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AUSTROADS RESEARCH REPORT

Future Asset Management Issues Part 1: Impacts of Greenhouse Gas Emissions on Asset Management

Austroads

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Future Asset Management Issues Part 1: Impacts of Greenhouse Gas Emissions on Asset Management

Austroads

Sydney 2010

Austroads profile

Austroads' purpose is to contribute to improved Australian and New Zealand transport outcomes by:

- providing expert advice to SCOT and ATC on road and road transport issues
- facilitating collaboration between road agencies
- promoting harmonisation, consistency and uniformity in road and related operations
- undertaking strategic research on behalf of road agencies and communicating outcomes
- promoting improved and consistent practice by road agencies.

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Austroads' membership comprises the six state and two territory road transport and traffic authorities, the Commonwealth Department of Infrastructure, Transport, Regional Development and Local Government, the Australian Local Government Association, and New Zealand Transport Agency. Austroads is governed by a Board consisting of the chief executive officer (or an alternative senior executive officer) of each of its eleven member organisations:

- Roads and Traffic Authority New South Wales
- Roads Corporation Victoria
- Department of Transport and Main Roads Queensland
- Main Roads Western Australia
- Department for Transport, Energy and Infrastructure South Australia
- Department of Infrastructure, Energy and Resources Tasmania
- Department of Lands and Planning Northern Territory
- Department of Territory and Municipal Services Australian Capital Territory
- Department of Infrastructure, Transport, Regional Development and Local Government
- Australian Local Government Association
- New Zealand Transport Agency.

The success of Austroads is derived from the collaboration of member organisations and others in the road industry. It aims to be the Australasian leader in providing high quality information, advice and fostering research in the road sector.

SUMMARY

Scope

This discussion paper is aimed to identify the issues relevant to the future operations of road network asset managers, arising from the consequences of greenhouse gas (GHG) emission reduction in the context of reducing the impact of climate change. As government, state road authorities (SRAs) and even councils look to develop policies to reduce GHG emissions, a greater awareness of what asset managers need to do both now and in the future is necessary as a consequence of the need to reduce GHG emissions. This paper identifies those issues that can be potential subjects of future research to assist asset managers.

Findings

The evidence

The evidence of significant and long term climate change is compelling. The predicted future climatic outcomes for Australia are likely to cause significant disruption to the population, industry and agriculture. It is likely that global stabilisation of the atmospheric CO_2 equivalent, or CO_2-e, concentration at around 450 ppm may not be achieved in the immediate future as there are less than seven years before this CO_2-e concentration level is reached.

Proposals to Reduce GHG Emissions

GHG emissions need to be less than half current levels to stabilise atmospheric CO_2-e concentration at around 450 ppm. This can be achieved by global GHG reductions of 60 to 70% by 2050. Although the transport sector is responsible for only about 14% of Australia's domestic GHG emissions, the transport sector should make a proportional contribution to reduce these emissions.

In the transport sector the current approaches to reducing GHG emissions are relatively modest as they produce only marginal reductions in the growth of aggregate GHG emissions. The approaches proposed to reduce GHG emissions for transport involve: (i) reducing car and fuel use by encouraging other transport alternatives and using more fuel efficient road vehicles; (ii) reducing fuel use in urban areas by improved network management to reduce delays; (iii) improving heavy vehicle fleet management to reduce the number of vehicles and increase fuel efficiency; and, (iv) develop low GHG emission zones by improved planning and controls.

Identification of the Impacts of Reducing GHG Emissions on Asset Management

Reductions in GHG emissions associated with road asset management practice could be achieved by adopting the following approaches: (i) provision and maintenance of more public transport/road interchange facilities to integrate the transport infrastructure together with integration of the management of all transport modes, including ITS, to improve transport efficiency; (ii) provision of dedicated public transport lanes in the existing road network, as well as providing separation of light and heavy vehicles on heavily trafficked roads; (iii) improvements to the levels of service on lightly trafficked roads to cope with the increased size of heavy vehicles; and, (iv) widespread use of alternative materials and energy saving approaches in the provision and maintenance of roads.

Identification of Areas of Future Research for Asset Managers

Because of the need to reduce GHG emissions, asset managers need to modify their current asset management practices. To assist this, the following areas for future research were identified:

- quantifying the long term performance of recycled asphalt pavements (RAP) and in situ cold RAP and determining the optimal proportions of these materials in asphalt pavements to reduce GHG emissions while retaining typical long term asphalt pavement performance
- quantifying the long term performance of geopolymer concrete and determining the optimal proportion of its constituent materials to achieve typical long term pavement performance
- quantifying the long term performance of 'warm' asphalt mixes as well as confirmation of the stated reduction in GHG emissions using this approach
- developing highly durable maintenance treatments where exclusive truck lanes become a significant component of the road infrastructure.

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1 INTRODUCTION

1.1 Aim

The aim of this discussion paper is to identify the issues relevant to road network asset managers arising from the need to achieve greenhouse gas (GHG) emission reduction as a response to climate change. As state road authorities (SRAs) and local government look to develop policies to reduce GHG emissions, a greater awareness of what road asset managers need to do both now and in the future to reduce GHG emissions is required. This paper seeks to identify issues and actions that can be the potential subject of future research to assist asset managers.

This is one of two discussion papers aimed at identifying issues relevant to future asset management operations as a consequence of climate change. The other discussion paper will address issues associated with the impact of ‘peak oil’ on bitumen and fuel costs and its consequential impact on road use and asset management funding.

1.2 Background

GHG emissions include carbon dioxide (CO_2), methane, chlorofluorocarbons and nitrous oxide (OECD 2002) which are generated by human and human related activities, such as fossil fuel burning and are considered by the Intergovernmental Panel on Climate Change (IPCC) to be largely responsible for global warming (Glazebrook & Rickwood 2007, IPCC 2007). The IPCC consists of some 2,500 senior scientists and reviewers, as well as government agencies from around the world (Chapman 2002, IPCC 2001). Consequently, the IPCC is regarded as an eminent scientific body able to provide reliable and scientifically based predictions.

Global warming is considered to be the primary cause of climate change with global temperatures reaching a level where dangerous climatic effects are likely to occur (Hansen et al. 2007). Carbon dioxide emissions are considered to be the critical component of GHG.

According to Stern (2006), climate change represents the single greatest example of market failure in human history, because prices associated with GHG generating activities have not addressed the external cost of the consequences of climate change. The consequences of climate change provide a case for government intervention to mitigate climate change outcomes for the community, the environment, business and the economy. Stern (2006) also notes that the benefits of strong early intervention on climate change will outweigh the costs.

The Australian Transport Council (ATC) communiqué for broad transport outcomes included the need for a reduction in GHG emissions as a strategic priority (ATC 2001). The costs of reductions in GHG emissions, or abatement costs, in the transport sector are expected to be higher than any other sector of the Australian economy (Stern 2006) and are therefore likely to take the longest time to fully implement.

2 CLIMATE CHANGE

2.1 The Evidence

There is strong documented evidence showing that global temperatures have risen significantly over the period from 1800 to 2000 (Van Paassen & Watkins 2006). Recent evidence suggests that the majority of the warming observed over the last 50 years was due to human activities which will continue to change atmospheric conditions throughout the 21st Century (Chapman 2002, IPCC 2001). By the mid to late 20th Century GHG emissions were at their highest recorded levels ever. In 2006 atmospheric CO_2 concentrations were measured to be 430 ppm (parts per million) and predicted to rise annually at a rate of some 3 ppm and reach 450 ppm within seven years (Hansen et al. 2007). GHG emissions are often expressed in terms of CO_2 equivalent, or CO_2-e, which is a measure of GHG emissions across all GHG emissions normalised to the impact of the equivalent amount of CO_2 (Nous Group & SKM 2007).

The 'safe' limit for atmospheric CO_2-e concentration is around 450 ppm, based on research according to Hillman, Fawcett & Rajan (2007). At this level of CO_2-e concentration, climate effects are expected to stabilise and result in less dramatic climatic outcomes. However, as noted above, this level of CO_2-e concentration is likely to be reached within less than seven years.

CSIRO (2001) recorded that Australia warmed by 0.7 °C between 1910 and 1999 with the majority of this warming occurring after 1950. In addition, rainfall decreased in eastern Australia after 1950 while increasing in north-western Australia (CSIRO 2007), although these rainfall changes cannot directly be attributed to climate change at this stage. Many of the changes in the patterns of flora and fauna distribution throughout the world and the extinction of some species are regarded as a possible consequence of climate change (Flannery 2005).

Further evidence of global warming is shown by the diminishing sea ice in the northern hemisphere which has decreased in an area the size of the UK every decade since 1972 (Hillman, Fawcett & Rajan 2007). Correspondingly, global sea levels have risen by some 17 cm during the 20th Century, and at an increasing rate from 1993 (CSIRO 2007).

2.2 The Future Predictions

The prediction of the future consequences of unabated climate change and its associated activities requires moving outside existing and past knowledge and moving into areas of considerable uncertainty (Houghton & Styles 2002).

The IPCC (OECD 2002) has predicted rises in global temperatures between 1 °C and 2 °C by 2020 and between 2 °C and 5 °C by 2070. The following predictions are based on the estimated average global warming from six of the IPCC's Special Report on Emission Scenarios (SRES) (IPCC 2000) for Australia up to the year 2100.

2.2.1 Climate

Overall Australia is expected to become hotter and drier. The annual temperatures in Australia are predicted to increase by 2 °C to 6 °C by 2100 (Austroads 2004). The changes in average annual rainfall patterns across Australia are likely to be dramatic as indicated below:

- The south west of Western Australia is estimated to have a 25% reduction up to maximum of 46% reduction in rainfall which will have a major impact on water supply.
- Similarly southern South Australia is estimated to have a 16% to 29% reduction in rainfall which will have an impact on agricultural practices.

- The north east of Victoria and southern New South Wales is estimated to have a 25% reduction up to a maximum of 46% reduction in rainfall which will have a major impact on water supply and agricultural practices.
- More rain is expected in northern Australia with the shifting south of the monsoonal rain band causing predicted average increases in rainfall of 69% in Darwin.

The above climatic changes will have impacts on the location of future population centres and the future long term locations of agriculture and industry. The climate changes are likely to make the road infrastructure more vulnerable to the predicted extreme events for rainfall and wind.

2.2.2 Population

Associated with Australia becoming hotter and drier, greater population concentration increases are expected in Sydney, Melbourne, Perth and Brisbane where most (77%) of Australia's population growth is expected to occur by 2051. Non-metropolitan Queensland is also expected to receive a significant increase in population. New economy industries (high technical and finance) and service industries are expected to grow as part of industry restructuring with greater concentrations of population (Austroads 2004).

2.2.3 Agriculture

Dryland salinity is estimated to increase from the current level of 5.7 million hectares to 17 million hectares by 2050 (Austroads 2004). Dryland salinity occurs in areas where the annual rainfall ranges from 600 mm to 800 mm. Increased dryland salinity means a loss of productive agricultural output. The general decline in the availability of water and its quality will also reduce agricultural output unless less water dependent agriculture is developed.

2.2.4 Road Freight

Past estimates have predicted that the road freight task growth will double for the period 2000 to 2020 (BTRE 2002) on the basis that the road freight task is a function of GDP. Assuming a 3.2% growth of GDP, the total road freight task (tonne-km) is expected to rise annually by 4.1% up to 2015 (NTC/Rare 2008). Beyond 2015, road freight growth is assumed to be related to population by a logistic function to give a 49% increase in road freight per capita by 2100 (Austroads 2004).

The more recent estimates of road freight task (NTC/Rare 2008) growth of around 4% per annum are roughly in line with the average annual growth in road freight task of 5% over the period from 1980 to 2000. These are significant increases in road freight that will impact on the condition of the road infrastructure and cause increased GHG emissions unless measures are taken to reduce them.

3 MEASURES PROPOSED TO REDUCE GHG

In order to stabilise atmospheric CO_2-e concentration at around 450 ppm, which is twice the pre-industrial-age level, GHG emissions ultimately need to be less than half current levels which can only be achieved by global GHG reductions of 60 to 70% by 2050 (Chapman 2002, Flannery 2005, Wong 2008). The transport sector has some ability to make a contribution to the reduction in GHG emissions. However, in view of the severe consequences of climate change, the expected reductions in GHG emissions for the transport sector are relatively modest (DCC 2008), as noted in Section 3.1, and could conceivably be further reduced in the future. It is also expected that the road transport sector will be the last sector to reduce GHG emissions because of the higher abatement costs of this sector (Stern 2006). The measures currently being discussed to bring about this reduction are outlined below.

3.1 Broad Measures to Reduce GHG in Transport

The whole transport sector in Australia is responsible for about 14% of Australia's GHG emissions (Cosgrove & Lu 2003, Garnaut Climate Change Review 2008) with around 88% of these emissions due to road transport vehicles (cars, buses, trucks, etc.) (DCC 2008). Of these road transport vehicles, the largest single contributor to GHG emission is the passenger car at 54.5% of GHG emissions. By applying modest abatement measures, the growth in transport GHG emissions was predicted to be reduced only by around 2 to 4% over the Kyoto period (1990 to 2010) (Cosgrove & Lu 2003, DCC 2008).

Therefore due to the strong imperative to reduce the growth in GHG emissions and stabilise climate change, a number of broad approaches were proposed to reduce GHG emissions for transport, as outlined below by the various proponents referenced:

- Reductions in passenger car use by encouraging the use of improved and reliable public transport alternatives (Skene 1991), improved urban design (Newman 1991) to reduce urban road travel and congestion pricing (Chapman 2002) to directly impact on user demand on specific roads.
- Reductions in fuel use by using more fuel efficient road vehicles (Heywood 2008) that offer fuel reductions from 30 to 50% and carbon pricing (Hensher 2007) to further reduce the wider demand for road transport fuels.
- Improved efficiency in managing and operating the urban road network to reduce fuel use and congestion by the wide use of Intelligent Transport Systems (ITS) (Austroads 2002, BTRE 2004).
- Improved freight efficiency of the heavy vehicle fleet by using larger configured heavy vehicles with higher payloads to reduce heavy vehicle numbers (NTC/Rare 2008) in combination with diesel engines having improved fuel efficiency (Heywood 2008).
- Other non-transport measures such as reafforestation (Richardson 2007) can potentially be used to directly offset all of Australia's transport GHG emissions. However, this measure is costly, although these costs are reduced by the value of the timber products harvested from the forests less the costs of replacing the harvested forest.

Most of the above approaches need political will and a re-direction of infrastructure funding to implement as many of these approaches cannot be implemented in the short term. The impetus for improving the fuel efficiency of vehicles is likely to increase with rising fuel costs due to carbon and congestion pricing and the impact of 'peak oil' on fuel prices.

3.2 Likely Short to Medium Term Measures to Reduce Transport GHG

Recent increases in transport fuel prices have seen a significant growth in the demand for urban public transport. For example, Melbourne's suburban trains had a patronage growth of 20% between 2005 and 2007 (Metlink 2007), while overall public transport patronage grew by 30% from 2004 to 2007 in south east Queensland (Translink 2007). This growth has probably also been influenced by the fact that there has been only marginal improvements in the fuel efficiency of the new car fleet (Thoresen 2008) in the face of these rising fuel prices. However, the increased use of public transport also needs to be supported and reinforced by the increased capacity of public transport and improved levels of service. These improvements need short to medium term increases in funding for a fully integrated public transport sector in both urban and rural areas.

While some potential reductions in road travel may be compensated for by increased public transport usage, sustainable reductions in greenhouse gas emissions may only be achieved by increasing fuel prices through:

- the use of carbon pricing or a carbon credits trading system (Chapman 2002)
- congestion pricing as well as the natural increases in fuel prices arising from the impact of 'peak oil'.

The effectiveness of carbon pricing strongly depends on the price assigned for carbon. These measures need political will to implement because of the public's sensitivity to further increases in fuel prices. If these measures are implemented in the short to medium term, it is likely that the road traffic growth predictions may not be as high as expected and the nature of the vehicle fleet will tend to change with smaller fuel efficient lower mass cars being the predominant passenger vehicle.

More fuel efficient heavy vehicles (in terms of fuel cost per tonne kilometre) are also likely to occur in the form of larger heavy vehicles carrying higher payloads that are supported by more axle groups due to various trailer combinations and increases in axle mass loadings. These heavy vehicle configurations can reduce the freight cost per tonne kilometre and the number of heavy vehicles needed for a given freight task. With further increases in fuel cost brought on by 'peak oil' there may be a strong case for substitution of diesel fuel with compressed natural gas (CNG), although CNG fuel containers will increase the tare weight of vehicles. The possible combination of smaller highly fuel efficient cars and larger heavy vehicles on high level of service urban and rural roads may have the perception, at least, of reduced safety. It is also unlikely that growth in the road freight task will diminish because of the limited possibility of alternative transport modes so the continuing need to improve road freight efficiency while reducing GHG emissions will be strong.

4 LONGER TERM CONSEQUENCES OF REDUCING GHG EMISSIONS ON ASSET MANAGEMENT

4.1 Potential Infrastructures Changes

4.1.1 Changes due to Relocation of Population and Industry

In the medium term, large scale population and industry shifts are unlikely to occur unless there is a very dramatic change in climate. However, the longer term consequence of the need to reduce GHG emissions should initiate more urban consolidation and growth in the capital cities because of the presence of the existing infrastructure and the capability to incrementally increase the capacity of this infrastructure more efficiently than in regional areas. Provided these urban areas include access to employment and industry, agricultural products (food, etc.), education and training facilities and residential accommodation, it may be possible to reduce GHG emissions by using more public transport in combination with fewer passenger car trips that use highly fuel efficient engines.

The above outcomes need to be encouraged through active urban and transport planning, an integrated public and road transport system, incentives for less car use and more reliable and frequent public transport. The impacts of these changes on road asset management could be as follows:

- A stronger operational focus on the workable integration of public transport infrastructure with road transport infrastructure, including the increased provision and maintenance of more public transport/road infrastructure interchange facilities such as car parks at bus/rail interchanges and the provision and maintenance of more walking and cycling facilities that are fully integrated into the road infrastructure.
- The potential provision of dedicated public transport lanes, such as bus lanes, in the existing road infrastructure where this is feasible.
- An increased use and maintenance of ITS information and management systems so that commuting can be planned to minimise travel time even though more than one travel model may be used.
  This will mean more sharing of information between the asset managers of the different transport modes and infrastructures.
- Major institutional changes to road and public transport asset management so that the above integration can occur.

The implementation of the above can only be achieved through institutional changes to public transport and road infrastructure management as well as the integration of urban and transport planning.

4.1.2 Changes due to Changed Vehicle Characteristics

The potential changes in the short to medium term due to changing vehicle characteristics such as lighter and more fuel efficient cars in combination with heavier and larger combination truck and trailer configurations, such as B-triples, may bring about the need for separation of these vehicles for safety and operational reasons particularly in heavily trafficked rural and outer urban areas. The current restrictions on these types of heavy vehicles in urban areas would be expected to continue unless some form of physical separation of light and heavy vehicles is made with the use of truck only lanes where there exists the feasibility of accommodating these into the existing road infrastructure. Potential efficiencies could exist with this outcome because thinner pavements of less width could be used for the light vehicles, while thicker pavements would only be needed for the truck lanes. Some of these changes to lane configurations may be able to be made within existing road formations at relatively low additional cost. However, the maintenance cost demands of truck only lanes will potentially be higher than present as the consequences of truck traffic delays due to maintenance works effects will impact on heavy vehicle costs requiring the use of much longer lasting surface treatments and/or pavements.

The typical relatively low trafficked rural road may need improvements to horizontal alignment and lane width in critical locations, such as curves, because of the increased size and number of trailers associated with heavy vehicles on long haul routes. Increases in pavement strength and improved wearing resistance of surface seals may also be needed where increased axle loads are used. These changes indicate that there will be increased maintenance costs with a strong emphasis on assessing where additional improved local treatments are needed.

Where it is not possible to upgrade the existing road infrastructure, restrictions on large heavy vehicle access will need to apply. These restrictions will have increased GHG emission consequences due to the inefficiency of smaller heavy vehicles, although the extra emissions will be relatively minimal in remote areas.

4.2 The Need for New Management Systems

4.2.1 Full Scale Adoption of ITS

The challenges of sharing road infrastructure with other transport modes (buses, cyclists, pedestrians) and the potential separation of light vehicles from heavy vehicles will need improved information systems and coordination to ensure that the best possible capacity is achieved. The adoption of ITS across a potentially complex system will help this coordination and the achievement of improved capacity.

Many of the ITS applications needed for the above do not currently exist and will need to be purposely developed for these unique situations. The implementation and operation of these applications will demand a high level of skill, information and understanding from asset managers to be fully effective (Austroads 2002).

4.2.2 Integrated Asset Management System

Again as a consequence of a shared transport infrastructure, it may be necessary to develop an integrated asset management system rather than operate separate management systems for each part of the transport infrastructure. This is mainly because of the potential impact of maintaining one asset and its impact on an adjacent and/or shared asset. Longer term funding of an integrated system must ensure that all parts of the integrated system receive adequate funding to maintain the overall desired levels of service.

Day to day asset management operational issues may need an even closer integration of the asset management systems to ensure that all parts of the integrated system are operating as a whole and producing the desired outcomes.

4.3 The Need for Institutional Change

It is highly likely that major institutional change will be needed to bring about the changes that must occur with the integration of infrastructure funding and the operational and asset management of an integrated transport infrastructure. Implementation of institutional change is a challenge because if it is poorly managed a considerable loss of professional and technical expertise may be transferred to other sectors of the economy.

The strong political will needed to significantly reduce GHG emissions in land transport would be more effective through well planned and executed institutional change. The drive for institutional change should be initiated by government where the transport agencies are an arm of the government.

5 IDENTIFICATION OF AREAS OF FUTURE RESEARCH FOR ASSET MANAGERS DUE TO CLIMATE CHANGE

Although the transport sector is responsible for only about 14% of Australia's GHG emissions, there is an opportunity for all sectors to make some contribution to reducing these emissions. As the power generation industry is responsible for the largest single component of Australia's emissions, it may therefore be seen as having the greatest responsibility to make reductions. However, if the transport sector aimed to make some reductions of its own emissions, then the sector would contribute to the overall reduction in emissions.

5.1 Measures to Directly Reduce GHG Emissions via Asset Management

In attempting to reduce GHG emissions, road asset managers may need to use alternative road materials and less energy intensive practices to deliver infrastructure services at current or improved levels of service. The following sections outline a number of issues that arise from reducing GHG emissions that need to be addressed by asset managers.

5.1.1 Alternative Materials

Recycled materials

Recycled asphalt pavement (RAP) has been used successfully for many years in road rehabilitation. However, the acceptance and understanding of RAP as a reliable and soundly performing material is not universal despite its apparent reported significant cost savings. There have been a number of quantitative, medium-term tests done on the performance of RAP. One such study found that after 10 years, sections of pavement that used RAP performed as well as sections that used virgin asphalt concrete (Chen & Daleiden 2005).

Use of recycled pavement also produces less GHG emissions, with the reductions in proportion to the percentage of RAP used in the mixture (Ripoll & Farré 2008), as shown in Table 5.1 below.

Table 5.1: Reductions in GHG emissions due to various RAP alternatives

Asphalt Mixture	RAP (%)	GHG emission (kg per ton of asphalt mix)				□/REF (% change)
		CO2	CH4	N2O	CO2-e	
Reference	0	34.7	1.81E-3	7.06E-4	34.97	–
Alternative 1	5	33.6	1.75E-3	6.77E-4	33.87	-3.2%
Alternative 2	10	32.5	1.69E-3	6.48E-4	32.77	-6.3%
Alternative 3	15	31.4	1.64E-3	6.18E-4	31.97	-9.5%
Alternative 4	20	30.4	1.58E-3	5.89E-4	30.57	-12.6%
Alternative 5	25	29.3	1.52E-3	5.60E-4	29.47	-15.7%

Source: Ripoll & Faré (2008).

The results in Table 5.1 show that the GHG emissions depend upon the proportion of RAP in the asphalt mixture. This includes the GHG emissions related to the transportation and preparation of RAP. While this trend of reduced GHG emissions with increasing RAP content could continue, higher percentages of RAP content are understood to affect performance of the pavement, so there are real practical limits to the increased use of RAP. For example, a 75% RAP content pavement was found to have poor resistance to cracking, due to the brittleness of the aged binder (Chen & Daleiden 2005).

The 10-year study on RAP-pavements noted above was conducted in Texas, which has a climate that is not dissimilar to that in some areas of Australia. However, similar medium to long-term qualitative studies need to be done in Australia before RAP can be a standard material for pavement construction and maintenance. In addition, investigation into the optimal proportion of RAP that produces the greatest GHG emission reduction consistent with similar long term performance of normal asphalt pavements should be addressed.

In situ cold recycled materials

RAP as described above is often brought in from a stockpile. However, it is possible to recycle asphalt on site when rehabilitating a pavement. This has been practiced internationally for many years with reasonable results; however, it requires specialised equipment.

Current recycling practice involves cold-milling the existing pavement to the desired depth. The collected material is then mixed with water and binder until the proper homogeneity is obtained. A tack coat is laid on the newly exposed course, and the recycled course is applied over the tack coat. Finally a wearing layer of some type is laid and the final pavement compacted.

An environmental assessment found that the cold emulsion recycling technique results in nearly 50% energy savings compared to conventional hot mix reinforcement. When the entire chain, from manufacture to application is assessed, the estimated energy consumption is also reduced by 50%. This translates to half the production of GHG emissions of a hot-mix reinforcement (Baillie & Bertaud 2008).

While the savings from reduced energy use and new material cost may be significant, the payback period for the investment in the specialised equipment and training of operators needs to be estimated. As noted above, quantification of the long-term performance of in situ cold RAP pavements RAP needs to be determined in Australia to estimate the payback period and confirm the viability of this practice.

Geopolymer concrete

Conventional concrete uses Portland cement which requires limestone and other materials to be heated up to 1,500 °C to enable the necessary chemical reaction that produces cement (Fernández-Jiménez et al. 2006). The by-products of this reaction plus the energy used for heating means that approximately one tonne of CO_2 is produced for each tonne of concrete. According to the International Energy Authority, conventional concrete production alone is responsible for between 6% and 7% of global CO_2 emissions.

Instead of using Portland cement, geopolymer concrete uses fly ash, which is produced as a by-product from coal-fired power stations. Extraordinarily high volumes of fly ash are produced each year (over 600 million tons were produced globally in the year 2000), much of which currently goes into landfill (Palomo et al. 2007).

Geopolymer concrete has a compressive strength suitable for structural applications and is comparable in behaviour to conventional concrete. In addition, it has superior bonding to steel reinforcements and excellent resistance to attack by sulphate (Rangan 2008).

An independent assessment of one company that produces geopolymer concrete reported that production of their geopolymer concrete produced less that 40% of the GHG emissions of Portland cement. Furthermore, a comparison of the aggregate binder systems showed there was a production of less than 20% of the GHG emissions of the binder system in conventional concrete (Net Balance Foundation 2007).

Because it uses a waste product, geopolymer concrete is more cost effective and produces overall less GHG emissions than conventional concrete; although commercial production of geopolymer concrete in Australia is currently limited, as the industry is still in the early stages of growth.

Although geopolymer concrete has been tested under a variety of conditions; no studies have currently been done into the suitability and long term performance of geopolymer concrete for pavement construction and maintenance. Initially this material could be a low risk application in kerb and channel or footpaths at the local government level.

5.1.2 Energy-saving Approaches

'Warm' asphalt mixes

In a conventional hot asphalt mix, the aggregate is dried and heated to temperatures of approximately 180 °C before the bitumen, which has also been heated to a similar high temperature (depending on the aggregate used), is injected. These high temperatures are used to ensure that the aggregate is completely coated by the bitumen, and that the remaining mix is workable and is easily laid and compacted.

Some European companies have begun to use 'warm' mixes with no apparent loss of final in situ performance. A temperature reduction of 40 °C in the manufacturing and laying process had no measurably significant negative effect on the development of roughness, macrotexture, and braking force coefficient of the pavements in the short term (Carbonneau, Henrat & Létaudin 2008).

Monitoring CO_2 and O_2 emissions during plant production of standard and energy-saving mixes found that CO_2 emissions for energy-saving mixes were reduced by 5% to 30% and O_2 emissions increased by up to 14%. Working with lower temperatures also meant less energy consumption. A gas-fired dryer for example, was found to use 16.5% less gas when processing an equal quantity of energy-saving mix as of standard hot-mix (180 tonnes/hour). An attempt was also made to measure emissions during the laying process, but these levels proved to be too low for detection. It is generally accepted that a temperature reduction of about 12 °C halves fume emissions (Carbonneau, Henrat & Létaudin 2008).

The use of 'warm' asphalt mixes could ultimately replace hot asphalt mixes provided the above claims to no reduction of in situ performance can be demonstrated in Australia while achieving the stated reduction in GHG emissions. Long term performance monitoring of asphalt pavements using this approach needs to be undertaken as well as confirmation of the stated reduction in GHG emissions.

LED traffic signals

In many places around the world, including Australia, incandescent and halogen lamps in traffic signals are being replaced by LED array lamps. According to the Californian Department of Transport (Iwasaki 2003), which began retrofitting their signal lamps in 1998, the primary benefits are:

- up to 85% reduction in energy consumption
- replacement of signal lamps are improved to a five year cycle for red modules and a 10-year cycle for others (incandescent/halogen lamps often need to be replaced every one to two years)
- increased reliability ('burn-out' repairs are reduced by up to 90%, meaning less overtime and a lower chance of a signal failing in operation)
- able to use a battery backup system economically.

The reduced energy consumption of 85% means reduced GHG emissions of similar proportion, and lower operation costs. It has been found that the initial investment in LED modules is paid off through energy savings in approximately three years, depending on energy prices (US EPA 2000). An approach to ensure a wider adoption of LED technology needs to be followed up by all SRAs, including their use for street lighting.

5.2 Measures to Indirectly Reduce GHG Emissions

This section addresses approaches that enable the reduction of GHG emissions directly caused by road users. Some of the approaches have worked well in specific applications, while others have not been as successful. In either case further consideration should be given to the suitability, scale and efficacy of a local application of these approaches and their consequences on road asset managers.

Some of the approaches discussed are not directly related to asset management. However, each approach can impact on the way assets are used and therefore have the potential to reduce GHG emissions. Furthermore, the introduction of these approaches will, as a consequence, require investment in new, or modifications to existing, infrastructure which are issues that asset managers will have to deal with.

5.2.1 Environmental Zones

Environmental zones, also called low-emission or clear zones, have been implemented in many European cities. They work by excluding vehicles above a certain gross vehicle tonnage from inner city areas which as a result directs heavy vehicle traffic on to more appropriate routes, if they are available. Access to the environmental zone by otherwise excluded vehicles is regulated by permits, where larger, older and less efficient vehicles incur a higher permit charge. Environmental zones directly improve air quality, reduce noise pollution and GHG emission within the zone and provide an incentive for fleet operators to upgrade their fleets to more efficient vehicles.

The benefits to individual cities will vary considerable depending on factors such as how the environmental zone is implemented, public compliance, the average age of the vehicle fleet on the road, and pre-existing emission standards for vehicles. A study of environmental zones in Stockholm, which were implemented in 1996, calculated that by the year 2000 there had been reductions within the environmental zone of NO_x and particulate matter of 10% and 40% respectively. It was further calculated the reductions in the atmosphere of NO_x and particulate matter at large were up to 2% and 9% respectively. This outcome was based on an environmental zone that excluded vehicles on the following basis: (i) were over 3.5 gross tonnes and did not meet the Euro I emission standard; (ii) any vehicle nine to 15 years old, unless it had a new engine or was retrofitted with a certified emission control device; and, (iii) any vehicle over 15 years old. It was found that among heavy vehicles, there was a compliance of 90% (Johansson & Burman 2000).

An assessment of how this approach can be implemented in Australia needs to be investigated to determine its technical viability and political acceptability.

5.2.2 Congestion Charging

Congestion charging is based on the concept that consumers should pay for costs that they impose in order to encourage the efficient use of road-space. However, this approach has rarely been implemented in major cities. The benefits of congestion charging will vary markedly depending on where and how such a scheme is implemented.

In 2003 congestion charging was introduced to inner London. Inner-city London was considered to be an ideal candidate for congestion charging because of limited road capacity (much of the network not having been expanded since medieval times) coupled with viable transport alternatives. The congestion charging for London took the form of a £5 (raised to £8 in 2005) fee for private vehicles entering central London between 7.00 am and 6.30 pm on a weekday. Exemptions were made for motorcycles, licensed taxis, vehicles used by disabled people, some alternative fuel vehicles, buses and emergency vehicles.

As a result, average travel speeds increased by 38% (from 13 to 17 km/h), peak period congestion delays reduced by about 30%, and bus congestion delays declined by 50%. At the same time, bus patronage increased by 14%, and subway patronage by about 1%. Taxi travel costs were also reduced by 20% to 40% due to reduced delays.

Some criticisms of the London scheme noted that it did not take into account how far a vehicle travelled inside the charging zone, and that the fee did not vary according to peak travel times or by location, where some roads have a greater congestion problem than others (Litman, 2006).

It was estimated that the traffic and speed changes in the charging zone have resulted in a 16.4% reduction in CO_2 emissions between 2002 and 2003 when the scheme was first introduced. There were also 13.4% reductions in NO_x, and 6.9% reductions of particulate matter over this same time period (EEA 2008).

An assessment of how this approach can be implemented in Australia needs to be investigated to determine its technical viability and political acceptability.

5.2.3 Speed Control

It is well known that the speed at which a vehicle travels has a strong correlation with fuel consumption. It is therefore reasonable to suggest that judiciously imposing more restrictive speed limits can result in lower emissions under certain circumstances. It is understood that the optimal speed is 80 km/h where departures from this speed result in higher GHG emissions.

It is not always appropriate to simply lower all speed limits. Cases where speed limits have been lowered to achieve beneficial results are for sites where there are existing concerns about pollution. An example of this is from Rotterdam where a 3.5 km stretch of a major motorway was reduced from 120 to 80 km/h. In addition to reductions in noise pollution (50%) and accidents (60%), the benefits to emissions were as shown in Table 5.2:

In this case, the speed reduction was popular because of the existing concerns of residents about the high levels of pollution in the area (EEA 2008).

Table 5.2: Estimated reductions in GHG emissions with lower speed

Pollutant	% Reduction
CO_2	15
CO	21
NO_x	15 – 25
PM10*	25 – 35

*Particulate matter measuring 10 μm or less.

Source: EEA (2008).

Reducing speed limits is not a simple matter when the flow of traffic through a network, or section thereof, is considered. Lowering a speed limit for a given section of road could create congestion elsewhere and result in a net increase of GHG emissions. Careful modelling is therefore required to inform decisions about when and how to use this strategy.

An assessment of how speed controls can be appropriately adopted to Australia conditions needs to be investigated to determine its technical viability and political acceptability.

5.2.4 Intelligent Transportation Systems

Intelligent Transportation Systems (ITS) enable road networks to be used efficiently via the transfer of information throughout the network, so that each component (roads, intersections and drivers, etc.) no longer works in isolation, to achieve an overall reduction in congestion. Anything that reduces congestion will bring results in reduced emissions of GHG and pollutants, and deliver time and cost savings to motorists.

Currently there is limited data on the impact of ITS on reducing GHG emissions. The reductions that can be achieved depend greatly on individual applications, and the localities they are servicing.

The consequences of this approach on asset management need to be considered because the approach delivers increased network efficiency.

5.2.5 Improved Network Design

Well-designed roads with sufficient capacity will perform better in terms of reduced GHG emissions than roads that have been built section-by-section according to what was needed at the time. How much improvement in performance, in terms of reduction in congestion and reduced emissions, is possible will depend on the inadequacies of a particular road and the magnitude and type of its traffic flow.

A Norwegian study (Bang 2007) used the AIMSUN simulation tool to compare 3 types of typical improvement to an ‘inherited’ road network. Each simulation used 20 different vehicle types. For the typical improvements, the reductions are shown in Table 5.3:

Table 5.3: Reduced GHG emissions due to network improvements

Network Improvement	Reduction in Pollutants			
	CO_2	CO	NO_x	NMVOC*
Narrow winding 1 and 2 lane road replaced by modern 2-lane road (200 vehicles/hour)	11%	67%	75%	68%
2-lane road of fair standard replaced by a 4-lane motorway (1,200 vehicles/hour)	26%	48%	61%	49%
Congested urban motorway expanded by one extra lane (5,000 vehicles/hour)	38%	56%	61%	58%

*Non-Methane Volatile Organic Compounds.

Source: Bang (2007).

The scope for implementing this approach is likely to be relatively limited in an established road network, nevertheless an identification of potential segments of the road network for these improvements needs to be undertaken for asset managers to quantify the reductions potential for GHG emissions.

6 FINDINGS

6.1 The Evidence and Future Predictions for Climate Change

The current evidence of significant and long term climate change is compelling and difficult to dispute. The predicted future climatic outcomes for Australia are likely to cause significant changes to the population, industry and agriculture. It is also likely that global stabilisation of the atmospheric CO_2-e concentration at around 450 ppm may not be achieved given that it is predicted that there are now less than seven years before this CO_2-e concentration level is reached.

6.2 Proposed Measures to Reduce GHG Emissions

GHG emissions need to be less than half current levels to stabilise atmospheric CO_2-e concentration at around 450 ppm. This can be achieved by global GHG reductions of 60 to 70% by 2050. Although the transport sector is responsible for only about 14% of Australia's GHG emissions, there is an opportunity for all sectors to make some contribution to reducing these emissions.

In the transport sector the current approaches to reducing GHG emissions are relatively modest as they produce only marginal reductions in the growth of GHG emissions. The following approaches have been proposed to reduce GHG emissions for transport:

- reductions in car use by encouraging the use of public transport, improved urban and network design and congestion pricing
- reductions in fuel use by using more fuel efficient road vehicles and carbon pricing to further reduce the demand for road transport fuels
- improved efficiency in managing and operating the urban road network to reduce fuel use and congestion by the wide use of ITS
- improved efficiency of the heavy vehicle fleet using larger heavy vehicles with higher payloads to reduce heavy vehicle numbers in combination with diesel engines having improved fuel efficiency
- development of low emission zones by re-routing heavy vehicle traffic and the introduction of speed controls
- other non-transport measures such as reafforestation can directly offset all of Australia's transport GHG emissions.

6.3 Identification of the Impacts of Reducing GHG Emissions on Asset Management

Reductions in GHG emissions associated with road asset management practice could be achieved as follows:

- via a stronger operational focus on the workable integration of public transport infrastructure with conventional road infrastructure, including the increased provision and maintenance of more public transport/road interchange facilities
- the provision of fully connected dedicated public transport lanes in the existing road infrastructure throughout the urban arterial road network
- the physical separation of light and heavy vehicles so that thinner pavements are used for light vehicles and thicker pavements are used for the truck lanes on heavily trafficked roads

- local improvements to alignment, pavement strength, wearing surfaces and lane on lightly trafficked roads to cater for the increased size of heavy vehicles
- efficiencies associated with increased use and sharing of ITS and management system information between the asset managers of the different transport modes
- the use of alternative materials (recycled materials, in situ cold recycled materials, geopolymer concrete) and energy saving approaches ('warm' asphalt mixes, LED traffic signals) with lower GHG footprints
- major institutional changes to road and public transport asset management so that the above integration can occur.

6.4 Identification of Areas of Future Research for Asset Managers

As a result of a need to reduce GHG emissions, asset managers will need to modify their future practices. To assist this, the following areas for future research have been identified:

- quantifying the long term performance of RAP and in situ cold RAP and determining the optimal proportions of these materials in asphalt pavements to reduce GHG emissions while retaining typical long term asphalt pavement performance
- quantifying the long term performance of geopolymer concrete and determining the optimal proportion of its constituent materials to achieve typical long term pavement performance
- quantifying the long term performance of 'warm' asphalt mixes as well as confirmation of the stated reduction in GHG emissions using this approach
- developing highly durable maintenance treatments where exclusive truck lanes become a significant component of the road infrastructure.

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Abstract:

This paper aims to examine the impact of reducing greenhouse gas (GHG) emissions on road asset management in the next 10 to 20 years. This is the first of three discussion papers related to a strategic review of future asset management issues. The current evidence of significant and long term climate change is compelling. GHG emissions need to be less than half current levels to stabilise atmospheric CO_2-e concentration, although the proposed GHG emission reductions in the transport sector are relatively modest, they will substantially impact on asset management.