An Investigation into Strategies and Solutions for the Future of Roads

A Sustainable Built Environment National Research Centre (SBEnrc)

Industry Report

Sustainable Built Environment National Research Centre

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Synopsis

The coming decades will see a great deal of innovation and creativity in the way that road networks are designed, constructed, used, and maintained. This report presents a summary of key findings related to '*Technology and Process Innovation'.* The report covers three areas selected by partners, namely active traffic management, route and signal lighting, and renewable energy.

Acknowledgements

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Strategies and Solutions for the Future of Roads

Introduction

The coming decades will see a great deal of innovation and creativity in the way that road and transport networks are designed, constructed, used, and maintained. This will be sparked in part by the need to respond to climate change, resource shortages, shifting transport preferences, and increasing maintenance costs.

The SBEnrc is committed to assisting our nation to navigate this challenging future in a way that strengthens our economy, creates jobs, and delivers strong environmental outcomes. As with all SBEnrc projects, this project has been developed in close collaboration with government and industry partners to guide and inform the creation of outcomes to provide tangible value to the road and transport sector.

This report presents a summary of key findings from the SBEnrc project '*Strategies and Solutions for the Future of Roads*' in the research stream of '*Technology and Process Innovation'.* The following three areas have been selected by industry partners for investigation:

- Active traffic management using detection and monitoring devices, freeway control systems and driver information systems to reduce traffic congestion, trip time, and vehicle emissions;
- Updating route and signal lighting to reduce running costs while providing appropriate and safe levels of illumination; and
- The inclusion of renewable energy generation technologies in road and transport infrastructure and adjacent land.

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Active Traffic Management Methods

Managed Motorways as a concept began in the United Kingdom in the early 2000's. Since then a number of measures for the active management of traffic on motorways have been developed. Such measures can include the ability to change lane useage, speed limits, and on-ramp flow rates depending on various control conditions.

These active traffic management measures can influence road user behaviour and improve traffic flow, increase road safety, reduce fuel consumption of vehicles, reduce time spent in congestion. Due to the interconnected nature of road systems such outcomes can influence the performance of other sections of the system, such as traffic re-routing due to ramp controls or crashes that may impeade vehicle flow.

According to the U.S. Department of Transportation there are a number of benefits of investing in active traffic management measures, including:[1]

- Increased throughput,
- Increased capacity,
- Decrease in incidents,
- Decrease in incident severity,
- More uniform speed,
- Decreased headway between vehicles,
- More uniform driver behaviour,
- Increased trip reliability,
- Reduction in traffic noise,
- Reduction in emissions, and
- Reduction in fuel consumption.

Whilst the use of individual active traffic management mechanisms can yield significant benefits, these benefits compound when a combination of measures is used as part of a coordinated road network management system. Such systems can deliver significantly reductions in congestion, crashes, fuel use (and associated greenhouse gas emissions), and particulate matter emissions.

Smart management of motorways can also lead to the greater utilisation of existing infrastructure to deliver a greater volume of traffic which can lead to the deferment of capital investment needed to keep up with growing demand - providing time to explore multi-modal transportation options.

However despite the potential improvements to freeway performance VicRoads cautions that '*not every freeway needs to have every component of managed freeways*',[2] and hence it is important to ensure that the measures implemented are suitable for both the road and the road system as a whole.

The following section provides a brief overview of key traffic management measures and their roles in managed freeway operations, informed largely by the experience of VicRoads. The following section provides an overview of three key types of active traffic management measures, namely:

1. Detection and Monitoring Devices,
2. Freeway Control Systems, and
3. Driver Information Technology Systems.

Each of these measures will be briefly introduced and their implementation will be illustrated to form the basis for the discussion for further implementation in Australia.

Detection and Monitoring Measures

The detection and monitoring of freeway operations is the foundation of systems to better manage main road networks. Such measures provide real time data to inform control measures such as lane use and ramp metering, along with notifications to road users.

A summary of key detection and monitoring measures is presented in Table 1 (which contains edited extracts from the VicRoads Managed Freeway Guidelines).

City of Pittsburg Trial, USA

The City of Pittsburgh has trialled a detection and monitoring system designed by Carnegie Mellon University that involves the use of cameras and in-road sensors to measure traffic volumes at nine intersections in order to fine-tune traffic lights to best accommodate actual vehicle flow.

Over a 3 month period in 2012 the system demonstrated reductions in wait times at intersections of an average of 40%. Travel time through the area was found to have declined by 26%, the average number of stops that a vehicle made was reduced by 31%, and vehicle emissions were reduced by an estimated 21%.[3]

According to the Pittsburg Gazette: '*Pittsburgh Mayor Luke Ravenstahl said the pilot's success was a breakthrough that could make the city's traffic system work more efficiently and reduce the need to do expensive road widening or eliminate on-street parking to facilitate traffic flow*'.

Freeway Control Systems

Drawing on data from the detection and monitoring measures a number of freeway control systems can be used to improve freeway performance, as in Table 2.

VicRoads Managed Motorway Trial, Australia

In 2007 VicRoads undertook a pilot project worth $1M to investigate the use of managed motorway measures along the Monash Freeway. This pilot

Table 1: Managed freeway detection and monitoring measures[4]

Measure	Description
Vehicle Detection Equipment	*Vehicle detection equipment provides volumes, speed, occupancy, and vehicle classification on a lane by lane basis, and is the basis of freeway monitoring and control.*
Closed Circuit Television (CCTV)	*Provides vision of the freeway, enabling more detailed assessment of conditions than provided by vehicle detection equipment and are also shared with key incident and emergency management.*
Incident Detection Capabilities	*Direct detection of incidents (image processing systems), algorithms applied to traffic data, and help phones.*
Environmental Monitoring	*Monitors environmental conditions such as temperature, wind speed and water levels, and can also directly activate equipment such as pumps and warning signs.*
Travel Time Tracking Equipment	*Tracks vehicle movements for travel time calculations.*

upgraded the existing traffic lights used to control flow entering the motorway using a ramp signal algorithm.[5]

According to VicRoads:

> *'Improved travel speed both in the AM and PM peak has resulted in a net savings of approximately 5 minutes per vehicle over the 15km section... The daily economic benefits (travel time savings and vehicle operating cost savings) were estimated to be around $94,000 per day.'*

Building on the success of the pilot project VicRoads developed a $1.39 billion M1 upgrade project that included coordinated ramp signalling at 64 sites along the 75km corridor. The project used a lane use management system on over 19.5km of the motorway that comprises of:

- Integrated lane control,
- Variable speed controls, and
- An en-route information system that can use pictograms or text messages to communicate directly with drivers about traffic conditions, expected trip times, and safety reminders.

The project was completed in 2010 and according to John Gaffney from VicRoads the use of active traffic management measures resulted in *'a reduction in congestion of 30% during peak periods, a reduction in crashes of up to 20%, and an expected community benefit of $14.5 billion in terms of reduction in crashes and monetised travel time savings'*.[7]

Table 2: Managed freeway control system measures[6]

Measure	Description
Freeway Ramp Signals (FRS)	*Manages access to the freeway, to prevent capacity being exceeded (and subsequent flow breakdown), by breaking-up groups of entering vehicles to avoid overload of the merge area. This is most effective when implemented as a corridor-wide adaptive system providing full control of the freeway and allowing effective management of queues at entry ramp signals.*
Variable Speed Limits (VSL)	*Assists in maximising safety in adverse conditions, such as high winds, road works and incidents. VSL can also assist in maximising capacity during heavy demand and is best achieved in conjunction with FRS.*
Lane Use Management	*Allocation and management of available road space to achieve desired performance outcomes and can include dynamic use of the shoulder for exit queue storage.*

Driver Information Technology Systems

Driver information technology systems (ITS) can be used to inform road users on the performance of the freeway in order to make decisions about which routes to take, which is valuable information to avoid delays in the case of crashes or road works, as summarised in Table 3.

City of Edmonton Smart Roads Projects, Canada

According to IBM in their Smarter Cities Challenge Report (2011), the City of Edmonton's mission is to be the global leader in urban traffic safety. The City has adopted a longer term 'Vision Zero' for fatalities and serious injury collisions, with shorter term strategies and targets using safe system approach.[8]

The City of Edmonton is using a range of smart road options including:

- *Intelligent Transportation Systems* that use new and emerging technology to reduce congestion, save money, improve safety and reduce environmental impacts in all areas of transportation.
- *Traffic Responsive System* that actively monitors traffic patterns in the Northlands area 24 hours a day, 7 days a week, and automatically applies the appropriate signal timing plans to improve traffic flow.
- *Yellowhead Trail Simulation Laboratory and Edmonton Showcase*: The City has completed the concept and planning phase of the Yellowhead Trail ITS project and is waiting funding for implementation. By combining the current intelligent traffic tools with the new computer system, traffic will be controlled more efficiently.

Table 3: Managed freeway Driver Information Technology Systems (ITS) measures

Measure	Description
Real Time Information Signs (RTIS)	*Variable message signs located on arterial roads on the approach to freeway entry ramps providing travel time and other freeway condition information and enable motorists to make route choice decisions before entering the freeway.*
Variable message signs (VMS)	*Allows information to be conveyed to motorists once on the freeway. This information can warn them of expected travel times, hazards or disruptions and detail action for them to take.*
Website	*Pre-trip information and should form part of a broader network-wide travel information strategy. This can include links to CCTV cameras to provide a visual indication of freeway conditions at selected locations.*
Radio	*Radio messages can reach road users both before and during the trip.*

According to the City of Edmonton, '*Realising the Way We Move vision will largely depend on how well the City embraces innovation in transportation and how citizens embrace the options for various commuting methods to support a more compact and integrated city. The City of Edmonton sees immense opportunities for decision making in using analytics to turn data into intelligence.'*

Visit the SBEnrc YouTube channel for a short film on this project

Challenges and Issues Related to Managed Motorways

Whilst there are significant benefits from investment in the infrastructure and technology to enable active traffic management of freeways, there are also a number of challenges that need to be considered for these benefits to be achieved.

Lack of National Guidelines

Australia currently does not have a set of national guidelines for managed motorways which presents a challenge to road and transport authorities intending to incorporate the use of active traffic management measures. The lack of a national guideline has led to disparate approaches to active traffic management measures amongst the state and territory road and transport authorities.

Furthermore there is a lack of international consensus on the role of contemporary traffic theory and the appropriate metrics of success for active traffic management measures. For instance the U.K. measures performance of motorways by looking at the reliability of travel times and the reduction in the impact of incidents on traffic flow. In Victoria however, the performance of motorways is measured primarily based on lane throughput, safety factors, the number of accidents, and travel times.

As part of the enhancement of the understanding of managed motorways in Australia, the '*National Smart Managed Motorways Program*' has been established by the Australian Government Department of Infrastructure and Regional Development to '*deliver more efficient motorways through the application of smart infrastructure technologies to improve real-time management of major motorways*'.[9] As part of the program the government is investing in active traffic management measures in the absence of a national guideline.

Lack of Central Integration of Measures

The central integration of the active traffic management measures enables a system wide approach to motorway management and allows greater effectiveness of managed motorways.

A centralised system can allow:

- The provision of consistant information to road users across the system (such as information on conditions on the motorway and other motorways),
- Greater integration of traffic management devices such as ramp signalling and variable speed limits to maximise traffic throughput across the motorway system, and
- Enhance management of flow during accidents, road works and other events through lane use management.

The central integration of the active traffic management measures with data collected from motorways can deliver real benefits through the use of automated algorithms.

Such systems deployed in a live traffic environment enable greater utilisation of the motorway capacity while reducing trip time and delays to motorists – a win-win situation.

Energy Saving Options for Route, Street, and Signal Lighting

Energy Efficient Light Fittings

There are now a number of Australian examples of energy efficient public lighting projects, as listed in Table 4. Some projects have opted for fluorescent lamps (T5) which offer savings in capital outlay however the gap in cost is closing rapidly as the price of light emitting diodes (LEDs) is falling. Another reason is that LED street lighting is not yet included in the Australian Standards.

In 2014 the main market for LEDs was in Europe and the US where standards for street lighting tend to be much higher than those in Australia. This means that the outputs of units that are available tend to exceed the expectations of the Australian Standards by, in some cases, up to seven times.[10]

Table 4: Australian energy efficient street lighting projects (Compiled from various sources)

	Date	Type	Quantity	Cap. Cost	Savings/yr
Logan City Council, QLD	*2014*	*LED/CFL*	*222*	*undisclosed*	*$16,500*
City of Whittlesea, VIC	*2014-15*	*T5*	*6,900*	*$2.6 million*	*$387,000*
Yarra Ranges, VIC	*2014*	*T5*	*7,000*	*$1.85 million*	*$400,000*
Lighting the Regions Project, VIC	*2013-16*	*LED*	*23,000*	*$5.1 million*	*$2 million*
City of Sydney, NSW	*2012-15*	*LED*	*6,500*	*undisclosed*	*$300,000*

Light Emitting Diodes

Traffic Lights

Following the release of the Australian Standard for LED traffic signals in 2002, SBEnrc partners are leading the way in upgrading traffic signals to LEDs:

- Main Roads Western Australia has upgraded over 80% of traffic lights;
- The New South Wales Roads and Maritime Services has required since 2012 that '*the use of LED lanterns for all new traffic signal installations and reconstructions of existing traffic signals*'; and
- Queenland Department of Transport and Main Roads has stated that over time it will be '*converting standard signal lanterns to LED*'.

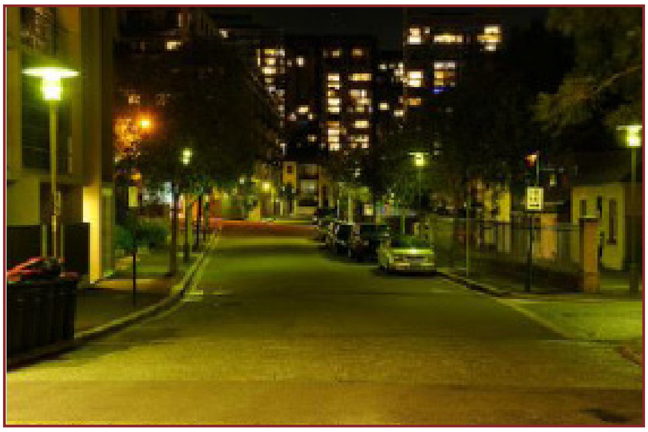
Route and Street Lighting

There are approximately 2.3 million street lights in service in Australia, with around one third on main roads and two thirds on local streets. The annual energy cost of public lighting in Australia exceeds $125 million ($250m including maintenance). According to a study for the Commonwealth of Australia, street lighting is the single largest source of greenhouse gas emissions from local government, typically accounting for 30 to 60 per cent of their greenhouse gas emissions.[11]

The study found that the current major lighting types are mercury vapour (12% of major road lighting national numbers – down from 25% in 2002/3) and high pressure sodium (86% of national numbers – up from 75% in 2002/3).[12]

City of Sydney LED Street Lighting Project

The City of Sydney has committed to reducing greenhouse gas emissions by 70%, including a switch to LEDs for street lighting (responsible for a third of its energy bills). The City of Sydney reports to have '*saved almost $370,000 and reduced energy use more than 46% since March 2012, with the City's roll out of more than 5,545 energy efficient LED street and park lights*'.[13]



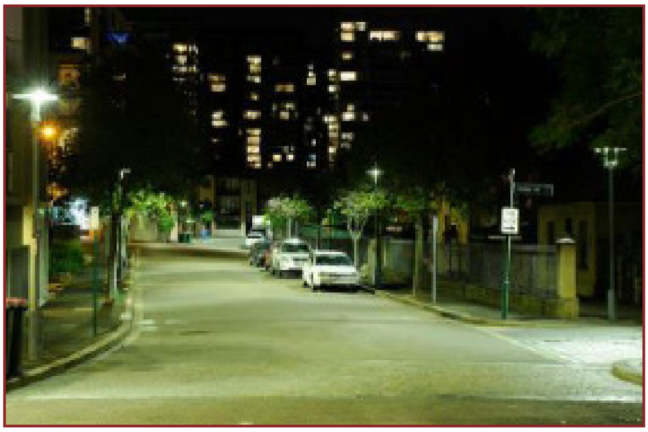


Figure 1: Sydney street before and after LED street lighting upgrade

Los Angeles LED Street Lighting Program

In June 2012 the City of Los Angeles completed a program to retrofit 141,089 street lights with LED's.[14] The Major stated that,

> *'This project cuts LA's energy use by more than two-thirds, saves taxpayers millions of dollars, and reduces carbon emissions by more than 47,000 metric tons every year'.*

The total cost of installation over the four years was $57 million of which $40 million had to be financed. The loan will be repaid in seven years with repayments being made entirely from savings in energy costs (estimated at over $7 million/year or nearly 60%) and maintenance costs ($2.5 million/year). Hence, after 7 years the City is expected to benefit directly from savings in the order of $10 million/year. This is not to mention indirect benefits such as a reduction in vehicle theft, burglary-robbery-theft, and vandalism of 10.5% being recorded from 2009 to 2011.

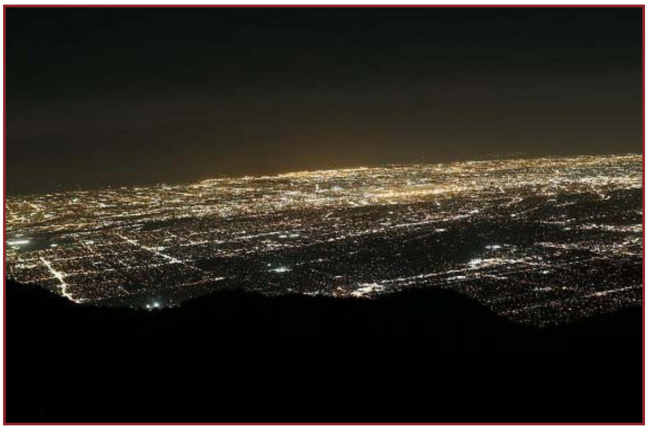


Figure 2: Los Angeles before and after LED street lighting upgrade

A range of other operational and social benefits have been highlighted by the LA Bureau of Street Lighting, including;

- Better compatible with monitoring systems,
- Smaller lamps making them easy to transport and install,
- Reduced packaging which amounts to a 50% reduction in warehousing space requirements,
- Improved uniformity ratio or light and greater visibility,
- Instant off-on operation while having the option to be dimmed, and
- The directional nature of LED light making house-side shields to prevent glare viable.

Other advantages offered by LED's include better dimming control and easier integration of control nodes.

Dynamic Road Lighting

Given the superior energy performance of LEDs the next step is to consider key performance criteria (such as traffic levels, crash rates, pedestrian security, etc.) to assess suitable lighting levels and the potential for dimming light.

Amsterdam A44 Dimmable LED Trial

The lighting on a 7 kilometre stretch of the Amsterdam A44 has been retrofitted with 293 LEDs and a system that controls the dimming of the lights at appropriate times that can reduce energy demand by some 40%. Frank van der Vloed, General Manager of Philips Lighting Benelux, said that the project '*will help provide a safe night-time driving experience while helping to lower energy consumption*'. The system can reduce the intensity of light down to 20% depending on lighting needs. In the case of accidents or inclement weather the lighting is increased by a central control system.[15]

Figure 3: Amsterdam A44 before and after LED street lighting upgrade

Generating Renewable Energy from Road Infrastructure

Solar Power Generation in Road Easements and Rest Stops

Given that there are extensive road easements in Australia there is growing interest in the potential to use this land for renewable energy generation.

According to the Law Reform Commission of Victoria '… *the potential gains in facilitating the development of solar energy collection given the current concern in relation to fossil fuel use, both as to stocks and effects, more than justify facilitating the means by which solar energy easements may be acquired*'.

Early movers to capture the energy producing potential of easements are Canada and the United States, using either individual tracking systems or array of Solar Photovoltaic cells.

The City of Welland, Ontario, Canada

City of Welland has commissioned the construction of a 20kW solar power tracker system produced by i-Energy, a Taiwan-based developer and supplier of photovoltaic power conversion and optimization products

The system is located in an easement near a road intersection that is unsuitable for other uses due to easement restrictions. The City receives a feed-in-tariff credit from Welland Hydro Electric.

Dr Steven Huang, CEO of i-Energy stated that, '*This project can be a model for other municipalities to reposition otherwise non-productive land into solar energy production sites*'.

Figure 4: City of Welland Road Easement Solar Power Tracker System

Figure 5: Oregon Solar Highway Project

Oregon Solar Highway Project

In 2008 the first solar highway project in the United States of America was installed by the Oregon Department of Transport (ODOT). The solar array is located in a highway easement south of Portland as a proof of concept.[16]

The nearly 750 square meter array consists of 594 panels and generates some 112,000 kW/yr to provide electricity to adjacent interchanges and safety parking areas while generating Renewable Energy Certificates. According to ODOT, '*Electricity produced by the system feeds into the utility grid during the day. At night, energy flows back from the utility grid to illuminate the interchange*'.

The commercial feasibility of the project relied on a public-private partnership between the Oregon Department of Transport and Portland General Electric (PGE), Oregon's largest electricity utility. Importantly from a financing perspective, a power purchase agreement committed the Department into purchasing electricity from PGE for a 25 year period. In return PGE, through a subsidiary, took responsibility for financing, ownership, design, operation and maintaining the asset.

The success of the project has led to a larger solar array being installed on land adjacent a rest stop on Interstate 5. The installation which was completed in 2012 included a 1.75 MW array with nearly 7,000 panels.

Such demonstration projects are now seeing a shift in focus from small scale renewable energy generation for lighting or signage to the use of road easements and land adjacent to rest stops.

Solar Power Generation in Highway Noise Barriers

The use of solar photovoltaic noise barriers has been well established in Europe with the first dating back to 1989 when the world's first solar integrated noise barrier was installed along the A13 highway in Switzerland. The barrier runs a distance of just under 1km and generates 176 MWh of electricity each year. In 2009 the first solar integrated noise protection wall was constructed in Italy, shown in Figure 6. The wall runs a length of 1,067m, is 5.6m high, and integrates some 3,944 solar panels to produce some 730kW. In Australia the first solar integrated noise barrier was completed in 2007 on the Tullamarine-Calder Interchange in Victoria that runs a length of 500m and generates 24kW.[17]

Figure 6: Solar Integrated Noise Barrier, A22 Autostrada, Brennero,Italy.

Wind Power Generation in Road Easements and Structures

As with solar photovoltaic cells there is potential to site wind turbines in freeway easements, along with highway weigh stations; however given the noise associated they are less than ideal for situating near rest areas, unlike solar panels.

Also unlike solar panels wind energy technology does not offer the same benefits of decentralised systems, such as locating small numbers of turbines in various road easements along a highway.

According to NREL '*Distributed wind offers some incremental advantages over central-station wind (e.g., production close to the point of consumption; avoidance of high retail electric rates; no requirement to consider transmission interconnection), but it also suffers from some distinct comparative disadvantages (e.g., greater capital costs per rated kW; reduced conversion efficiency; no economy of scale in installation and maintenance)*'.[18]

Hence in order to make wind power feasible for road infrastructure a new approach may need to be taken. Such an approach may be to use wind turbines to harness the wind generated by passing traffic, although this type of application is in its very early stages of development. The technology is being developed in two forms, firstly as stand along bollards with internal turbines (As shown above), and secondly by embedding horizontal turbines inside road barriers.

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Sustainable Built Environment National Research Centre

SBEnrc Overview

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.

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