in both capitals, Brisbane and Perth, have given rise to a greater number of trips by walking, cycling, and public transport, putting pressure on existing infrastructure, evidenced by this trend being selected in both states. The recent extreme weather events during the summer of 2011 have clearly cemented the concern regarding climate change impacts on roads in Queensland, and this is shown through the appearance of the trend 'increase in extreme weather events'.

The stakeholders were provided with a process to reach agreement on emerging trends relevant to the road network and that set the platform to identify strategic responses. These strategies can be developed in the short-term to combat the risks and build resilience in our road networks. This is known a scenario planning, and a unique methodology was developed for a workshop style framework to breakdown the complexity. Scenario planning enables decision makers to overcome preconceived ideas discuss strategies for the future and develop informed strategies that combat risk. Scenarios are not predictions; rather they provide support for informed decision-making, enabling analysis of decisions, the understanding of relationships between issues, and the challenging of cultural norms and assumptions. They are part art and part science enabling foresight for decision makers. This will be explored further in the ongoing research however insight into scenario planning can be discovered by adding an extra dimension to the list of trends and begin considering them in combination whereby they may amplify the trend over time and the associated risks, examples of which include:

- 'More extreme weather events' leading to increased damage of main roads and 'roads requiring more frequent maintenance;'

- 'Aggregate shortages' leading to increased costs of aggregates and 'more costly road maintenance' in Queensland;
- 'Road freight increases in size and quantity' leading to increased design strength requirements for road pavement, contributing to 'aggregate shortages' in Western Australia;
- Trends that may reduce impacts of another include; and
- 'City planning densification along rail lines and infill development' alleviating the impacts of 'road transport infrastructure reaching capacity.'

4. 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 road infrastructure is made, how they are shared, and how they are managed. It will be important for the road and transport 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.

As agencies look into the coming decades 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. The research reveals how industry stakeholders can continue to participate in the process of risk and strategy analysis associated with current and future trends, to develop a platform for informed and transparent decision-making in the identification of powerful strategies to address the future of roads and combat risks to road infrastructure.

Implications for state and federal agencies

This research proposes to state and federal agencies that there is a changing role for road agencies, and importantly, the structural shift that is occurring within them, which is leading them potentially focus less on new infrastructure and more on maintenance and enhancing the efficiency of existing roads. The outcomes of this research enable road agencies to identify emerging trends that impact on the state road network, and develop strategic responses that enable road agencies to combat risks and build resilience. This aligns with the desire of both QTMR and MRWA to adopt a more holistic planning framework that accounts for social, economic and environmental drivers and outcomes. The Government benefits from the project's research include:

- informed policy and management decisions for a resilient road network;
- greater insight into changing roles for road agencies and leverage points for action;

- a scenario planning methodology to stimulate responses and identify leverage points for strategic action; and
- more informed targeting of funding for future research.

Implications for industry

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. Industry benefits from this project include:

The outcomes of the 'Future of Roads' project provide industry with a number of benefits, including:

- a better understanding of emerging options to reduce greenhouse gas emissions associated with road construction;
- improving strategic positioning;
- providing guidance on areas of specialisation for product innovation for reducing the environmental impacts during road construction; and
- understanding market gaps and resultant business opportunities.

Implications for future research

There has been little focus nationally or internationally on assisting road agencies to understand the potential future risks of trends related to the changing expectations of road users, climate change and resource availability despite trends that suggest major reassessment may be needed. This research project highlights that methods are available to inform medium to long-term planning and resilience-building to provide reliable and extensive road networks in future. Road agencies around the world have been oriented mostly to building roads, ignoring the changing circumstances; however there are conflicting trends about car use and public transport that mean they must now redefine their role. Australian road authorities are pioneering how to investigate the pressures facing the future of roads and consider how a strategic response can be informed.

Further research into the environmental and social trends affecting road infrastructure is required to enable determination of the hierarchy and urgency of strategies required to navigate the future of roads. This second phase of research is currently under the final stages of consideration by the Sustainable Built Environment National Research Centre (SBEncr, Australia) and interested road agency research partners (existing and new).

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