AusLink Urban Arterial Road Network Congestion Review: Traffic Management Systems (Non-Freeways)

Consultancy Report Prepared for

COUNCIL OF AUSTRALIAN GOVERNMENTS

REVIEW OF URBAN CONGESTION TRENDS, IMPACTS AND SOLUTIONS

by

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AusLink Urban Arterial Road Network Congestion Review - Traffic Management Systems (non-Freeways)

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COAG Urban Congestion Review

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Executive Summary

This study has been commissioned by the SCOT Urban Congestion Management Working Group (UCMWG) on behalf of the COAG Urban Congestion Review to examine the role of traffic management systems in improving the management, operation, economic performance and productivity of national urban corridors, including through:

a) better integration of national corridors and adjoining local networks and systems;
b) better interaction and management of passenger and freight systems/flows; and
c) better management of local, cross-urban and through-urban flows.

Australia's national urban arterial roads have served Australia well in the past and have provided a good level of service for all road users including commuters, business travellers, freight vehicles and public transport. In recent years, however, increases in traffic movements have resulted in urban at-grade arterial roads reaching capacity at many locations. The current level of urban congestion is likely to grow significantly in the future as traffic volumes are expected to increase. It is therefore crucial to investigate new technologies and alternative methods of traffic management to reduce congestion without increasing road space.

Congestion can generally be defined as excess demand for road travel (Organisation of Economic Co-operation and Development (OECD), 2006). Supply of road travel infrastructure is not sufficient to meet demand levels during peak times to a given level of service. As a consequence, travel speeds fall and delays are explained.

Congestion can be distinguished as to whether it is recurrent or non-recurrent. Recurrent congestion is mainly demand-related and occurs due to regular weekday peaks in demand for the use of road space. There is also evidence that weekend peak flows are also becoming a concern. Infrastructure characteristics such as bottlenecks can give rise to recurring congestion at particular points on the network. Non-recurrent congestion is caused by traffic incidents such as accidents, special events or road works.

Three main factors influence the supply side of road travel. Firstly, capacity is one of the most important elements of road space supply. For example, the total kilometres of roads and the number of lanes determine the capacity of the road network. Secondly, the operation of the road network influences supply. Maximising the efficiency of operations, such as optimising signals improves "supply". Thirdly, the supply of the road transport equation is also affected by incidents such as accidents or road works.

Demand for road space is influenced by a large number of issues. Essentially demand is created when the need for travel between an origin and a destination arises. Demand therefore strongly depends on socio-economic and population factors. Another important factor influencing demand is the relative cost of road travel as well as the availability of alternative means of transport.

The costs of congestion vary depending on the type of user considered. Three main user groups can be identified: private travel, business travel, freight. The cost of congestion of private travel mainly comprise of the direct increases in travel time and vehicle operating costs. Reductions in accessibility and social involvement are social costs of congestion.

In this report we have developed an evaluation framework in order to identify successful, applicable and cost-effective new technologies and road management practices that address congestion on urban arterial roads.

Traffic management systems may be defined as the application of specific traffic control technologies or practices over a length of road or over an area, to achieve specified objectives, (Austroads, 1998). Traffic engineering actions on arterial roads should aim to obtain a balance between providing for traffic and providing for activities which occur beside and across the road.

For the first stage of the evaluation framework an extensive literature review was undertaken in order to collect diverse and innovative case studies from around the world. The collected case studies are grouped according to the type of measures they address. The following three groups emerged:

- Managed Elements and Integration of Traffic Management Systems for Urban Arterial Roads;
- Managing the Allocation of the Road Space; and
- Network Intelligence and Dynamic En-route Information.

The next step of the evaluation framework involved determining the applicability of traffic management approaches. The following three criteria were used whether:

- measures are applicable to the Australian urban context;
- measures are supply-oriented (i.e. changing the supply of road space rather than demand for road space); and
- measures can be applied to urban arterial roads.

The second stage in evaluating the applicable traffic management approaches was to assess the cost-effectiveness of different options so to identify which tools provide best value for money. The traffic management tools identified during stage 1 are further categorised in order to assess their cost-effectiveness.

It is important to point out that cost and benefits of each scheme strongly depend on the local context and the scope of implementation. In some circumstances, traffic management tools can provide larger benefits or require lower costs than in others.

In some cases, the categorisation of measures is not clear cut and two categories have been assigned as the costs of implementation depend on local circumstances. Most traffic management approaches that fall into the medium category are related to enhancing operations on arterial roads or management of existing road space. High costs and a high level of ‘build’ are mainly found in the group of measures relating to Network Intelligence. As these measures involve the application of new technologies they often require the establishment of new infrastructure in order to transmit relevant information. In contrast, management tools enhancing the operation of urban arterial roads require lower investment.

In addition to overall cost-effectiveness, it is important to identify how benefits apply to the relevant road user group. Generally, all traffic management measures identified here have an impact on reducing congestion; however, measures differ as not all benefits are transferable between users.

Combining the categorisation of measures into low, medium and high cost categories with the empirical evidence on the success of the traffic management applications, some tentative conclusions on the cost-effectiveness of measures can be drawn. Furthermore, the costs of different schemes per vehicle affected have been considered in assessing cost-effectiveness. However, it is important to point out that for a significant number of measures, it is difficult to assess cost-effectiveness as empirical evidence on the results is lacking.

A number of measures identified are likely to be cost effective but these should be evaluated further on a more detailed level. These include;

- Lorry Control Scheme;
- Traffic Signal Optimisation;
- Parking controls/clearways;
- Incident and accident management;
- Traffic congestion management;
- HOV (High Occupancy Vehicle) lanes;
- Quality Bus Corridors; and
- Contra flow bus lanes;

A small number of measures were felt to be less cost effective than the schemes identified above but again these should be evaluated further on a more detailed level. These include;

- Intelligent Access Program (IAP)
- Park and Ride
- En-route information systems to facilitate road user decisions

A significant proportion of the measures considered require more evidence to draw firm conclusions on whether they are cost effective in tackling congestion on urban arterial roads. More evidence is required on schemes that have been implemented in Australia. In particular post-project evaluation should be undertaken in order to obtain more information on their successfulness. These include:

- Car Park Guidance Systems (refer to Appendix A, Table 6,topic k) - Low cost measure to tackle recurrent congestion;
- Systems to collect and process data in near real time to provide "network intelligence" to the network operators.
- Real-time data used as inputs to drive the various traffic management tools and en-route information systems; and
- GIS based technology to focus on network wide solutions and management as opposed to singular locations or small areas of the network (refer to Appendix A, Table 8, topic c) - High cost measure to tackle recurrent congestion.

There is a need to give more emphasis to existing and new traffic/travel management tools for urban arterial roads to ensure the successful, applicable and cost-effective implementation of new technologies and road management practices that address congestion.

National and State policy can and will need to take the lead in defining an integrated approach needed to manage congestion. There also needs to be greater communication and co-ordination between agencies to ensure both national and local interests are met.

Options for addressing congestion are more likely to be effective if based on recognition that options that work on both the supply and demand side of transport markets will be needed (VCEC, 2006). Standalone solutions can only be effective to a certain extent but the best results are through combining solutions. A framework that assists in the application of this new regime, potentially based on the role and function of roads would enable congestion to be managed in a coordinated manner.

Ultimately all traffic management measures identified could have an impact on reducing congestion when applied in a co-ordinated and effective way. The evaluation framework presented and applied in this report can be used as a tool to make a first selection of traffic management tools that are likely to provide the largest net benefits if applied in Australia. As a next step, it is important to assess the detailed costs and benefits involved with the application of these tools for particular cases. The high level analysis conducted in this report should be taken to a more detailed level of investigating the potential benefits in particular circumstances.

1.0 Introduction

1.1 Background

In February 2006, the Council of Australian Governments (COAG) agreed to "reduce current and projected urban transport congestion, within current jurisdictional responsibilities, informed by a review into the main causes, trends, impacts and options for managing congestion focusing on national freight corridors" (COAG communiqué, 2006).

Australia's national urban arterial roads have served Australia well in the past and have provided a good level of service for all road users including commuters, business travellers, freight vehicles and public transport. In recent years, however, increases in traffic movements have resulted in urban at-grade arterial roads reaching capacity at many locations. The current level of urban congestion is likely to grow significantly in the future as traffic volumes are expected to increase as well as peak spreading. For example, Australia's freight task is expected to nearly double over the following 20 years. On the other hand, the measures to reduce congestion in the past have mainly involved 'build' solutions. For example, increases in capacity in the past could be achieved by adding lanes particularly at intersections. The ability to consider these options however, is rapidly diminishing as vacant space is either not available or land costs are prohibitively high. It is therefore crucial to investigate new technologies and alternative methods of traffic management to reduce congestion without increasing road space.

This study has been commissioned by the SCOT Urban Congestion Management Working Group (UCMWG) on behalf of the COAG Urban Congestion Review to examine the role of traffic management systems in improving the management, operation, economic performance and productivity of national urban corridors, including through:

d) better integration of national corridors and adjoining local networks and systems;
e) better interaction and management of passenger and freight systems/flows; and
f) better management of local, cross-urban and through-urban flows.

1.2 Purpose

The purpose of this report is to identify successful, applicable and cost-effective new technologies and road management practices that address congestion on urban arterial roads through intervention on the "supply side" of road transport. New technologies and road management tools are selected using an evaluation framework that takes into account the relevant user group, the nature of the net benefit and the likely cost and type ('build' or 'non-build') of the selected option.

Traffic management systems may be defined as the application of specific traffic control technologies or practices over a length of road or over an area, to achieve specified objectives, (Austroads, 1998). Traffic engineering actions on arterial roads should aim to obtain a balance between providing for traffic and providing for activities which occur beside and across the road.

1.3 Scope

The scope of this report is as follows;

- To identify current trends with urban arterial road congestion - the extent to which traffic problems are changing and expanding, and the resultant impacts on the loss of productivity of the road network, inefficiency, and social and environmental outcomes;
- To identify the extent to which current management tools and systems for national and international urban roads are capable of dealing with the trends;

- Examine what constitutes good management practice and what it can achieve in terms of net benefits;
- Establish a framework to guide the selection of the most appropriate solution for particular circumstances; and
- To articulate the key elements of a way forward, examining and assessing traffic management approaches which could be adopted in Australia to enable the introduction of new technologies and road management practices. This includes selecting the appropriate treatment from alternative options, as improvements could differ depending on the predominant function and use of a route, eg, key freight route, key public transport route etc.

1.4 Report Outline

Section 2 presents the current issues and trends in urban traffic and congestion and assesses whether current traffic management practices are viewed to be sufficient to cope with future developments.

Section 3 gives an overview of the methodology used to select those traffic management tools that are expected to provide the largest net benefits to reduce congestion in Australian cities.

Section 4 further investigates the cost-effectiveness of traffic management approaches that have been selected in Appendix A.

Section 5 summarises the key findings.

2.0 Overview of What is Happening on Arterial Roads

2.1 Introduction

In order to assess the usefulness of different types of traffic management tools to reduce urban congestion in Australia, an understanding is necessary of the current and future trends in managing traffic and congestion on Australian approaches. This section therefore provides a description of the current traffic management practices applied in Australia. This section also outlines the Australian circumstances in which the traffic management approaches discussed in the next sections could be applied.

2.2 Current and future trends on urban arterial road traffic and congestion

2.2.1 Defining congestion

Congestion can generally be defined as excess demand for road travel (Organisation of Economic Co-operation and Development (OECD), 2006). Supply of road travel infrastructure is not sufficient to meet demand levels to a given level of service. As a consequence, travel speeds fall and delays are explained. This general definition of congestion implies that it can be measured in various ways. Average speed, flow/density, delay and travel time variability can all be used to assess the level of congestion. Congestion prevents traffic from moving freely, quickly and/or predictably (OECD, 2006).

Congestion is undesirable as it reduces accessibility and increases costs associated with travel. In most cases, road transport is not an end in itself but rather a means to an end. Road transport enables access to social activities, employment, health care, education, etc. The level of access is determined by various factors including travel time and reliability. As congestion impacts on travel time and reliability it reduces accessibility. While accessibility is also influenced by other modes of transport, the high mode share of road transport in Australian cities when considering passenger trips (typically around 90%) implies that travel time increases and reductions in reliability can have a significant impact on accessibility. For example, a US study estimated that an increase of commuting time of 10 minutes decreases involvement in community activities by 10% (US Department of Transportation, 2006).

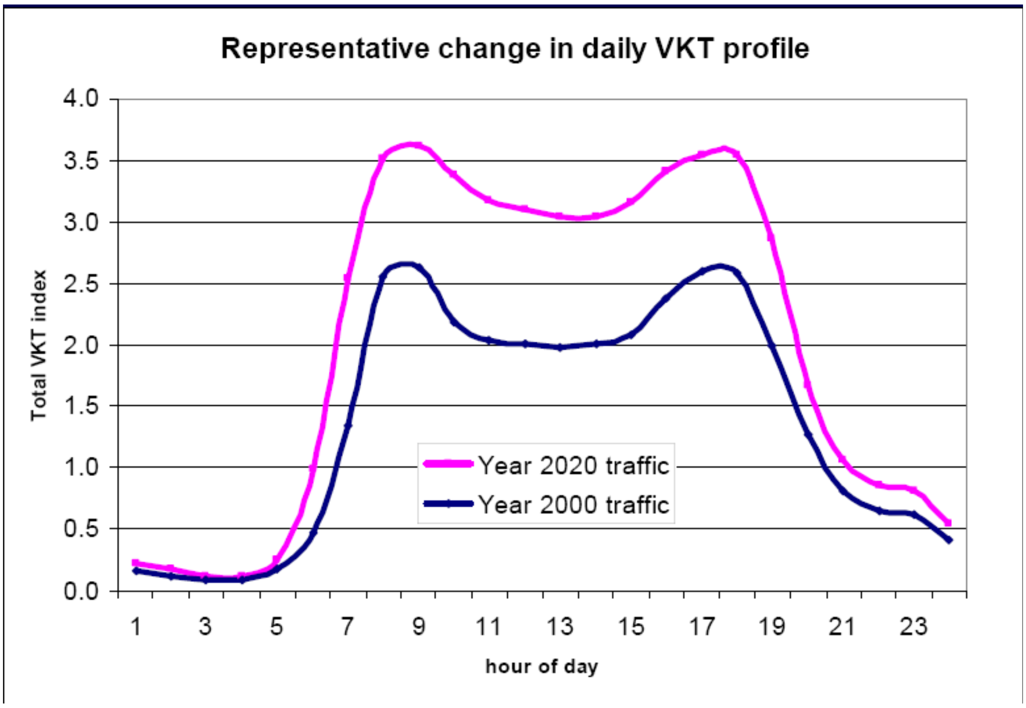
Congestion can be distinguished as to whether it is recurrent or non-recurrent. Recurrent congestion is mainly demand-related and occurs due to regular weekday peaks in demand for the use of road space (refer Figure 1). Traffic characteristics such as bottlenecks can give rise to recurring congestion at particular points on the network. Non-recurrent congestion is caused by traffic incidents such as accidents, special events or road works. In the US, the share of recurrent and non-recurrent congestion is estimated to be about 50% each (US Department of Transport, 2006). Other estimates within the OECD have shown that the share of non-recurrent congestion might be as low as 14-25% (OECD, 2006).

Congestion can occur on any type of road. However, the scope of this report is limited to examining traffic management tools for urban arterial roads. The definition of urban arterial roads used in this report **excludes** freeways. Arterial roads are generally roads that link two centres of activity and are subject to significant traffic volume.

2.2.2 Causes of congestion

As defined above, traffic congestion occurs when the demand for road space exceeds the supply. Causes of congestion are thus mechanisms that either increase demand for road space or decrease supply. A close examination of the causes of congestion is useful as any strategy to reduce congestion has to be based on addressing the causes for congestion.

Figure 1: Distribution of VKT over the time of day in Australian capital cities



(Source: BTRE, 2006a)

2.2.3 Demand and supply of road space

Measures aimed at reducing congestion can be either demand or supply side oriented. It is therefore important to distinguish both types of measures.

Three main factors influence the supply side of road travel. Firstly, capacity is one of the most important elements of road space supply. For example, the total kilometres of roads and the number of lanes determine the capacity of the road network. Secondly, the operation of the road network influences supply. Maximising the efficiency of operations, such as optimising signals improves "supply". Thirdly, the supply of the road transport equation is also affected by incidents such as accidents or road works. Importantly, the last two aspects can be influenced by traffic management approaches. It is thus the supply-side of the road network that can be optimised by traffic management tools.

Supply of road space is mainly determined by past investment decisions and current operations. Changes in the supply side of road space thus involve construction of new road space or reductions in existing road space. Changes in traffic operations are also considered to be supply side measures.

Demand for road space is influenced by a large number of issues. Essentially demand is created when the need for travel between an origin and a destination arises. Demand therefore strongly depends on socio-economic and population factors. Another important factor influencing demand is the relative cost of road travel as well as the availability of alternative means of transport. Other aspects that influence demand for road travel are availability of parking and the social perception of car versus public transport travel. Considering freight, the demand for road travel is strongly influenced by the economy.

While the focus of traffic management tools is to influence the supply side of the road network, it is important to point out that their success often depends on changes in the demand for road travel. For example, consider a situation of a congested urban arterial road with three lanes. One of the lanes is converted into a priority bus lane. If demand for private car travel on this road is unchanged, congestion increases as the same number of vehicles is faced with only two-thirds of the space.

The success of this measure therefore depends strongly on the shift in demand from private car to public transport. If a significant proportion of the people travelling in cars switch to bus transport, congestion is likely to be relieved. This simple example demonstrates that the success of some of the supply-side traffic management tools can strongly depend on shifts in demand. In turn, the successful passenger shift to buses is reliant on frequent and comprehensive bus networks and may require the establishment of infrastructure such as park and ride facilities.

2.2.4 Traffic trends

Figure 2 presents the past and projected traffic growth for Australian capital cities as estimated by BTRE (2006a). As is evident from the figure, the current level of traffic growth is forecast to continue over the next 15 years. Between 2005 and 2020, total metropolitan vehicles kilometres travelled (VKT) growth is expected to be at 37%. For example, between 2005 and 2020, VKT in Sydney and Melbourne is expected to grow by 38% and 33%, respectively. Total traffic can be disaggregated into passenger and freight components. Growth in passenger traffic is mainly driven by two factors: population growth and per capital income growth. However, approaching 2020, the relationship between increases in traffic and increases in per capital income is saturating. This implies that further increases in per capita income are unlikely to cause further traffic growth. After 2020 it is envisaged that traffic growth will be in line with population growth (BTRE, 2006a).

The main driver for freight growth is GDP growth. BTRE (2006) estimates that between 2003 and 2020 freight traffic in Australia's capital cities is expected to grow by 80%. Overall, relatively high growth in both passenger and freight traffic in urban areas is projected over the next 15 years.

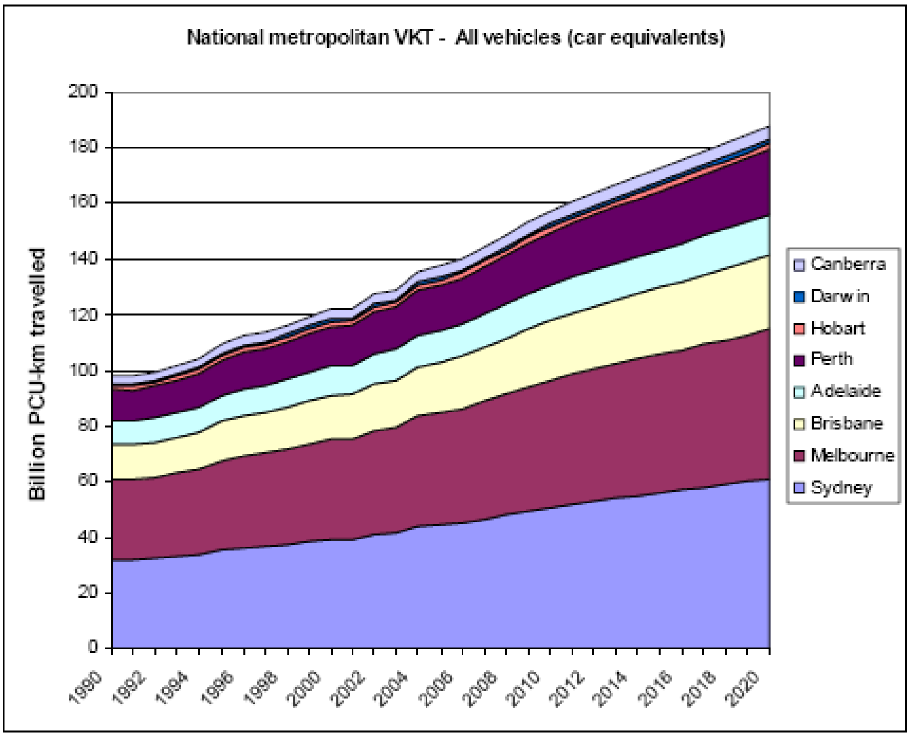
There were 13.9 million motor vehicles, including motorcycles, registered in Australia at 31 March 2005 (refer to Table 1). This represents an increase of 11.6% since the 2001 Motor Vehicle Census (MVC), when there were 12.5 million vehicles registered in Australia. The average annual growth over this time was 2.8%.

Table 1: Type of vehicle (Census years 2001 and 2005)

Type of vehicle	2001	2005	Change	Average annual growth
	no.	no.	%	%
Passenger vehicles	9 835 884	10 896 410	10.8	2.6
Campervans	33 586	40 693	21.2	4.9
Light commercial vehicles	1 769 583	2 030 254	14.7	3.5
Rigid trucks	338 411	368 520	8.9	2.2
Articulated trucks	62 597	69 723	11.4	2.7
Non-freight carrying trucks	18 204	19 962	9.7	2.3
Buses	67 572	72 620	7.5	1.8
Motorcycles	350 930	421 923	20.2	4.7
Total motor vehicles	**12 476 767**	**13 920 105**	**11.6**	**2.8**
Source: ABS 9309.0 - Motor Vehicle Census, Australia, Mar 2005				

In addition to the growth in total traffic, the distribution of traffic over the day plays an important role. It is possible that total traffic is growing but congestion is constant if the distribution of traffic over the time of day is spread more evenly. The expected shift in the distribution of traffic over the day is shown in Figure 1. The figure shows that traffic in the year 2000 was strongly concentrated around two peak periods. The forecast daily traffic distribution in 2020 is not only shifted upwards but also entails wider peaks. This implies that not only an increase in VKT is forecast (as already implied by Figure 2) but also a lengthening of peak periods. Growth in total VKT in Australian cities is unlikely to be matched by an increase in capacity. It is therefore expected that without improvements in traffic management and road travel demand management, congestion will grow significantly.

Figure 2: Total projected traffic growth for Australian capital cities



(Source: BTRE, 2006a)

The increases in total VKT as well as the lengthening of peak periods both suggest that future congestion is likely to increase if capacity increases and traffic management do not respond to increases in traffic. In order to better understand the impact of growing traffic on future congestion, firstly congestion has to be defined (refer to 2.2.1).

The Victorian Competition and Efficiency Commission (VCEC, 2006) reports the shares of weighted delay costs by road type in Melbourne. According to this estimation in Melbourne the share of delay costs on arterial roads in 2004 was 40%. This implies that congestion on arterial roads imposes higher costs than on any other type of road. VCEC further shows that the expected share of total delay costs of arterial roads in Melbourne in 2021 is about 45%. Even though this is the highest share by road function, future growth of arterial road delay cost is relatively small when compared to freeways and highways. It is unknown whether the share of total congestion on arterial roads in other Australian capital cities is of similar magnitude.

2.2.5 Consequences and costs of congestion

Congestion imposes significant costs in time delays, pollution, accidents, driver stress and additional vehicle wear and tear. Increases in travel time, reduced travel time reliability, increased vehicle operating costs and lower air quality are all consequences of congestion.

The costs of congestion vary depending on the type of user considered. Three main user groups can be identified: private travel, business travel, freight. The cost of congestion of private travel mainly comprise of the direct increases in travel time and vehicle operating costs. Reductions in accessibility and social involvement are social costs of congestion.

The cost of congestion when considering business travel not only includes the direct effects such as increased travel time but also reductions in productivity. Unproductive transit time can pose a significant cost on the economy. Similarly, the costs of congestion relating to freight are rather high as vehicles are often faced with specific delivery and pick-up times. Congestion can cause significant productivity losses when considering delays of time-sensitive freight.

Non-recurrent congestion does not only increase travel time but also decreases travel time reliability. Large variations in travel time can induce (freight) companies to include buffer time periods in their schedules. If travel time delays do not materialise, vehicles arrive too early and unproductive waiting time is created. Both increases in travel time and reductions in travel time reliability can thus lead to adverse effects on productivity.

Costs of congestion that are imposed on the wider community include environmental and safety costs. Congestion leads to higher fuel consumption which increases greenhouse gases and localised air pollution. Adverse health impacts as a result of higher air pollution can increase as a result of congestion. This applies particularly to congestion of urban arterial roads.

Lastly, it is important to point out that congestion on major urban arterial roads can also have an impact on smaller local roads as often alternative routes are used to avoid congestion. This can lead to significant increases in traffic on local roads which can have a potential negative effect on residential amenity and safety. It should be noted that arterial traffic is better able to achieve equilibrium than freeway traffic. However, congestion on freeways can also have an impact on arterial roads.

2.2.6 Quantifying costs of congestion

Various attempts have been made to quantify the costs of road congestion in metropolitan areas. It is important to point out that methodologies used to quantify the costs of congestion differ greatly and the magnitude of costs estimated is strongly dependent on the methodology used.

The Bureau of Transport and Regional Economics (BTRE, 2006) uses a method calculating the deadweight loss of congestion that is, the net social benefit if congestion charging was introduced. Using this methodology, in 2005 the social cost of congestion in all Australian capitals is estimated at $9.39 billion. The costs for Sydney and Melbourne are estimated to be $3.5 billion and $3.0 billion, respectively. Furthermore, the cost of congestion is expected to double from 2005 to 2020. BTRE estimates the cost of congestion of Australian capital cities in 2020 to be $20.4 billion.

In Melbourne, methodologies focusing on time delays and additional vehicle operating costs have been used to estimate congestion. Studies have produced cost estimates ranging from $1.8-$4 billion per annum, growing to $4-$8 billion in the next decade or so. These have been used in some cases to argue for major policy shifts and large increases in infrastructure spending in an effort to reduce the costs of congestion. However, modelling undertaken for VCEC by the Victorian Department of Infrastructure (DOI) suggests that these estimates are too high. The available data from VicRoads, modelling by DOI and other sources indicate that the costs of congestion are unevenly spread across Melbourne (VCEC, 2006).

Rising costs of congestion cannot only be found in Australia. In the US, a recent study by the Texas A&M University (TAMU, 2005b) confirmed that congestion has spread significantly over the 20 years from 1982 to 2003 across various US cities. Evidence includes 67% of the peak period travel was congested in 2003 compared with 32% in 1982; 59% (in 2003) of the major road system was congested compared to 34% (in 1982); and the number of hours of the day when congestion might be encountered has grown from about 4.5 hours (in 1982) to about 7.1 hours (in 2003). In America's 85 largest urban areas, the 2003 figures show that "congestion caused 3.7 billion hours of travel delay and 2.3 billion gallons of wasted fuel, an increase of 79 million hours and 69 million gallons from 2002 to a total cost of more than US$63 billion" (TAMU, 2005). Similarly, congestion is an increasing problem in many European countries.

2.3 Current traffic management practices relating to urban arterial road traffic and congestion

Management of urban arterial roads in Australian capital cities is the responsibility of State road Authorities. Currently, there is no overall approach to traffic management in Australia. At this stage, there is also no comprehensive research into the usefulness of different traffic management methods to reduce congestion. However, a number of traffic management initiatives to reduce congestion are currently used in Australia such as:

- Manual intervention in traffic signal control rooms; through the presence of experienced personnel and the police
- Automatic/Dynamic signal coordination;
- Incident and accident management systems;
- High Occupancy Vehicle lanes;
- Various public transport priority initiatives such as bus lanes;
- Clearway and parking management strategies; and
- Variable speed signs.

There is no conclusive evidence as to which practices or combination of practices are successful as ongoing monitoring and detailed post-implementation evaluation are often lacking.

2.4 Current and forecast problems and the capacity of traffic management practices to address them

Despite the fact that a number of traffic management approaches to reduce congestion are currently used in Australian capital cities, more research is required to fully understand the potential of the various systems and thereby help to identify those practices which alone or in combination have the capacity to deal with future congestion. Considering the projections of traffic volume increases over the next 15 years together with the lack of opportunities to build more physical infrastructure, the importance of identifying new technologies and traffic management practices to address congestion becomes immediately clear.

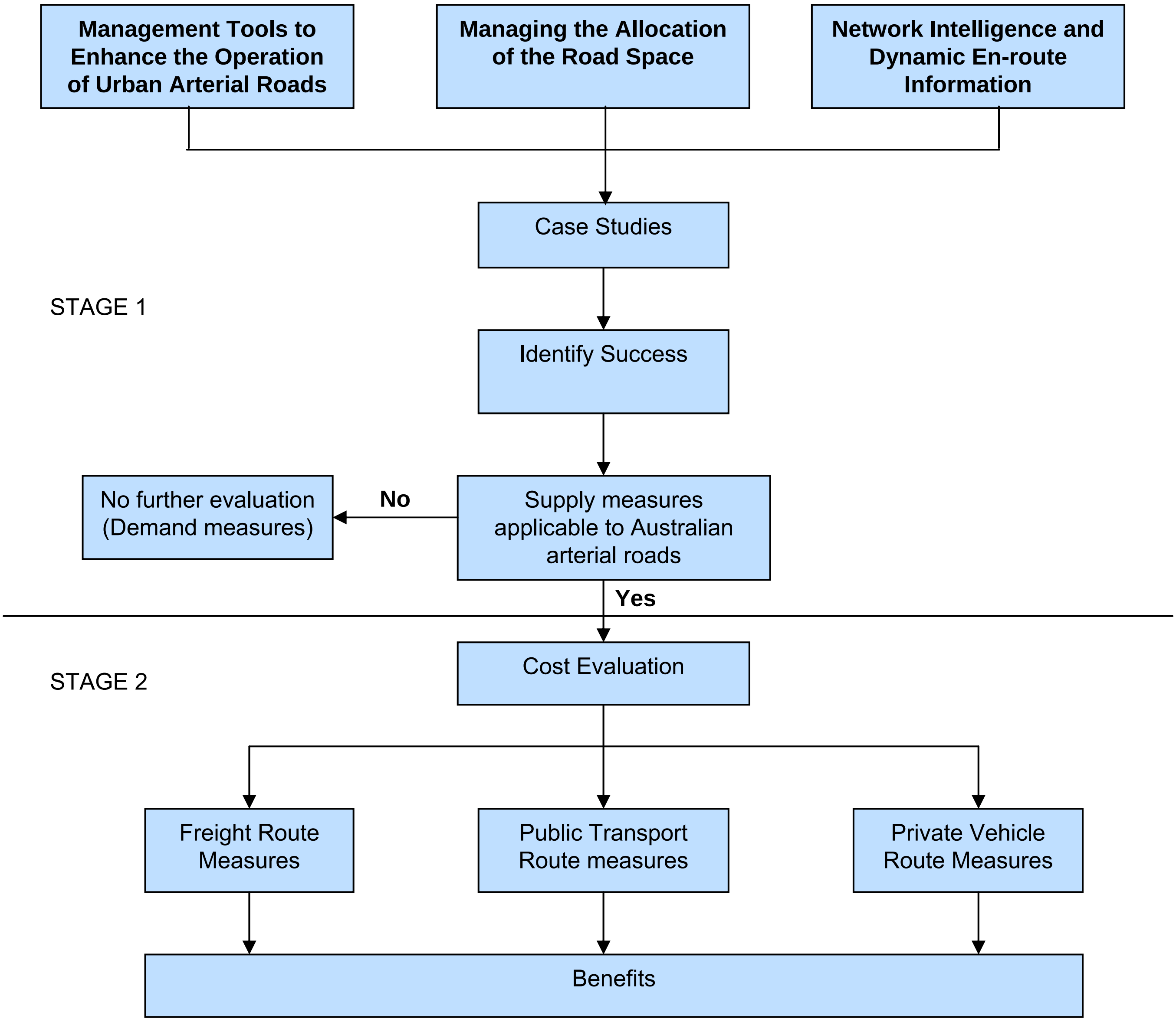
Although modelling undertaken for VCEC by the Victorian Department of Infrastructure (DOI) has suggested this estimate to be high, the forecast growth in metropolitan traffic of 37% over the next 15 years and the current cost of congestion of $9.39 billion suggest that in order to prevent congestion levels from rising sharply, a comprehensive set of management tools is required. The following section presents international and local experience of traffic management approaches and investigates the extent to which these practices are applicable to Australian urban arterials.

3.0 Evaluation Framework

3.1 Introduction

Figure 3 sets out the evaluation framework we have developed In order to identify successful, applicable and cost-effective new technologies and road management practices that address congestion on urban arterial roads.

Figure 3 – Evaluation Framework



3.2 Stage 1 – Identification of Applicable Measures

There are potentially numerous measures that can be used in order to reduce urban congestion on arterial roads in Australia. For the first stage of the evaluation framework an extensive literature review was undertaken in order to collect diverse and innovative case studies from around the world (refer to Appendix A).

The collected case studies are grouped according to the type of measures they address. Table 6 identifies management tools to enhance the operation of urban arterial roads, especially under congested conditions, and the net benefits associated with these tools. Table 7 looks at the management of existing road space to enhance the productivity and economic performance of national infrastructure. Finally table 8 looks at measures that understand network performance utilising both real time and historical data, in order to manage and operate infrastructure effectively.

In order to select the most relevant case studies we assessed whether the introduction of the measure described in the case study can be considered to be successful. Cases where measures have not contributed to significant reductions in congestion were dismissed and not investigated further. It is important to point out that the methodologies for determining whether particular traffic management approaches are successful or not greatly vary across the case studies.

As case studies were collected from Europe, Northern America and Oceania, post-implementation reviews do not always follow the same principles. For example, some case studies focus on travel time delay, others on traffic volume. As a consequence, the assessment of whether particular case studies have been successful or unsuccessful is not always based on the same methodology. Furthermore a large number of case studies lack post-implementation review altogether or just provide qualitative information. It should be noted that in order to enable selection of successful projects, pre- and post-project evaluation of traffic management tools should be encouraged.

The next step of the evaluation framework involved determining the applicability of traffic management approaches. The following three criteria were used whether:

- measures are applicable to the Australian urban context;
- measures are supply-oriented (i.e. changing the supply of road space rather than demand for road space); and
- measures can be applied to urban arterial roads.

Note that arterial roads in this context do not include urban motorways or freeways. Measures that fulfil all three criteria are considered further in stage 2 of the evaluation framework. The first stage of the evaluation framework thus enables a selection of successful, applicable traffic management tools.

3.3 Stage 2 – Evaluation of costs and benefits

The second stage in evaluating the applicable traffic management approaches was to assess the cost-effectiveness of different options so to identify which tools provide best value for money. The traffic management tools identified during stage 1 are further categorised in order to assess their cost-effectiveness. Three categories are constructed in order to assess the cost-effectiveness of the selected traffic management approaches (TMA). The categories are presented in Table 2 and relate to the level of investment required to implement the traffic management approaches and the extent to which tools can be considered to be ‘build’ solutions.

Table 2: Cost evaluation categories

Category	Definition
Low	TMAs in this category are not resource-intensive and are largely non-build options. Reasonably small reductions in congestion can thus make TMAs in this category cost effective, due to their low cost.
Medium	TMAs that are partly ‘build’ solutions and that require a medium level of investment fall into this category.
High	This category includes TMAs that require substantial investment in infrastructure and / or technology and can be considered as ‘build’ options. Only if large, significant reductions in congestion can be achieved, would TMAs in this category be considered cost-effective.

The traffic management approaches selected during stage 1 of the evaluation framework are categorised according to Table 2. In order to assess value for money the expected costs of each scheme have to be compared to the potential benefits. As a consequence, for each measure, the demonstrated or expected benefits documented are compared against the cost evaluation categories. This comparison results in four different outcomes:

- Least cost-effective
- Cost-effective
- Very cost-effective
- More evidence needed.

The latter category applies for traffic management tools for which no post-implementation data is available.

Limitations

Options for addressing congestion are more likely to be effective if based on recognition that options that work on both the supply and demand side of transport markets will be needed (VCEC, 2006). Solutions can only be standalone to a certain extent but the best results are through combining solutions. A framework that assists in the application of this new regime, potentially based on the role and function of roads would enable congestion to be in a managed in a coordinated manner.

It is important to point out that cost and benefits of each scheme strongly depend on the local context and the scope of implementation. In some circumstances, traffic management tools can provide larger benefits or require lower costs than in others. For example, introducing a High Occupancy Vehicle (HOV) lane can provide more benefits if a significant number of people share similar origins and destinations. In the same way, costs for implementing a park and ride facility might be relatively lower in places where land for parking is readily available. In order to interpret results appropriately, it should be kept in mind that the methodology applied here tries to assess cost-effectiveness in general. This implies that a measure that is generally deemed to be cost-effective can nevertheless provide a low value for money if particular circumstances apply.

4.0 The Way Forward – A New Regime

4.1 Cost Evaluation

Chapter 4 identified the most appropriate traffic management tools with respect to whether:

- measures are applicable to the Australian urban context;
- measures are supply-oriented (i.e. changing the supply of road space rather than demand for road space); and
- measures can be applied to urban arterial roads.

The next stage in evaluating traffic management tools involved an assessment of the cost-effectiveness of different options in order to identify which tools provide best value for money. Three categories have been constructed in order to assess the cost-effectiveness of the selected traffic management tools (TMT). The categories presented in Table 1 relate to the level of investment required to implement the TMT and the extent to which tools can be considered to be 'build' solutions.

4.1.1 Categorisation of traffic management tools by costs

As outlined in chapter 3, the traffic management approaches selected during stage 1 of the evaluation framework are examined further in this chapter. Table 3 ranks the cost of the most common traffic management practices reviewed in this report, using the categories detailed in section 3.3.

In some cases, the categorisation of measures is not clear cut and two categories have been assigned as the costs of implementation depend on local circumstances. The results in Table 3 show that most traffic management approaches that fall into the medium category are related to enhancing operations on arterial roads or management of existing road space. High costs and a high level of 'build' are mainly found in the group of measures relating to Network Intelligence. As these measures involve the application of new technologies they often require the establishment of new infrastructure in order to transmit relevant information. There is a need to establish an assessment methodology to establish the benefits over time to justify the high initial costs. In contrast, management tools enhancing the operation of urban arterial roads require lower investment.

Table 3: **Cost Evaluation of Measures**

Measure		Low	Medium	High
Management Tools to Enhance the Operation of Urban Arterial Roads	Intelligent Access Program (IAP)			●
	Lorry Control Scheme - Restrictions on goods-vehicle loading and unloading time	●	●	
	Park and Ride		●	
	Traffic Signal Optimisation		●	●
	Parking controls/clearways	●	●	
	Incident and accident management		●	
	En-route information systems to inform road user decisions	●	●	
	Car Park Guidance System		●	●
	Traffic congestion management - congestion charging			●
Management of Existing Road Space	HOV (High Occupancy Vehicle) lanes		●	●
	Quality Bus Corridors		●	
	Contra flow bus lanes		●	
Network Intelligence and Dynamic En-route Information	Systems to collect and process data in real time to provide "network intelligence" to the network operators			●
	Real-time data used as inputs to drive the various traffic management tools and en-route information systems			●
	GIS based technology to focus on network wide solutions and management as opposed to singular locations or small areas of the network			●

4.2 Categorisation of traffic management tools by relevant road user groups

Apart from cost-effectiveness, it is important to distinguish traffic management tools according to the relevant road user group (refer to Table 4). All the traffic management measures identified could have an impact on reducing congestion. Dependent on the road user group (freight, public transport or vehicles), different measures will be more applicable to managing congestion.

Freight should be considered to include all commercial vehicles from utility vehicles through to heavy goods vehicles.

For example, a priority bus lane reduces travel time for bus passengers. However, if the introduction of the priority bus lane results in the reduction of the lanes available to other vehicles, congestion of private and heavy vehicles is possibly increased. Only if a significant proportion of private car users shift modes, can a reduction in overall congestion be achieved.

Table 4 illustrates which user group the selected traffic management tools apply to.

Table 4: **Framework for Application of New Regimes**

	Measure	Freight	Public Transport	Vehicles / Cars
Management Tools to Enhance the Operation of Urban Arterial Roads	Intelligent Access Program (IAP)	●		
	Lorry Control Scheme - Restrictions on goods-vehicle loading and unloading time	●		
	Park and Ride		●	●
	Traffic Signal Optimisation	●	●	●
	Parking controls/clearways	●	●	●
	Incident and accident management			●
	En-route information systems to inform road user decisions	●		●
	Car Park Guidance System			●
	Traffic congestion management - congestion charging		●	●
Management of Existing Road Space	HOV (High Occupancy Vehicle) lanes		●	●
	Quality Bus Corridors		●	
	Contra flow bus lanes		●	
Network Intelligence and Dynamic En-route Information	Systems to collect and process data in real time to provide "network intelligence" to the network operators		●	
	Real-time data used as inputs to drive the various traffic management tools and en-route information systems	●		●
	GIS based technology to focus on network wide solutions and management as opposed to singular locations or small areas of the network		●	●

4.3 Benefits by road user group

In addition to overall cost-effectiveness, it is important to identify how benefits apply to the relevant road user group. Generally, all traffic management measures identified here have an impact on reducing congestion; however, measures differ as not all benefits are transferable between users. Table 5 summaries some of net benefits according to road user group.

Successful, applicable and cost-effective new technologies and road management practices that address freight congestion on urban arterial roads will have a number of benefits. Delays can be reduced by providing alternative route guidance and improving safety, which in turn reduces the impact of incidents. This in turn has a positive impact on travel times and improves the reliability of freight movement. As a result, this would lead to lower costs, and reduce the social and environmental impacts of freight.

Improving the reliability and travel time and reducing delays that affect public transport movements can lead to increased utilisation of public transport services, thereby reducing arterial congestion through modal shift from vehicles to public transport. Increased utilisation of public transport services can also arise from a desire for savings in petrol and vehicle operating costs as well as reduced commuting stress. By providing credible and accurate travel information people can make an informed choice about the mode of transport and route by which the travel. The greater the number of passengers that use public transport the more cost efficient services become, and the greater the modal shift achieved the more social and environmental benefits are realised.

Most of the measures identified in Appendix A are aimed at tackling vehicular congestion, recurrent and non-recurrent. Improving road safety can reduce the number of accidents and the impact of the subsequent delays to vehicles on arterial roads. Providing credible and accurate travel information can encourage travel behaviour change (route choice). Reducing parking demand can encourage modal shift, increasing vehicle occupancy rates which can reduce the number of vehicles on the road. This in turn can have positive benefits on the community and the environment.

Table 5: Summary of benefits by road user

Benefits	Freight	Public Transport	Vehicle
Improve travel times	●	●	●
Improve reliability	●	●	●
Improve safety	●	●	●
Cost	●	●	●
Reduce delays	●	●	●
Reduction in accidents	●		●
Improve freight delivery efficiency	●		
Modal shift		●	
Increase vehicle occupancy rate			●
Reduce parking demand			●
Provide credible and accurate travel information		●	●
Reduce impact of incidents	●	●	●
Change travel behaviour (route choice)	●		●
Social / environmental	●	●	●

4.4 Cost effectiveness of measures

Combining the categorisation of measures into low, medium and high cost categories with the empirical evidence on the success of the traffic management applications from the tables in section 4, some tentative conclusions on the cost-effectiveness of measures can be drawn. Furthermore, the costs of different schemes per vehicle affected have been considered in assessing cost-effectiveness. However, it is important to point out that for a significant number of measures, it is difficult to assess cost-effectiveness as empirical evidence on the results is lacking.

Intelligent Access Programs (refer to Table 6, topic a), are considered to be less cost effective in addressing congestion, they are cost-intensive and its impact on congestion is possibly marginal. The IAP is a Commonwealth Government initiative that provides an automated technology based system (using GPS) to monitor freight vehicles, IAP allows transport operators to carry an additional 10% load on line haul vehicles between certain locations, on the provision that specific compliance issues are met.

A number of measures identified are likely to be cost effective but these should be evaluated further on a more detailed level. The Lorry Control scheme (refer to Table 6, topic a) is a low to medium cost measure dependent on the level of monitoring and enforcement that is implemented specific to this scheme. By restricting or limiting access to cities at certain times of the day, this measure can achieve a significant reduction in congestion on arterial roads.

Although a medium cost measure, the outcome of Park and Ride is strongly dependent on demand shift generally resulting from perceived cost savings. Bus-based park and ride refers to the provision of a dedicated regular bus service running to and from a city centre and a number of car park sites in areas close to the edge of the area along radial routes. Sites are positioned so as to intercept motorists coming into the town from further a field rather than go all the way into town. They can reduce levels of traffic in main urban areas, providing a sustainable alternative car use.

Traffic Signal Optimisation (refer to Table 6, topic d) can result in significant reduction in travel time and could be a cost effective measure in managing recurrent congestion, particularly if manual operation using experienced personnel directly monitoring and intervening in control rooms is used to complement existing systems. The Sydney Coordinated Adaptive Traffic System (SCATS) is an innovative traffic management system developed by the Roads and Traffic Authority to co-ordinate the traffic signal network. The system reacts to changing traffic conditions by adjusting the phasing of each traffic light cycle for 3,000 traffic signals across NSW. This has shown a 20% travel time reduction.

The empirical evidence of parking controls/clearways (refer to Table 6, topic h) shows that significant reductions in recurrent congestion were achieved for medium cost. The Red Route scheme in London and Birmingham (UK) is principally one of greater enforcement of urban clearway principle with strict 'no stopping' regime. They were designed to deter inconsiderate drivers of any vehicle from stopping illegally, and thereby delaying all vehicles. Bus journey reliability increased by 27% with journey time reduced by 10%, car journey reliability increased by 20% with journey time reduced by 20% and freight movements have benefited from similar levels of benefit.

Incident and accident management (refer to Table 6, topic j) is a cost effective non-recurrent congestion measure which has shown mixed results in its effectiveness to reduce congestion. A weather-dependant variable speed limit system in New South Wales, Australia uses weather stations and moisture detectors in conjunction with speed limits signs and a new fixed digital speed camera. When rain is detected, the limit drops from 100 to 90kmh. this new technology will greatly increase road safety and reduce wet weather crashes.This is a medium cost measure to implement.

A low to medium cost measure, En-route information systems can have only a limited effect on reducing non-recurrent congestion. One scheme in Sydney estimates a potential travel time savings of 8% on a number of major arterial roads through the provision of driver information (variable message signs). They are dependent on alternative routes being available to the road user.

A number of the measures considered require more evidence to draw firm conclusions on whether they are cost effective in tackling congestion on urban arterial roads. More evidence is required on schemes that have been implemented in Australia. In particular post-project evaluation should be undertaken in order to obtain more information on their successfulness. This includes Car Park Guidance Systems (refer to Table 6, topic k) which is a low cost measure which tackles recurrent congestion.

Traffic Congestion Management is a high cost but cost effective measure in tackling congestion on arterial roads. Transport for London's monitoring has shown that the scheme has reduced traffic congestion within the charging zone by 30% (after one year) and improved conditions on many roads around the zone. The reduced congestion allows traffic to flow more easily and improves the reliability of journeys (14% reduction in journey times). Bus services have been increased and have benefited from the reduced congestion. Reliability has improved by an average of 30%. Overall bus speeds within the charging zone improved by 6%. The scheme is producing net revenues of over £80 million per year.

The success of HOV (High Occupancy Vehicle) lanes (refer to Table 7, topic a) is dependent on changes on usage patterns. A medium to high cost measure due to the potential monitoring costs, this could be a cost effective measure to tackle recurrent congestion. The HOV lane scheme on Victoria Rd Sydney was introduced in 1977. It is about 7.1km long and allows buses and vehicles with 3+ occupants. There are 2 other lanes for non-priority traffic. Bus reliability has been improved by 50% and vehicle occupancy rate are up by 10%.

Evidence shows that quality bus corridors (refer to Table 7, topic h) can be successful in encouraging modal shift and reducing bus travel time and therefore have a positive impact on recurrent congestion. Quality Bus Corridors in Dublin incorporate signal priority to protect the buses from congestion and to provide faster travel times by bus than by car. This was combined with the improved waiting facilities, which include real-time passenger information, an upgraded bus fleet, and restrictions on parking along the priority routes. Between 1997 and 2003, for travel into the city centre in the morning peak period, the total number of people traveling by car fell by 25.7 per cent and the car mode share fell from 58 per cent to 39 per cent.

Evidence shows that contra flow bus lanes (refer to Table 7, topic f) can be successful in encouraging modal shift and reducing bus travel time and therefore have a positive impact on recurrent congestion.The Southern Expressway in Adelaide, Australia is a one-way fully grade separated road facility which is fully reversible so that direction of travel matches the weekday peak flow demands. This increases peak direction capacity to alleviate congestion and reduce travel times for commuter traffic between outer southern suburbs and inner suburbs / city centre.

A significant proportion of the measures considered require more evidence to draw firm conclusions on whether they are cost effective in tackling congestion on urban arterial roads. These include:

- Systems to collect and process data in real time to provide “network intelligence” to the network operators (refer to Table 8, topic a) - High costs measure to tackle recurrent and non recurrent congestion;
- Real-time data used as inputs to drive the various traffic management tools and en-route information systems (refer to Table 8, topic b) – Tackles recurrent and non recurrent congestion, high cost measure; and
- GIS based technology to focus on network wide solutions and management as opposed to singular locations or small areas of the network (refer to Table 8, topic c) - High cost measure to tackle recurrent congestion.

5.0 Summary of Main Findings

5.1 Next Steps in Evaluation

The evaluation framework presented and applied in this report can be used as a tool to make a first selection of traffic management tools that are likely to provide the largest net benefits if applied in Australia. As a next step, it is important to assess the detailed costs and benefits involved with the application of these tools for particular cases. The high level analysis in conducted in this report should be taken to a more detailed level of investigating the potential benefits in particular circumstances. The way forward can thus be described in terms of **three** steps.

Firstly, it is important to assess the application of traffic management tools for particular circumstances. The full potential of a general analysis has been exploited in this report so the next step is to identify pilot or trial locations so the investigation of potential costs and benefits can become more concrete. This is particularly important as the magnitude of costs and benefits strongly depends on the scope of the application. Even though the scope for some of the high cost schemes is generally defined, the level of investment required for medium and low cost options depends on each particular application.

To illustrate the point, consider the example of implementing a priority bus lane. The cost involved comprise of consultation, information distribution, construction of signs. All of these costs vary strongly with the length of the bus lane and the area it is implemented in. This example demonstrates that it is important to now continue the analysis on a more detailed level.

Secondly, a more detailed analysis of the benefits in terms of reductions of congestion for traffic management tools at particular sites should be conducted. This step does not involve a full cost benefit analysis but rather an analysis of the measurable non-monetary benefits of traffic management tools. For this analysis to be undertaken, assumptions have to be made about the circumstances under which traffic management tools are applied. This illustrates the importance of step 1. Effects should be measured using the relevant indicators for each user group.

Thirdly, full cost benefit analysis of traffic management tools is essential in order to determine their cost-effectiveness. This implies that results obtained during step 2 can be monetised, e.g. travel time reductions are now given a monetary value. Cost benefit analysis following the methodologies developed by the Australian Transport Council should be applied in order to fully assess the net benefits of each option. In addition to the common factors included in cost benefit analysis, it is also of importance to pay particular attention to the needs of each user group (private vehicles, public transport, and freight). In this case, it would be a major advantage if travel time savings of time-sensitive freight could be valued differently than travel time savings to private vehicles.

Overall, the high level framework developed in this study identifies the most appropriate traffic management tools to be applied in Australia. Further analysis should be conducted on a lower level, potentially via the selection of pilot or trial sites.

5.2 Conclusion

There is a need to move towards a new traffic/travel management regime for urban arterial roads to ensure the successful, applicable and cost-effective implementation of new technologies and road management practices that address congestion.

National and State policy can and will need to take the lead in defining an integrated approach needed to manage congestion. There also needs to be greater communication and co-ordination between agencies to ensure both national and local needs are met.

Options for addressing congestion are more likely to be effective if based on recognition that options that work on both the supply and demand side of transport markets will be needed (VCEC, 2006). Solutions can only be standalone to a certain extent but the best results are through combining solutions. They also need to take account of measures that tackle recurrent and non-recurrent congestion. A framework that assists in the application of this new regime, potentially based on the role and function of roads would enable congestion to be in a managed in a coordinated manner.

Although a wide range of measures have been evaluated some of the traffic management approaches lack post-implementation review altogether. It should be noted that in order to enable selection of successful projects, pre, and post-project evaluation of traffic management tools should be encouraged.

It is important to point out that cost and benefits of each scheme strongly depend on the local context and the scope of implementation. In some circumstances, traffic management tools can provide larger benefits or require lower costs than in others. For example, introducing a High Occupancy Vehicle (HOV) lane can provide more benefits if a significant number of people share similar origins and destinations. In the same way, costs for implementing a park and ride facility might be relatively lower in places where land for parking is readily available. In order to interpret results appropriately, it should be kept in mind that the methodology applied here tries to assess cost-effectiveness in general. This implies that a measure that is generally deemed to be cost-effective can nevertheless provide a low value for money if particular circumstances apply.

Apart from cost-effectiveness, it is important to distinguish traffic management approaches according to the relevant road user group. Dependent on the road user group (freight, public transport or vehicles), different measures will be more applicable to managing congestion. For example, a priority bus lane reduces travel time for bus passengers. However, if the introduction of the priority bus lane results in the reduction of the lanes available to other vehicles, congestion of private and heavy vehicles is possibly increased. Only if a significant proportion of private car users shift modes, a reduction in overall congestion can be achieved.

Ultimately all the traffic management measures identified could have an impact on reducing congestion when applied in a co-ordinated and effective way. The evaluation framework presented and applied in this report can be used as a tool to make a first selection of traffic management tools that are likely to provide the largest net benefits if applied in Australia. As a next step, it is important to assess the detailed costs and benefits involved with the application of these tools for particular cases. The high level analysis in conducted in this report should be taken to a more detailed level of investigating the potential benefits in particular circumstances.

Appendix A - Case Studies

Table 6: Management Tools to Enhance the Operation of Arterial Roads

Topic	References	Strengths / Weakness	Is it Applicable?
a) Management of travel on urban roads, including freight/passenger traffic flows			
	Scheme: Intelligent Access Program (IAP) Site: Various in Australia Description: • The IAP is a Commonwealth Government initiative that provides an automated technology based system (using GPS) to monitor freight vehicles and activities to better demonstrate compliance to regulations. It is a voluntary program to be operated by jurisdictions and offered to transport operators as an operating condition to schemes, permits or applications, permitting heavy vehicles with increased access to road networks. IAP remotely monitors heavy vehicles using 'telematics services' – in-vehicle systems that utilise sensors to monitor parameters of interest. Source: Egeler, Koniditsiotis and Karl (2005) and also see www.rta.nsw.gov.au/heavyvehicles/iap/index and www.iap.com.au	*Strengths* • The IAP monitoring process makes it possible to ensure the vehicle is operating in compliance with the jurisdictional conditions of access. Private sector companies (Service Providers) will offer certified In-Vehicle Units (IVU) to Transport Operators which not only serve for the IAP but also offer other applications to the transport operator. • IAP allows transport operators to carry an additional 10% load on linehaul vehicles between certain locations, on the provision that specific compliance issues are met. • Up to an additional 40% of gross profit can be achieved (see www.smarttrans.com.au) • Improvement in collaborative activities across various stakeholders including the RTA, transport operators, IAP service providers and the regulatory authority. *Weakness* • This technology is still relatively new and no quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: Lorry Control Scheme Site: London, UK Description: • The Lorry Control Scheme is "a London-wide night time and weekend ban on lorries over 18 tonnes gross vehicle weight. The ban includes all roads in London except trunk roads and several other exempt roads." "Any goods vehicle over 18 tonnes gross vehicle weight that wishes to use a road that is part of the London Lorry Control Scheme during the controlled hours must be covered by an exemption permit. These permits are available to vehicles that can demonstrate a need to use restricted streets at controlled times." Source: Transport for London (2005)	*Strengths* • To control access of goods vehicles onto non-trunk roads. *Weakness* • It increases the difficulty for freight to deliver goods during peak times. • Requires rigorous monitoring and enforcement.	**Applicable** • Can be used on urban arterial roads • Supply measure
	Scheme: Restrictions on goods-vehicle loading and unloading time Site: Sapporo, Japan Description: • Sapporo experienced with restricting goods-vehicle loading and unloading to 9:30am-11:30am and 14:30pm-16:30pm between October 1997 and February 1998 in order to reduce traffic congestion in the city centre. Source: OECD (2002)	*Strengths* • The ban reduced loading times, as operators sought to make the most efficient use of the time available. *Weakness* • It increases the difficulty for freight to deliver goods during peak times. • Requires rigorous monitoring and enforcement.	**Applicable** • Can be used on urban arterial roads • Supply measure
	Scheme: Establishment of a city logistics terminal just outside the city centre Site: Odense, Denmark (Denmark's third largest city with a population of 185,000) Description: • A study has shown excellent potential for reducing freight	*Strengths* • The study estimates that total freight traffic could be reduced by 2% through use of lorries with a maximum weight of six tonnes. • This practice would reduce energy consumption and CO_2 emissions by 15%. *Weakness* • However, the study estimates that it would increase hydrocarbon emissions by	**Not Applicable** • If smaller vehicles are used then this could increase congestion.

Table 6: Management Tools to Enhance the Operation of Arterial Roads

Topic	References	Strengths / Weakness	Is it Applicable?
	transport, pollution, and energy consumption by establishing a city logistics terminal, located just outside the city centre. Source: OECD (2002)	14%. • If smaller vehicles are used, total freight traffic rises by 2%, but CO2 and other types of pollution are significantly reduced.	
	Scheme: Park and Ride Site: Various in UK Description: • Bus-based park and ride refers to the provision of a dedicated regular bus service running to and from a city centre and a number of car park sites in areas close to the edge of the area along radial routes. These sites are positioned so as to intercept motorists coming into the town from further a field rather than go all the way into town. Source: FaberMaunsell (2006)	*Strengths* • It reduces levels of traffic in main urban areas, providing a sustainable alternative car use. • It reduces the requirement for parking provision in major centres. *Weakness* • Demand for Park and Ride sites needs to be managed carefully as subsidies may be required to operate an effective system.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already applied in Australia
b) Access to adjacent development			
	Scheme: Restrictions on vehicle access to the city centre Site: Rome, Italy Description: • Authorised non-residents (such as shop owners or doctors with offices in the centre) are required to pay yearly the equivalent of 12 monthly public transport passes for a permit to access the controlled area. There are 23 electronic gates which identify the vehicle and calculate the applicable tariff for vehicle entrance into the restricted area. The gate infrastructure, based on the technology used for the Telepass system, includes TV camera and IR illuminators, microwave transponder and on-board unit with smartcard. Source: Transport and Travel Research (2004)	*Strengths* • Reported changes in modal split were observed: -13% car, +14% moped, and +16% public transport. • The vehicle occupancy rate increased from 1.51 to 1.53. It produces a significant operating profit. *Weakness* • There were no significant changes for the length of the peak periods. • Shop owners in Rome would prefer a standard congestion charge that allows all vehicles into the city centre for a fee whereas residents prefer the restricted access scheme that gives them free access.	**Not applicable** • Some urban cities in Australia provide high levels of parking (i.e. Melbourne).
	Scheme: Restrictions on public parking spaces – "Blue Zones" Site: Bern, Switzerland Description: • All public parking spaces that were neither "limited stay" nor "pay" spaces have been re-classified as Blue Zones since 1992. Blue Zones are located in residential areas. On weekdays parking is limited to 60 minutes between 8am and 6pm. Three-hour parking is permitted in the inter-peak period. In areas with a high level of leisure traffic, restrictions can be extended to weekends. Residents can purchase a parking permit at a cost of 240 francs per month. Visitors and other users can purchase daily parking permits. Source: Transport and Travel Research (2004)	*Strengths* • The system was introduced in 1999, including the removal of 10% of public parking spaces. The Blue Zone resulted in a reduction of traffic volume by 15% on average (14% in the morning peak, 21% in the evening peak and a 13% reduction in the number of vehicles in restricted areas. • It reduced demand for parking spaces by 13% on average, and hence, residents had fewer problems finding a space and search traffic was reduced. *Weakness* • It requires regular and strict enforcement for success. • In the CBD, charges have barely had any impact on demand as they are not high enough.	**Not applicable** • Influences demand for travel rather than supply of road travel.
	Scheme: Various access management measures for arterial streets Site: Various US cities	*Strengths* • Raised medians can increase roadway safety by reducing the number of conflict points and managing the location of the conflict points.	**Not applicable** • Influences demand for travel rather than supply of road

Table 6: Management Tools to Enhance the Operation of Arterial Roads

Topic	References	Strengths / Weakness	Is it Applicable?
	Description: Typical treatments include consolidating driveways to minimise the disruption to traffic flow, median turn lanes or turn restrictions, acceleration and deceleration lanes and other approaches to reduce the potential collision and conflict points. Source: TAMU (2005a) and TAMU (2005b)	• The reduction in conflict points equates to a reduction in crashes. • In various US cities, it reduces delay from 12% at low signal density (<3 signals/mile) and the lowest congestion level to 22% at high signal density (>3 signals/mile) and the highest congestion level. *Weakness* • No quantitative result has been found.	travel.
	Scheme: Limit the maximum capacity of a single freight vehicle entering the city centre Site: Paris, France Description: • Regulation set to limit the maximum capacity of a single freight vehicle entering the city centre during the day to $24m^2$. Source: Austroads (2005)	*Strengths* • It has an advantage to encourage the use of road network for freight traffic during off peak times. *Weakness* • At the same time, it increases the difficulty for freight to deliver goods during peak times. • Requires rigorous monitoring and enforcement.	**Not applicable** • Could result in an increase in the number of freight vehicles.
	Scheme: An access control zone in the historic centre Site: Barcelona, Spain Description: • Only vehicles holding a special smart card have access. Delivery vehicles are banned during certain time windows. This system now has digital video enforcement. Special lanes are allocated to deliveries between 7am and 5pm, to general traffic between 5pm and 10pm and then to residential parking at night. Source: OECD (2003)	*Strengths* • To minimise conflicts between delivery vehicles and other vehicles. *Weakness* • It increases the difficulty for freight to deliver goods during peak times. • Requires rigorous monitoring and enforcement.	**Not applicable** • Not applicable due to the nature of urban cities in Australia.
c) Lane Control			
	Scheme: Guided busway Site: A641 Manchester Road in Bradford Description: • Mix of guided busway, with-flow bus lanes and priority at signal controlled junctions. Scheme opened in February 2002. Source:	*Strengths* • Scheduled bus journey time between Odsal Top and Bradford Interchange is 15 minutes in the morning peak and 13 minutes at other times. The express bus service is about three minutes quicker. • Patronage grew by between 7 and 10 per cent *Weakness* • installation of 11 new signal-controlled pedestrian crossings was an essential component of the scheme but had an adverse effect on bus and car journey times • Monitoring • Length of planning and construction • Costs	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
d) Signal Coordination			
	Scheme: Sydney Coordinated Adaptive Traffic System (SCATS) Site: Sydney, Australia Description: • SCATS is an innovative traffic management system developed by the Roads and Traffic Authority to co-ordinate the traffic signal network. The system reacts to changing	*Strengths* • 20% travel time reduction (Booz Allen Hamilton, 1998) *Weakness* • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia

Table 6: Management Tools to Enhance the Operation of Arterial Roads

Topic	References	Strengths / Weakness	Is it Applicable?
	traffic conditions by adjusting the phasing of each traffic light cycle for 3,000 traffic signals across NSW. Source: NSW RTA (2002)		
	Scheme: Adelaide Coordinated Traffic Signals (ACTS) Site: Adelaide, Australia Description: The traffic signal optimisation project involves improving the performance of the Adelaide Coordinated Traffic Signals (ACTS) system. This system uses the SCATS software under licence from the NSW RTA. SCATS responds dynamically to traffic densities by continually adjusting green time allocation at sites, adjusting cycle times and coordination at linked sites. Nevertheless the background parameters in SCATS need periodic review due to broad changes in traffic patterns. This project is undertaking such a review.	Strengths • Improved alignment of ACTS with strategic routes and the road hierarchy. • The implementation of improved SCATS parameters has generally reduced average travel times by 5 – 15%. • Traffic patterns do change. In Adelaide's case there is an increased emphasis on strategic north – south routes and the inner ring route over radial routes Weakness • It is important to document the intended operation of linked intersections in SCATS .	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	• Scheme: Split Cycle Offset Optimisation Technique (SCOOT) • Site: Various cities in the UK • Description: The SCOOT system operates in a similar way to the SCATS and responds automatically to traffic conditions, altering signal settings to optimise junction operation. Over 170 towns and cities in the UK now use SCOOT. • Source: FaberMaunsell (2006)	• Better signal co-ordination leads to more efficient use of the network • Co-ordinating and synchronising operating systems can be problematic	**Applicable** • Can be used on urban arterial roads • Supply measure
	• Scheme: Bus SCOOT • Site: Cardiff, UK • Description: Bus SCOOT is a facility incorporated into SCOOT to give priority to buses. It uses information from an Automatic Vehicle Location (AVL) system via GPS technology or a beacon based system. Cardiff uses GPS technology. • Source: FaberMaunsell (2006)	*Strengths* • In the AM peak when priority was given to all buses there was an average reduction in delay to buses of 4 seconds per bus per junction and an average reduction in lateness of 70 seconds. • With priority given to only those buses behind schedule there was a reduction in delay to buses to 3 seconds per bus per junction and a reduction in lateness of 92 seconds. *Weakness* • The potential benefits of bus priority were significantly affected by operational and technical problems, including the high level of co-ordination required between different stakeholders; the number of interfaces between different systems; a lack of formal monitoring procedures; and the complexity of the systems combined with the relatively new use of the technology.	

Table 6: Management Tools to Enhance the Operation of Arterial Roads

Topic	References	Strengths / Weakness	Is it Applicable?
	Scheme: Split Cycle Offset Optimising Technique (SCOOT) Site: Toronto and Ontario, Canada Description: • The SCOOT system operates in a similar way to the SCATS and has been implemented in CBD for 75 signals. SCOOT responds automatically to traffic conditions, altering signal settings to optimise junction operation. Over 170 towns and cities in the UK now use SCOOT. Source: Booz Allen Hamilton (1998) and Booz Allen Hamilton (2006a)	*Strengths* • Better signal co-ordination leads to more efficient use of the network • 8% travel time reduction • 17% delay reduction *Weakness* • Co-ordinating and synchronising operating systems can be problematic	

	Scheme: Closed loop signal system
	Site: Abilene, Texas, US
	Description:
	• The system was installed as a result of the Texas' Traffic Light Synchronisation (TLS) program. The TLS was funded through Oil Overcharge funds made available through the Texas Governor's Energy Office.
	Source: Levy (1997)
		Strengths
		• One year after the installation of the system:
		  • 37% delay reduction
		  • 22% travel speed increase
		  • 14% travel time reduction
		  • 12% CO_2 reduction
		• Subsequent projects yielded between $8 and $11 worth of benefits in reduced stops and delays, as well as fuel savings, for every $1 spent.
		Weakness
		• No quantitative result has been found.
			Applicable
			• Can be used on urban arterial roads
			• Supply measure
			• Already being applied in Australia

	Scheme: FAST-TRAC Site: Oakland County, Michigan, US Description: • It is a SCATS-based arterial road signal coordination system which monitors about 600 of 13000 signalised intersections Source: Cambridge Systematics (2005) and Booz Allen Hamilton (2006a)	*Strengths* • From a study of three mile corridor, it achieved peak travel speed increase and travel time reduction of 7% to 9% in peak direction and 7% to 20% in off-peak direction. • Non-peak travel speed increased and travel time reduced by 15% to 32%. *Weakness* • No quantitative result has been found.	
	Scheme: BALANCE Site: Munich, Germany Description: • BALANCE is a traffic light network control system. Source: Booz Allen Hamilton (1998) and Booz Allen Hamilton (2006a)	Strengths • 14% delay reduction Weakness • No quantitative result has been found.	
	Scheme: SURF 2000 Site: Paris, France Description: • SURF 2000 is a traffic control system. Source: Proper (1999) and Booz Allen Hamilton (2006a)	Strengths • 20% travel time reduction Weakness • No quantitative result has been found.	

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Topic	References	Strengths / Weakness	Is it Applicable?
	Scheme: MOVA - Microprocessor Optimised Vehicle Actuation Site: Various in UK Description: • It is a signal control strategy that alters traffic signal timings in response to actual traffic conditions at isolated junctions. Inductive loops on the approach to the signals allow MOVA to allocate the optimum green time to the different traffic movements. The system can be programmed to reduce the waiting time of the priority vehicles. Source: Vincent (1999)	Strengths • Improves journey times for all vehicle classifications but can also be used to give priority to individual user classes, such as public transport modes. Weakness • It would not be viable where signals are not present.	
e) Traffic Signal spacing			
f) Controlled turns versus filtered turns at signals (trade off between safety and efficiency)			
g) Local Area Traffic Management (LATM) and implications for arterial roads			
	Scheme: Local Areas Traffic Management Site: Melbourne, Australia Description: • Local Area Traffic Management (LATM) refers to physical changes to a local street, which is primarily designed to benefit residents and nearby users. Original LATM plans (1998-2002) for 19 precincts. Developed review criteria in 2004 to determine effectiveness of schemes treatments after installation and ensures learning for future. Source: Institute of Transportation Engineers, Presentation by Melissa Falkenberg (2005), Local Area Traffic Management - A Victorian approach	Strengths • Reduction in casualty crashes to 1 per 1000 head of population by 2007 (during 2003 was 1 per 840 head of population) • Reduction in 85%ile speeds to be 54km/h or less on local streets • Reduction in resident complaints to Council relating to speeding by 50% by 2007 Weakness • No quantitative result has been found.	**Not Applicable** • Being applied in Australia to manage road safety. • When practised on an area-wide basis, has displaced significant traffic volumes into the arterial road network, resulting in increased peak period congestion.
	Scheme: Speed reduction measures in residential area Site: The Groves in York, UK Description: • Council installed a 20 mph zone comprising of speed tables and chicanes to reduce rat running in this residential area adjacent to historic city centre. Source: Booz Allen Hamilton (2006b)	Strengths • On one street personal injury accidents over 3 years reduced from 7 to 3. • Traffic speed reduced from 27 mph to 15 mph. • Traffic flow remained constant (4,000 vehicles per day). Weakness • It requires constant monitoring and enforcement.	**Not Applicable** • Being applied in Australia to manage road safety. • When practised on an area-wide basis, have displaced significant traffic volumes into the arterial road network, resulting in increased peak period congestion.

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Topic	References	Strengths / Weakness	Is it Applicable?
	Scheme: Speed reduction measures in a shopping street Site: Norwich, UK Description: • The scheme was implemented at St. Stephens St, a major shopping street but also a major traffic route. Council installed kerb build outs, flat topped humps and extensive guard-railing to ensure pedestrians only cross at road humps. Source: Booz Allen Hamilton (2006b)	Strengths • Almost 100% reduction in personal injury accidents (previously 12 per year) • Traffic volumes reduced significantly: 45% reduction in AM peak hour and 40% reduction in PM peak hour. Weakness • Negative visual impact of scheme (especially guard rail).	
	Scheme: Introducing 32kph zones outside schools Site: Various in the UK Description: • Introducing 32kph zone outside schools can be the difference between life and death. British Government data says that on average, a child is hurt or killed on UK roads every 30 minutes. Pedestrian and cyclist casualties peak in the morning and afternoon peaks. Source: World Highways (2005)	Strengths • Increase child road safety • Hit at 32kph, a child a 95% chance of survival, compared with a 55% chance if hit at 48kph and a 15% chance at 64kph. Weakness • Child road safety has not been top of the agenda for Britain's hard-pressed politicians and may experience difficulty in implementation.	
	Scheme: Various traffic calming measures Site: Various places in the UK Description: • In 1994, the County Surveyors Society reviewed 152 case studies and provided more detail of the 85 case studies of traffic calming implemented in the late 1980s and early 1990s in the UK. Over half of the schemes (56%) were located in urban residential areas with 29% occurring on main roads in rural locations and the remaining 15% in town centre areas. The LATM measures used include road humps, carriageway narrowing, chicanes, refuges, mini-roundabouts, road markings, road signs, gateways, table functions, coloured surfacing and rumble strips. Source: Transport and Travel Research (2004)	Strengths • Among these measures, 74% of the schemes were aimed at reducing speed, with 64% aimed at accident reduction, and 36% at reducing the volume of through traffic. • Nearly every scheme was intended to address two of these problems and many were aimed at all three, with 17% of the schemes also addressed environmental improvements. • With a reduction in traffic in local areas as a result of the implementation of these schemes, it improved liveability, reduced accidents, and air and noise pollution. Weakness • Some of these measures reduced road capacity in local areas and resulted in rerouting, which reduced efficiency. • For bus services, if journey times on a bus route passing through traffic calmed streets are increased significantly because of the implemented measures, this will reduce the attractiveness and comfort of the service.	**Not Applicable** • Being applied in Australia to manage road safety. • When practised on an area-wide basis, have displaced significant traffic volumes into the arterial road network, resulting in increased peak period congestion.
h) Parking controls/clearways			
	Scheme: Parking cash out Site: Pfizer (Pharmaceutical company), Kent, UK Description: • All employees are entitled to park on site but can take advantage of Pfizer's parking 'cash-out', introduced June 2001. Under the scheme employees receive £2 (before tax) for every day that they work on site but do not bring a car. The bonus is calculated on the basis of the cost of providing a parking space – assessed on capital cost, security, maintenance, planting and lighting (£400 - £500 a year). It is also set at a rate thought likely to change behaviour. The	Strengths • Mode shift achieved • Managed local parking • Reduced local congestion Weakness • Cost of cash out software • Management nervousness • Adverse staff reactions over parking cash-out – particularly from shift workers who do not add to traffic congestion • PT operators are not positive enough about the prospect of growing the market.	**Not applicable** • Influences demand for travel rather than supply of road travel.

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Topic	References	Strengths / Weakness	Is it Applicable?
	scheme is operated through the use of security access (proximity) cards. Points are added on entry to the site and deducted from those leaving through the car park barrier. Motorcyclists and car sharers also benefit from the scheme (only one person in the car needs to use their security card at the car park barriers). Points instead of money are used to avoid tax being paid for use of parking spaces. Unused points are transferred to payroll at the end of the month and converted into money. Source: DfT (2004), Making Travel Plans Work – Lessons from UK case Studies	• Taxation of the parking cash-out as a benefit in kind remains a major barrier and prevents this reward being offered to contract employees.	
	Scheme: Red Routes Site: London and Birmingham, UK Description: • The concept was principally one of greater enforcement of urban clearway principle with strict 'no stopping' regime. They were designed to deter inconsiderate drivers of any vehicle from stopping illegally, and thereby delaying all vehicles. Source: FaberMaunsell (2006)	*Strengths* • Results have shown: • Bus journey reliability increased by 27% with journey time reduced by 10% • Car journey reliability increased by 20% with journey time reduced by 20% • Freight movements have benefited from similar levels of benefit. • Illegal parking reduced by 75% • No detrimental effect on local business • Adopts a whole route and network approach which leads to a more 'joined-up' approach. *Weakness* • Strong opposition from local traders is often encountered during consultation given the perceived impact on parking for potential customers.	**Applicable** • Can be used on urban arterial roads • Supply measure
	Scheme: San Francisco Transit First Policy Site: San Francisco, California, United States Description: • The policy allows parking to occupy up to 7% of a building's gross floor space. New buildings must have an approved parking plan prior to receiving an occupancy permit. In some cases, only short-term parking is approved; while in other cases, a mix of short-term, long-term and carpool parking is approved. Source: K. T. Analytics Inc. (1995) based on OECD (2002)	Strengths • Downtown transit ridership has remained steady at 60%, while 17% downtown commuters drive alone and 16% carpool. Weakness • In the early 1990s, city planners indicated that there had not been a major increase in downtown peak traffic over the previous decade in spite of considerable office growth.	**Not applicable** • Influences demand for travel rather than supply of road travel.
	Scheme: Parking surcharges Site: Copenhagen, Denmark Description: • Between 1990 and 1991, Copenhagen introduced fees for most of the public parking areas in the inner city. Source: OECD (2002)	Strengths • One year later, the number of cars parked in the inner city had dropped by 25%, and traffic to and from the area was reduced by about 10%. • An analysis by the regional public transport company showed that 2% of all passengers to the four city stations had recently shifted from car to train/metro. Weakness • No quantitative result has been found.	**Not applicable** • Influences demand for travel rather than supply of road travel.
i) Incident and accident management			
	Scheme: Incident management system using SCATS Site: Sydney, Australia	Strengths • 6% to 12% travel time reduction	**Applicable** • Can be used on urban arterial

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Topic	References	Strengths / Weakness	Is it Applicable?
	Description: • The Sydney metropolitan road network is monitored by over 320 CCTVs by the RTA. Detector loops are being progressively installed at 500 metres intervals across the freeway network. These inputs, together with information from the SCATS, which controls the traffic signals, and information phoned in by road users to the call centre; enable incidents to be rapidly detected and verified. Considerable effort is also currently being focussed on progressively developing preset automated incident response plans. Source: NSW RTA (2002) and Booz Allen Hamilton (1998), based on Booz Allen Hamilton (2006a)	Weakness • No quantitative result has been found.	roads • Supply measure • Already being applied in Australia
	• Scheme: Incident management system using SCATS • Site: Adelaide, Australia • Description: One of the key functions of SCATS is the real time collection of traffic presence and density data, along with system generated alarms for congestion and faults to alert operators. o CCTV monitoring provides visual traffic information in real time. o The Traffic Management and Control System provides traffic data from the incident detection loops on the Southern Expressway. o Video incident detection systems at the Heysen Tunnels and Southern Expressway entrances provide alarms of congestion or incidents to TMC operators. Source: Communiqué from Andrew Excell, (15, August 2006), A/Regional Manager Metropolitan Transport Services Division – Metropolitan Region.	Strengths • Once implemented, the new Traffic Management and Control System will integrate existing functions that are currently on separate systems. • Will also provide new functionalities such as traffic data output and possibly real time travel times. • Greater network coverage for CCTV, automatic incident detection, and variable message signs, particularly on strategic urban routes. • Improved interfaces to police CAD system and public transport operations systems to enable more efficient transfer of information. Weakness • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: CityLink's Central Control Computer System (CCCS) Site: CityLink Toll Motorway, Melbourne, Australia (currently owned and operated by Transurban, comprising 22km of freeways) Description: • CCCS, developed by MI Transport Systems, integrates traffic management and tunnel plant control systems into a single operator interface and includes a state-of-the-art incident management system, with automatic incident detection by real time digital image processing, automated response plans and decision support systems for response management. Source: Transurban's website (www.transurban.com.au), CityLink's website (www.citylink.com.au) and University of Queensland (2003)	Strengths • Improve journey time reliability • Reduce travel time • Improve safety Weakness • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia

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Topic	References	Strengths / Weakness	Is it Applicable?
	Scheme: COMPANION Hazard Warning System Site: M90 Motorway, UK Description: • COMPANION is designed for use on inter-urban roads, with its objective to reduce the number of 'shunt' style accidents by warning drivers in advance of stationary vehicles ahead. The system uses a roadside hazard warning system, based on electronic guide markers Source: FaberMaunsell (2006)	Strengths • Activation of the system is now automatic, meaning the system is self sufficient. • Has proven to reduce speeds by 10% - 20% when activated. • The system is showing some improvement of accident rates with pre-implementation rates of 0.10 PIA's per MVkm, and the current post implementation rates estimated to be 0.06. Weakness • If these are only implemented in isolated locations, it can be confusing for strategic road users.	**Applicable** • Can be used on urban arterial roads • Supply measure
	Scheme: TransGuide System Site: San Antonio, Texas, US Description: • TransGuide monitors traffic conditions to provide information to motorists and respond to incidents. Source: US Department of Transportation (2000)	Strengths • Total accidents reduced 35% • Total accidents reduced 40% during inclement weather • Secondary incidents reduced 30% • Overall accident rate reduced 41% • Significant improvements in driver confidence • Average response time reduced 20% • Average delay savings per incident: 700 vehicle-hours • Average reduction in fuel consumption per incident: 2600 gallons • Benefits translate to annual savings of $1.65 Million Weakness • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: GDOT NaviGAtor System Site: Atlanta, Georgia, US Description: • GDOT NaviGAtor monitors traffic incidents. Source: US Department of Transportation (2000)	Strengths • Average time to verify incidents reduced from 4.2 minutes to 1.1 minutes during the first three weeks of system operation • Average time to generate an automated incident response after incident verification reduced from 9.5 minutes to 4.7 minutes during the first three weeks of system operation • Mean time between incident verification and the clearance of travel lanes reduced from 40.5 minutes to 24.9 minutes during the first three weeks of system operation • Maximum time between incident verification and the clearance of travel lanes reduced from 6.25 hours to 1.5 hours during the first three weeks of system operation • Benefit to cost ratio in 1997: 2.3:1 (calculated as a result of reduced delay due to accidents on the freeway) Weakness • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure
	Scheme: Red Light Running Enforcement Site: Various in US Description: • Automated enforcement of red light running offences using roadside cameras. Red light running can cause serious accidents which subsequently causes congestion and delays. Source: Sussman (2000)	Strengths • 25% to 70% reduction in crashes Weakness • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia

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Topic	References	Strengths / Weakness	Is it Applicable?
	Scheme: Various incident management programs Site: Various US cities Description: • It includes service patrols and camera systems Source: TAMU (2005a)	Strengths • The US Highway Economic Requirements System (HERS) estimated the effect of service patrols as a 25% reduction in incident duration which, when modelled at the section level with Highway Performance Monitoring System (HPMS) data resulted in a 65% reduction in incident delay. • The camera systems contributed an additional 4% to 5% reduction in incident delay. • When both treatments are combined, this would suggest a 30% reduction in incident duration and a 70-75% reduction in incident delay. Weakness • Like other incident and accident management schemes, it requires a program to cover the high cost of camera surveillance and service patrols systems.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
j) Speed control (also see g – LATM measures)			
	Scheme: Vehicle Activated Signs Site: UK (various) Description: • VAS can prevent overheight vehicles striking bridges by measuring the height of an oncoming vehicle, typically with an infra-red beam, and signal an overheight vehicle to stop or divert. • A VAS can signal to overweight vehicles to avoid weak bridges or other weight restrictions. • A weight-sensitive VAS can instruct HGV drivers to switch to the 'crawler' lane in an uphill section of major road. • VAS can be used to inform motorists of variable speed limits, through a roundel or SID installation. Source: Department for Transport	Strengths • The costs avoided in preventing just a single serious bridge strike may well outweigh the entire cost of installing the VAS. • An even more sophisticated system could use video recognition of vehicle classes to issue individual instructions to each vehicle, diverting different classes of vehicle onto different routes to optimise carriageway usage and reduce congestion. Such a system could be a major part of the future of VAS Weakness • Whilst variable speed limits have a good track record in reducing 'bunching' and related delays on trunk roads, they have had less of an impact on minor roads and are not considered to be cost-effective.	**Applicable** • More appropriate for freeways than arterial roads but could be applied where alternative routes are available. • Already being applied in Australia
	Scheme: Weather-dependant variable speed limit system Site: New South Wales, Australia Description: • The AUD$2.3 million project (completed in 2006) uses weather stations and moisture detectors in conjunction with speed limits signs and a new fixed digital speed camera. When rain is detected, the limit drops from 100 to 90kmh. Source: Traffic Technology International (2006a)	Strengths • Road Minister Eric Roozendaal expected this new technology will greatly increase road safety in the Mount White area and reduce wet weather crashes. Weakness • The system is a new technology and has never been used in Australia before, which may require further improvements.	**Applicable** • More appropriate for freeways than arterial roads but could be applied on major arterial roads. • Already being applied in Australia
	Scheme: Two "variable speed limits" schemes Site: M25 Motorway, UK Description: • The schemes involve the use of variable message signs, loop detectors and speed cameras. Source: Booz Allen Hamilton (2006a) and CEDR (2003) further provides the technical detail in the application of variable message signs in the European context.	Strengths • The schemes achieved approximately 25% to 30% in accident reductions. Weakness • No quantitative result has been found.	

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Topic	References	Strengths / Weakness	Is it Applicable?
	Scheme: The Transcalm speed hump device Site: Various in the UK Description: • The device was invented by Graham Heeks with Cambridge University and claims to "revolutionise current traffic calming and road safety methods". The device does not affect law-abiding drivers but only speeding motorists. Source: World Highways (2006) and also see Dunlop Transcalm website (www.transcalm.com)	Strengths • Trancalm has been piloted successfully for over four years in the City of London, where highways and transportation director, Joe Weiss, describes it as the "Rolls-Royce of road humps". • Emergency services are said to have hailed it as a major improvement. • Statistics from the UK Department for Transport show that for each 1 mph (1.6 kph) reduction in speed there is a 5% drop in accidents causing injury. Weakness • The installation of the device seems to be more expensive than the other more common types of road humps.	
	Scheme: Controlled Motorway Site: M25 Motorway, UK Description: • Inductive loops in the road measure speed, flow and occupancy data. This is used by the Controlled Motorway algorithm in the roadside cabinet to identify when the flow and speed relationship indicates likely flow breakdown. The system then selects an appropriate reduced speed limit designed to optimise the overall flow of traffic on the road. When the outstation identifies a requirement to reduce speed, the speed limits are automatically set. Source: FaberMaunsell (2006)	Strengths • The strengths of this scheme are related to safety and efficiency. There was a sustained reduction in accidents of 28% compared to the previous year. In addition to this motorists were found to be more inclined to keep in their lane, as well as to keep to the inside lane (flow rate increased by 15%) and to maintain proper separation distances. • High levels of user acceptance have been recorded Weakness • No quantitative result has been found.	**Not Applicable** • More appropriate to freeways not arterial roads • Urban Traffic Control System more applicable to arterial roads • Often too many local roads / intersections which would result in a large number of speed signs.
k) En-route information systems to inform road user decisions			
	Scheme: Drive Time Site: Melbourne, Australia Description: • Developed by VicRoads, is being installed progressively on all metropolitan freeways. It provides road users with information about travel times and traffic conditions via computerised signs. It also enables the Traffic Management Centre staff to provide prompt advice to drivers when a serious incident occurs, by using the variable message signs located along the freeways. Drive Time trip information signs tell drivers how long it will take them to reach various freeway exits. As well as providing estimated travel times, a colour-coded indicator advises where the traffic is light (green), medium (yellow), or heavy (red). Source: http://traffic.vicroads.vic.gov.au/trafficinfo/default.aspx?width=1280	• No quantitative or qualitative data available	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia

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Topic	References	Strengths / Weakness	Is it Applicable?
	Scheme: Provision of driver information Site: Sydney, Australia Description: • Estimation of potential travel time savings on a number of major Sydney arterial roads through the provision of driver information. Source: Booz Allen Hamilton (1998) based on Booz Allen Hamilton (2006a)	Strengths • Estimated 8% travel time reduction through the provision of variable message signs • Estimated travel time reduction of 5% through the provision of variable speed limit signage Weakness • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: UTMC Demonstrator Site: Reading, UK Description: • The scheme extracts information from two existing public transport databases (rail and buses) and integrates this with information from existing traffic management systems. The information provides a comprehensive picture of the state of road and public transport networks, which the system offers to the public through several different media, including: Roadside electronic signs: • Internet • Company intranets • Email alerts • Tailored text messages through mobile phones • The information allows the public to make better journey decisions either before they start or during their journeys. For instance, drivers already travelling to the town centre could alter their route or change the car park they use based on information they see on roadside electronic signs. Source: FaberMaunsell (2006)	Strengths • The system provides greater availability of traffic and travel information through the use of real time information. • Integrated information from existing systems rather than having to set new systems up. • More consistent information is provided to travellers, for example by combining VMS with radio messages • A network of information sources are in place to disseminate information to travellers following live incidents or inform of the potential effects of planned events. Weakness • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: Provision of traffic information via variable message signs Site: Montgomery County, Maryland, US Description: • Traffic information on variable message signs heeded. Source: Booz Allen Hamilton (1998) based on Booz Allen Hamilton (2006a)	Strengths • 8% to 11% travel time reduction Weakness • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: RACS Site: Tokyo, Japan Description: • Route guidance system. Source: Booz Allen Hamilton (1998) based on Booz Allen Hamilton (2006a)	Strengths • 9% to 14% travel time reduction Weakness • No quantitative result has been found.	

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Topic	References	Strengths / Weakness	Is it Applicable?
	Scheme: Autoguide Project Site: London, UK Description: • Using cars fitted with real time route guidance systems. Source: Booz Allen Hamilton (1998) based on Booz Allen Hamilton (2006a)	Strengths • 6% travel time reduction Weakness • No quantitative result has been found.	
	Scheme: TRAV-TEK Program Site: Orlando, Florida, US Description: • It employed 100 vehicles fitted with electronic route guidance systems. Source: Booz Allen Hamilton (1998) based on Booz Allen Hamilton (2006a)	Strengths • 19% travel time reduction Weakness • No quantitative result has been found.	
	Scheme: TANGO Project Site: Gothenburg, Sweden Description: • It used five cars fitted with route guidance systems. Source: Booz Allen Hamilton (1998) based on Booz Allen Hamilton (2006a)	Strengths • 20% travel time reduction for unfamiliar journeys Weakness • No quantitative result has been found.	
	Scheme: RDS-TMC / VICS Site: UK Description: • Broadcast of real time traffic and travel information direct to the motorist using the RDS-TMC facility Source: ITS Assist	Strengths • Commercially viable, motorists would pay an average of £130pa for the service • 87% of motorists in the trial felt that RDS-TMC had saved them time and stress Weakness • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: Car Park Guidance System Site: Manchester, UK Description: • Manchester like many cities and towns suffers from large amounts of traffic. Additional congestion and stress is caused when motorists attempt to enter car parks that are already full. 400 digital CCTV cameras have been installed in 40 car parks in Manchester, which feed information back to a manned 24-hour Control Centre. Three radio networks have been installed (NCPnet, Storenet and Nitenet) so communication between operators and personnel (car park staff) is possible. Variable message signs have been installed on key routes for the display of car park availability to road users. The Control Centre and VMS signs are linked to modern control equipment. Source: FaberMaunsell, 2006	Strengths Weakness • The VMS signs aim to ensure motorists can make an informed choice about car parking availability and their best route into the centre • Increased efficiency of the network as drivers are not 'cruising' for car park spaces. • It requires sign up from all car park operators to be fully effective. •	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia

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Topic	References	Strengths / Weakness	Is it Applicable?
	Scheme: Parking Guidance System Site: Southampton (UK), Valencia (Spain) Description: • Use of real time parking utilisation information and VMS signs to inform motorists of which car parks have spare capacity Source: ITS Assist	Strengths Weakness • Reduce time spent searching for a space by 50% • 61% of motorists influenced by the signs • 30% motorists changed their parking destination • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: Parking guidance system Site: Aalborg, Denmark Description: • As part of the EU-sponsored Project Jupiter, the city of Aalborg has established a parking guidance system that provides motorists with real-time information on the number of available parking spaces in the centre city parking facilities. Parking availability is displayed on variable message signs posted along the main roads leading into the city centre. Roads around the periphery of the city centre lead car traffic to parking spaces located just outside the core central area. Source: OECD (2002)	Strengths Weakness • Following the implementation of this guidance system, the percentage of drivers unable to park in Aalborg has been reduced from 21% to 9%; pollutants have been reduced by 0.1%, and 930 km/day have been saved as a result of drivers not having to circle parking lots in search of an available space. • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
l) integrated arterial road management systems – the above elements can be considered as stand-alone management tools, however the integration of these can yield increased benefits			
	Scheme: RTA's Transport Management Centre (TMC) Site: Sydney and New South Wales, Australia Description: • The RTA's TMC monitors and manages the NSW road network 24 hours a day. It aims to ensure that the 180,000km network operates with maximum efficiency, including during peak commuter travel times, special events and following unplanned incidents such as vehicle accidents. Source: NSW RTA (2002) and also see RTA's website for more information http://www.rta.nsw.gov.au/trafficreports/index.html?hlid=12	Strengths • The TMC uses advanced monitoring, communication and traffic flow systems to make journey times more consistent, respond to and clear traffic incidents as fast as possible and with quality, up-to-date information, help road users choose the best routes, travel times, and modes of travel. • The Transport Operations Room (TOR) within TMC incorporates a highly sophisticated video switching system, a 24-panel video wall, 18 dedicated operator consoles, fully integrated voice-based communications, the Centre Management Computer System (CMCS), fast access to geographic information, Sydney Coordinated Adaptive Traffic System (SCATS) and dedicated operators from public transport providers and the NSW Police. • Other TMC tools include tidal flows, CCTV, VMS and web-based information. Weakness • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: Trafficmaster Site: UK Description: • Trafficmaster collects its traffic information from 7,500 sensor sites. On motorways Trafficmaster uses infrared sensors mounted on bridges to determine the average speed of traffic	Strengths • better utilise the road network capacity, through diverting traffic to alternate routes; • reduce traffic congestion; • reduce driver stress; and • improve the environment through reduced pollution Weakness	**Applicable** • More appropriate to freeways than arterial roads • Urban Traffic Control Systems more applicable to arterial roads.

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Topic	References	Strengths / Weakness	Is it Applicable?
	flow. On trunk roads Trafficmaster have installed Passive Target Flow Measurement, which uses ANPR on two cameras to calculate average journey times. Information collected is automatically fed through to traffic information services and back to the control centre for analysis. Traffic information is updated on a three-minute cycle, ensuring that the end-user is also supplied with the current status of traffic flow (via in-vehicle devices, or telephone). Trafficmaster also provides a web-based service (www.trafficmaster.net) and a telephone service - run in conjunction with the RAC. Trafficmaster is further augmented through access to the RAC and several other incident databases. Source: FaberMaunsell, 2006	• Operated as a commercial service so the cost of the scheme is unknown.	
	Scheme: Urban Traffic Management Control (UTMC) Demonstrator Site: York, UK Description: • The demonstrator project is the first phase in the implementation of a Traffic Congestion Management System (TCMS) that is to be rolled out over a five-year period to cover the whole city. The TCMS is an application that collects information on network conditions, air quality, roadworks and incident information and stores it on a common database. Other information is collected from other programs (UTC, SATURN etc) and disseminated to the public in a number of ways, including 28 car park guidance signs. The system makes extensive use of UTMC communications to enable similar equipment from different suppliers to share communication links, reducing operational costs Source: FaberMaunsell, 2006	Strengths • Educates user of the choices of transport mode available and preferable routes into the centre • Reduce congestion and the resultant pollution; • Assist decisions in the operation of bus priority systems. Weakness • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure
m) New and emerging technologies related to traffic congestion management and reduction			
	Scheme: Automatic vehicle control Site: Various in USA Description: Preliminary analysis was performed for the US Automated Highway System program. Source: Booz Allen Hamilton (1998) based on Booz Allen Hamilton (2006a)	Strengths • Analysis showed capacity increases of 300% for 'platooned' operation and 200% for 'non-platooned' operation; relative to current freeway operation could be predicted. • It was estimated that these capacity improvements could reduce travel times by 38% to 48%. Weakness • No quantitative result has been found.	**Not applicable** • Appropriate to freeways not arterial roads
	Scheme: London Congestion Charging Scheme Site: London, UK Description:	Strengths • Transport for London's monitoring has shown that the scheme has reduced traffic congestion within the charging zone by 30% (after one year) and improved	**Applicable** • Can be used on urban arterial roads

Table 6: Management Tools to Enhance the Operation of Arterial Roads

Topic	References	Strengths / Weakness	Is it Applicable?
	• The scheme has been in operation since 2003 to charge vehicle entering the central London area. The London Congestion Charging scheme charges users entering or driving within its perimeter. All access points are to the charging area are well signed and the scheme is enforced by Automatic Number Plate Recognition Cameras (ANPR) within the zone. Users can pay using a number of methods including the internet; retail outlets; and SMS text messaging. Source: Transport for London (2005) and FaberMaunsell (2006)	conditions on many roads around the zone. • The reduced congestion allows traffic to flow more easily and improves the reliability of journeys (14% reduction in journey times). • Bus services have been increased and have benefited from the reduced congestion. Reliability has improved by an average of 30%. Overall bus speeds within the charging zone improved by 6%. • There have been savings in accidents, fuel consumption and vehicle emissions. • The scheme is producing net revenues of over £80 million per year. Weakness • It has raised community concerns in various nearby areas.	• Supply measure
	Scheme: Stockholm's pilot congestion charging scheme Site: Stockholm, Sweden Description: • Congestion charges applied to traffic coming in and out of the city centre of Stockholm. Source: ITS International (2006)	Strengths • The scheme has helped to reduce traffic coming in and out of the city centre by 23%, which exceeded its initial goal of 15%. • The scheme has also achieved another primary goal – to significantly cut pollution in the city centre. Weakness • Initially, 70% of the Swedish capital's residents were against the idea. However, five months into the pilot scheme, which runs until 31 July, a new survey shows that 62% of the citizens of Stockholm are now positive for it and have said they will vote 'yes' to its permanent implementation in a referendum to be held in Sept 2006.	**Applicable** • Can be used on urban arterial roads • Supply measure

Table 7: Managing the Allocation of Road Space

Topic	References	Strengths / Weakness	Applicable
a) HOV (High Occupancy Vehicle) lanes (including bus lanes)			
	Scheme: HOV lane Site: A647 Stanningly Road and Stanningly By-Pass, Leeds, UK Description: • Opened on 11th May 1998 for 18month trial and was made permanent in Nov 1999. Covers a total of 1.5km of 2.0km long dual carriageway in two sections. They operate in the morning (07:00 – 10:00) and evening (16:00 – 19:00) peak periods on Mondays to Fridays. Only buses, coaches, other vehicles carrying 2 or more people, motorcycles and pedal cycles are allowed on these lanes (HGVs over 7.5T are not permitted). Project was part of an EU research project called ICARO (Increasing CAR Occupancy). Source: West Yorkshire Local Transport Plan 2006-2011; DfT's 'Bus Priority: The Way Ahead' initiative (case study on HOV Lanes) (DfT, 2004); Leeds City Council's HOV Fact Sheet (2002).	*Strengths* • Between 1997 and 1999, HOVs in morning period increased by 5 %; • Average car occupancy rose from 1.35 in May 1997 to 1.43 by June 1999 and 1.51 in 2002. Within the '2+' lane, the car occupancy rate is 2.19 persons per car. • Reduction of 30 % in casualties in a period of three years after scheme implementation. • Journey time savings of 4mins compared to 1½mins for non HOV traffic. • An increase from 55% to only 66 % in HOV drivers support for HOV lane (results from roadside interviews in 1999). • Lane violations only 6% *Weakness* • Immediately after opening 20 % traffic reduction (due to driver avoidance). • Extensive programme of after monitoring (pre and ongoing) • HOV driver support – 66% which is considered low. • Little change in air quality	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: HOV lane Site: A4174 Avon Ring Road Bristol Description: • Opened in 1998. The lane has been extended from the original 750m to 1.2km in length (comprising two sections separated by a roundabout) and operates in one direction in the morning peak only. Source: South Gloucestershire Local Transport Plan (2000 – 2006)	*Strengths* • increase in efficiency; • proportion of SOV has fallen from 80% to 68%; • traffic levels increased by 10% (result of vehicles re-routing from parallel roads) as the lane has 'smoothed' flows and allowed higher throughput. • Journey times for all vehicles have fallen from 20 minutes to 6 in the HOV lane and 12 in the mixed use lane. *Weakness* • Extensive consultation in advance of the scheme to obtain community support; • Large scale marketing / education campaign • Ongoing monitoring • Other complimentary measures required to •	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: HOV lane Site: Victoria Road, Sydney Description: • The HOV lane scheme on Victoria Rd was introduced in 1977. It is about 7.1km long and allows buses and vehicles with 3+ occupants. There are 2 other lanes for non-priority traffic. Source: Grimson and Anson (1981) based on Booz Allen Hamilton (2006b)	*Strengths* • 34% decrease in bus travel time from 1976 to 1980 between 7:30am and 8am and 22% decrease between 8am and 8:30am. • Bus reliability improved by 50% • Vehicle occupancy rate up by 10%. • 20% increase in HOV lane users 1977-1980, and 20% rise for HOV lane vehicles. *Weakness* • Proportion of HOV person volumes decreased over time. • Very high illegal use of HOV lane.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia

Table 7: Managing the Allocation of Road Space

Topic	References	Strengths / Weakness	Applicable
		• Require monetary and labour resources to patrol illegal use.	
	Scheme: HOV lane Site: Onewa Road, Auckland, New Zealand Description: • The HOV lane is 1km in length which allows buses, cycles, carpools 3+ occupants and motorcycles to travel. Source: Grimson and Anson (1981) based on Booz Allen Hamilton (2006b)	*Strengths* • One year after opening: • 9% increase in bus patronage. • 36% increase in carpool vehicles. • 18% decrease in other traffic. *Weakness* • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
b) HOT (High Occupancy Toll) lanes			
	Scheme: High occupancy vehicles toll lanes Site: San Francisco-Oakland Bay Bridge, US Description: • High occupancy vehicles are exempt from bridge tolls and area given priority lanes at toll plaza. Bridge is effectively a HOT system. Source: Legislative Analyst's Office (2000)	*Strengths* • 63% of all westbound trips were made using high occupancy vehicles. *Weakness* • 48% of carpools are formed on a casual basis by picking up people from transit shops. These people would ordinarily catch public transport.	**Not Applicable** • Not applicable to arterial roads
	Scheme: USA – Interstate -10 West Katy Freeway, Houston, Texas. Description: • The initial 13-mile HOV lane was constructed in 1984 and was dedicated solely for public transport use, which resulted in significant amount s of unused capacity on the HOV lane. In order to better utilise this available excess capacity, the HOV restrictions were eased to include carpools of two or more people. However, the HOV-2 travellers were permitted to use the HOV lane; traffic in this lane became congested. In response, the HOV restriction was increased to vehicles with 3 or more occupants. However, that resulted in the HOV lanes becoming underutilised once again. As a result, in 1998, a value pricing program on the existing HOV lane, called the Quickride Program, was implemented that allowed HOV-2 vehicles to pay a toll of $2 to use the HOV lane, while HOV-3 and public transport vehicles continued to use the facility for free. Single-occupancy vehicles remained prohibited Source: FaberMaunsell, 2006	*Strengths* • Balance the efficiency of the available road space through direct demand management. • Generate revenue to support the system operation. • Encourages increased vehicle occupancy and use of more sustainable choices of mode of transport. • Variable pricing schemes can be utilised to ensure that the lance is well utilised but free flowing. These can include different charges on different days/ months/ directions/ time of day etc. *Weakness* • All sites involve construction of additional HOT lanes or use of HOV lanes that were not previously available to solo motorists.	**Applicable** • Can be used on urban arterial roads • Supply measure
c) Freight lanes			
	No reference found yet		

Table 7: Managing the Allocation of Road Space

Topic	References	Strengths / Weakness	Applicable
d) Car only lanes (including narrow lanes and dynamic lanes)			
	Scheme: Hard shoulder Running Site: Holland Description: • As additional lanes could not be built quickly to relieve congestion issues the option of using existing hard shoulders has been trialled. Additional traffic control and surveillance equipment has been installed, including road markings, gantry signals, variable speed limits, and CCTV. The emergency services have also enhanced their operational procedures. Additional developments have included limiting their use to particular vehicle classes, narrowing lanes which allows continuation of hard shoulders, and the introduction of refuges for emergency vehicles broken down vehicles. Source: FaberMaunsell, 2006	*Strengths* • Additional capacity with reduced costs of construction and land take. • Traffic joining or leaving the link has more time to merge or change lanes with the main traffic flow. *Weakness* • Perceived safety implications (not founded as trials have actually found reduction in accidents due to less head to tail accidents as a result of tailback elimination).	**Not Applicable** • Not applicable to arterial roads – more suited to freeways • No hard shoulders on arterial roads • Verges and the extra space at the side of arterial roads not suitable for regular traffic flow.
e) Express lanes (separation of through traffic from weaving merging traffic)			
	Also see hard shoulder running above. Use of hard shoulder running between two junctions can mean the traffic just travelling between the junctions does not need to merge with through traffic	*Strengths* • Disruption to the mainline flow of the link is kept to a minimum therefore increasing the efficiency of the link. *Weakness* • Perceived safety problems through removal of safe stopping areas	**Not Applicable** • Not applicable to arterial roads – more suited to freeways • Are no hard shoulders on arterial roads • Verges and the extra space at the side of arterial roads not suitable for regular traffic flow.
f) Contra flow lanes			
	Scheme: Fully reversible road Site: Adelaide, Australia Description: The Southern Expressway is a one-way fully grade separated road facility which is fully reversible so that direction of travel matches the weekday peak flow demands.	Strengths Increase peak direction capacity to alleviate congestion and reduce travel times for commuter traffic between outer southern suburbs and inner suburbs / city centre. Transport Planning can add further information.	**Applicable** • Could be applied to major arterial roads.
	Scheme: Contraflow bus lane Site: Rotherham, UK Description: The scheme consists of a southbound contra-flow bus lane extending for 280 metres between the Bridge Street exit from the Interchange and Market Square (the junction of Market Place, High Street and Westgate). There are two bus stops in the contra-flow bus lane and another two bus stops with bus stop clearway	*Strengths* • Introduction of the contra-flow bus lane provided a more direct route through the town centre for a number of bus services. It also allowed the introduction of more convenient outbound bus stops serving the town centre. Reduced journey times were achieved on some services. On others, the reduction in journey time was used to improve reliability. • Services bound for Canklow Road: Distance operated per trip was reduced by 0.8km. On Services 130/132 (6 per hour) running time to Canklow was	**Applicable** • Can be used on urban arterial roads • Supply measure

Table 7: Managing the Allocation of Road Space

Topic	References	Strengths / Weakness	Applicable
	protection in the northbound general traffic lane. There is a short 24 hour bus lane in the centre of the carriageway at the north end of Corporation Street to provide access to Rotherham Interchange for northbound buses. Some carriageway widening was necessary to cater for two-way operation and provide enough room for bus stops, loading bays, parking spaces for disabled people and a taxi rank. Modifications were made to the signal-controlled junctions at both ends of Corporation Street and a Pelican crossing was upgraded to a Puffin. Three ramped pedestrian crossing areas were provided to ensure vehicle speeds were kept down. Buses are the only category of vehicle permitted to use both the contra-flow bus lane and the short northbound bus lane that provides access to the Interchange. Source:	reduced from 10 to 8 minutes. As running time allowed to Canklow on longer distance services 13/29/264 (1 to 2 per hour) was only 7 minutes, the benefit took the form of improved reliability. • Services bound for Sheffield Road (5 per hour): Distance operated per trip was reduced by 0.8km. Running time was not reduced because the scheduled time to the next timing point was considered to be tight. Benefits took the form of improved reliability. *Weakness* • Cost • Although 'after' traffic count data is not yet available, observation suggests no noticeable change in traffic volume.	
	Scheme: Contra-flow transit lanes Site: Spit Road and Military Road corridor, Sydney, Australia Description: • The scheme was introduced in Nov 1974 with 6.9km transit lanes between Balgowah (Sydney Rd) and Cremore Junction. The kerb-side peak period transit lanes (AM inbound and PM outbound) takes 1 of 3 lanes in each direction. Usage is allowed by buses, taxis, hire cars, 3+ vehicles and motorways. Source: Barton-Aschman Associates Inc. (1981) based on Booz Allen Hamilton (2006b)	*Strengths* • 11 minutes saving in bus travel time. • Carpools save 1 minute over non carpools on average: 10 to 20 minutes in critical congestion periods, 6 minutes over pre-project conditions. • 52% increase in carpooling and car occupancy increased from 1.43 to 1.49. *Weakness* • 4% loss in bus patronage.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: Contra-flow lanes Site: Pittsburg, US Description: • Contra flow lanes were designated for buses and vehicles with 3 or more occupants in a city-bound direction from 5am to noon and in the opposite direction from 2pm to 8pm on State Highway 279. Source: OECD (2002)	*Strengths* • Since its establishment, the number of cars using this lane during morning peak periods has increased from 146 in 1989 to 345 in 1991, and the number of users from 1,100 to 2,200. • During an experiment conducted in 1992 when the lane was opened to car pools of two persons, 868 cars and 2,600 people used the lane during morning peak periods. *Weakness* • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
h) Bus Corridors			
	Scheme: Dublin Quality Bus Corridors Site: Dublin, Ireland Description: • The scheme's core measure was bus priority lanes on each route, together with traffic signal priority to protect the buses from congestion and to provide faster travel times by bus	*Strengths* • Between 1997 and 2003, for travel into the city centre in the morning peak period • the total number of people travelling by car fell by 25.7 per cent • the total number of people travelling by bus increased by 60.6 per cent • the car mode share fell from 58 per cent to 39 per cent	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia

Table 7: Managing the Allocation of Road Space

Topic	References	Strengths / Weakness	Applicable
	than by car. This was combined with the improved waiting facilities, which include real-time passenger information, an upgraded bus fleet, and restrictions on parking along the priority routes Source:	• the bus mode share correspondingly rose from 42 per cent to 61 per cent. *Weakness* • Monitoring • Costs	
	Scheme: Public Transport Signal Priority Site: London, UK and Sydney, Australia Description: • Traffic signal pre-emption for late running buses to allow them to avoid queuing and further delays Source: ITS Assist, and ITS International (25/10/2004)	*Strengths* • Reduced delays to buses by 22% to 33% • 37% improvement in on-time running • 15% improvement in trips starting on time *Weakness* • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: Exclusive bus lanes Site: Almere, Netherlands • Description: Bus lanes are on all major roads. Intersections feature traffic signal pre-emption system for buses and special gates are designed to prevent illegal lane changes. Bus stops are arranged at intervals of about 600 metres to increase bus speeds (ordinary bus stop intervals in Netherlands are about 400 metres). Corresponding to bus stop intervals, housing zones are districted by city planning in circles within a 400-metre radius from each bus stop. Source: OECD (2002)	*Strengths* • Daily bus ridership in Almere 20% higher than national average of 13% due to its high level of service, offering reliable, eight-minute headways. *Weakness* • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure
	Scheme: With-flow bus lanes Site: Auckland, New Zealand Description: • Bus priority measures implemented on three key radial routes into Auckland CBD. The measures were accompanied by use of low floor buses on most service; 'greening' of bus lanes; and supply information packs to all households within 500 metres of routes. Source: Booz Allen Hamilton (2006b)	*Strengths* • Measures reduced average and variability in bus journey time. Also 10% peak period car traffic reduction on one route. • Patronage increases on the 3 routes of c. 12%, c. 25% and c. 40%, giving an annual patronage increase in the order of 800,000 pa. • BCR estimates ranged from 4.4 to 7.0. *Weakness* • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: With-flow bus lanes Site: Bangkok, Thailand Description: • 4 lanes of varying lengths between 1.09km and 4.85km which open to buses and minibuses. Source: Vongpuapan and Latchford (1985) based on Booz Allen Hamilton (2006b)	*Strengths* • Bus travel time savings from 3% to 12% AM peak and 1% to 27%. • Bus speed increase varying from 0.5kmh to 2.8kmh for the AM peak and 0.2 kmh to 7.3 kmh PM peak. *Weakness* • No quantitative result has been found.	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
g) Cycle Lanes/Principle Shared Paths			
	No references found – initiatives undertaken discuss results in terms of an increase in cycling, often recreational rather than as a congestion management tool.		

Table 7: Managing the Allocation of Road Space

Topic	References	Strengths / Weakness	Applicable
h) Travel Behaviour Change			
	Scheme: Think Tram Site: Melbourne Description: • Program designed to improve tram travel times, reliability and safety along the busiest parts of Melbourne's tram network - focussed on eight priority tram routes projects will include on-road works, use of new technology to improve traffic flow, and amendments to road rules. Source: www.vicroads.vic.gov.au	*Strengths* • Improve tram travel times • Improve frequency • Reliability • Improved safety and accessibility at nominated stops • Improved urban design • Provide a viable alternative to car travel *Weakness* • No monitoring data available on schemes already implemented. • Cost including extensive pre-consultation • Labour	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: Carshare schemes (carpooling) Site: Various, UK Description: • Car share schemes are adopted as a travel plan measure by many organisations in the UK to reduce congestion and demand on parking at the workplace. Bespoke centrally co-ordinated computerised car share matching services are developed and dedicated parking is provided. Source: *'Making Travel Plans Work'*, (DfT, 2002)	*Strengths* • Computer • Associates, Slough - level of carsharing increased from 6% in 2000 to 34% in 2001. • M&S Financial Services - level of carsharing increased 31% of workforce. • Reduces local congestion • Can be developed as Council wide car share scheme with secure sub-sites individual organisations. This can be promoted to *Weakness* • Cost of software • Cost of incentives to encourage car sharing • Labour - ongoing marketing and monitoring required. • Tax breaks are available in the UK but not Australia to promote car sharing. • Success partly dependent on package of sustainable transport measures	**Not applicable** • Influences demand for travel rather than supply of road travel.

Table 8: Network Intelligence and Dynamic En-route Information

Topic	References	Strengths / Weakness	Applicable
a) Systems to collect and process data in real time to provide "network intelligence" to the network operators;			
	Scheme: SmartBus **(**Keeping track of SmartBus vehicles) Site: Melbourne Description: • Position of all SmartBuses will be tracked in real time so that predictions of arrival times on information displays at bus stops are continually updated. These predictions will take into account unusually heavy traffic, accidents, road works, or temporary diversions. Each SmartBus will be fitted with a computerised unit that enables the SmartBus Control Centre to track the position of the bus. Location tracking information will be provided using satellite signals from the Global Positioning System (GPS), while the vehicle's odometer is used to help with tracking in areas where the satellite signals may not be available. • New Passenger Information Displays (PIDs) will be located at high patronage stops to provide real-time information on the arrival of the next SmartBus. They will display the current time, the route number and destination of the next SmartBus, and the estimated minutes until its arrival. A push button will trigger an audible message of the same information to help passengers with a visual impairment. Source: www.doi.vic.gov.au	*Strengths* • Bus companies will be able to monitor the progress of their buses as they make their way around their routes • Travel time data collected by the SmartBus system will provide the companies with better information to plan new and improved timetables which keep up with patronage and traffic changes. • If a SmartBus is running late, the Control Centre computer will communicate with the VicRoads traffic control system to automatically request priority at the next set of traffic lights by extending the green light phase. • On-board audible and visual messages will tell passengers the next stop. • External speakers on buses will also inform passengers waiting at stops the route number and destination when the bus arrives at a stop serving multiple routes. • On Route 888/889, 1.24 million passengers used the buses in 2005 compared to 1.18 million in 2004, 1.12 million in 2003 and 870,000 passengers in 2002. *Weakness* • Cost and labour • Long term planning • Will require monitoring	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Scheme: Real Time Bus Trial - Passenger Transport Information and Priority (PTIPS) system Site: Adelaide, Australia Description: • The Passenger Transport Information and Priority (PTIPS) system, used in ADELAIDE in conjunction with the Real Time Passenger Information System RTPIS (by Tyco), is a component part of the New South Wales RTA's bus priority system currently being rolled out throughout the Sydney Metropolitan network. The RTPIS system was installed as a trial along the Parade and Henley Beach Road, two conventional arterial roads, and all the significant intersections were interfaced to the PTIPS system with the aim of providing bus priority at all these intersections (10 in	*Strengths* • Tests demonstrated that priority can be provided by the system as expected and feedback from drivers was that they are aware of the priority operating. • No infrastructure costs to establish PTIPS in addition to those required to set up the RTPIS. PTIPS costs include the licence and initial set-up. • Contention for priority demands by all buses approaching an intersection is largely eliminated *Weakness* • As this PTIPS trial system is geographically limited the land use implications were not considered in assessment of the system. • Overall post contract benefits have not been quantified, • Implementation and expansion of this system is still in its infancy and it is	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia

Table 8: Network Intelligence and Dynamic En-route Information

Topic	References	Strengths / Weakness	Applicable
	total). PTIPS works in conjunction with SCATS (Sydney Co-ordinated Adaptive Traffic System) the operating system used in South Australia to control the traffic signals Source: Communiqué from Andrew Excell, (15, August 2006), A/Regional Manager Metropolitan Transport Services Division – Metropolitan Region.	too early to draw quantifiable conclusions. • If PTIPS could be effectively provided across a Public Transport Network, is that the provision of site specific hardware at traffic signals for bus intervention is at best inefficient.	
	Scheme: Vehicle-to-roadside and vehicle-to-vehicle wireless communications – Vehicle Infrastructure Integration (VII) Site: Various US areas Description: • The VII program is based primarily on the use of radio frequencies set aside by the Federal Communications Commission (FCC) for the express purpose of providing a safer and more efficient transportation system – Dedicated Short Range Communications (DSRC). The service aims to protect the safety of the travelling public, while dedicating efforts to increasing the mobility of roadways and mitigating congestion. Source: Traffic Technology International (2006b)	*Strengths* • The system contributes to balance traffic loads, enhance intersection safety, and improve mobility. • The system also takes advantage of accumulating queue length information. More reliable queue information would allow the existing traffic management system to add more time to the green light to "flush" the traffic. • The VII system also promotes collaboration with local authorities, service providers and the community. *Weakness* • No quantitative results available	**Applicable** • Can be used on major arterial roads • Supply measure
	Scheme: Active Traffic Management Site: M42, UK Description: • The section is a three-lane motorway (six lanes plus full hard shoulders). This scheme will combine new technologies with well-known motorway traffic management techniques. These include mandatory variable speed limits (such as those in use on the M25), enhanced driver information signs and a new congestion and incident management system. The system will allow operators to open and close any lane on the motorway to traffic in order to help manage congestion at busy times of the day or traffic build-up due to an incident. This will eventually include using the hard shoulder as a running lane between junctions under controlled conditions. Source: FaberMaunsell, 2006	*Strengths* • Reliable journey times • Reduced congestion • Enhanced information to drivers • Improved response times to incidents *Weakness* • No quantitative results available	**Not Applicable** • Appropriate for freeways not arterial roads
b) Real-time data to be used as inputs to drive the various traffic management tools and en-route information systems;			
	Scheme: Floating Vehicle Data (FVD) and Cellular Floating Vehicle Data (CFVD) Site: Various including the UK, US, Belgium and Australia Description: • FVD is a process and technology for the collection, analysis and forecasting of journey times using speed and location data directly from a sample of vehicles as an alternative to	*Strengths* • Viable and cost-effective real-time network monitoring tools • CFVD technology provides data streams designed for public access. These data represent a breakthrough in the geographic coverage possible and provide a direct measure of performance from the point of view of the driver. • Application: Demonstration services are being developed in the Baltimore	**Not Applicable** • Appropriate for freeways not arterial roads

Table 8: Network Intelligence and Dynamic En-route Information

Topic	References	Strengths / Weakness	Applicable
	fixed roadside sensors such as number plate readers. CFVD was developed by Israel based Estimotion Inc. and is a patented technology, which provides a unique, and high quality system for measuring and forecasting real time traffic flow based on anonymously sampling the positions of mobile phones. Source: ITS International (2005) and also see ITIS Holdings website (www.itisholdings.com)	region that include telephone traffic information services (IVR) and an internet-based strip-map that offers congestion information and travel times on the key highways in the area. • Application: The State of Maryland will have access to a growing data set that will include travel times and speeds on expressways as well as major and minor arterials. *Weakness* • An individual record of a mobile phone's position is typically less accurate than a corresponding GPS record. • However, this is compensated by the large number of mobile phones on any road, knowledge of the underlying road network and the application of statistical techniques.	
	Description: Public Transport Information Systems Site: various, UK Description: • The use of real time location information from buses to provide anticipated arrival information direct to the public through VMS, SMS, and internet Source: ITS Assist http://www.traveldirect.info	*Strengths* • Increased patronage by between 5% and 40% • Up to 81% of users found the information useful • 4% of passengers used public transport more as a result *Weakness* • No quantitative results available	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
	Advanced Traveller Information Systems Site: various UK and USA Description: • The provision of real time traffic updates to motorists through various media, including: VMS; HAR; radio; SMS; internet; telephone; RDS-TMC Source: ITS Assist, and US Federal Highway Administration, What Have We Learned about ITS (2000)	*Strengths* • 3.5% reduction in delay • 60% of motorists wanted arterials added • 5% changed route as result of information *Weakness* • No quantitative results available	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia
c) GIS based technology to focus on network wide solutions and management as opposed to singular locations or small areas of the network;			
	Scheme: London Traffic Control Centre Site: London, UK Description: • The London Traffic Control Centre (LTCC) is a central control point, staffed by the Metropolitan Police and TfL Street Management staff to: monitor network conditions; process, integrate and analyse data; introduce contingency traffic signal timings; direct police to specific problem areas and disseminate traffic information to public and media. The team also manages the installation of VMS, CCTV and Enforcement cameras. Source: http://trafficalerts.tfl.gov.uk/pinpointlite/main.php	• Resources – cost and labour • No quantifiable data	**Applicable** • Can be used on urban arterial roads • Supply measure • Already being applied in Australia

Table 8: Network Intelligence and Dynamic En-route Information

<table>
<tr><th>Topic</th><th>References</th><th>Strengths / Weakness</th><th>Applicable</th></tr>
<tr><td></td><td>Scheme: National Driver Information and Control System (NADICS)
Site: Scotland (Transport Scotland) http://www.trafficscotland.org/
Description:
• The NADICS system currently features an extensive range of ITS functions, such as queue management, Automatic Incident Detection (AID) and information dissemination via Variable Message Signs (VMS) and the internet.
Source: ITS International (2006)</td><td>Strengths
• The system is believed to provide four key benefits to Transport Scotland:
• Improve journey time reliability;
• Reduce disruption caused by incidents, roadworks and events;
• Provide alternative route guidance to minimise the impact of events; and
• Provide credible and accurate travel information.
Weakness
• The technology is still considerably new and will experience continuous development.</td><td>Applicable
• Can be used on urban arterial roads
• Supply measure
• Already being applied in Australia</td></tr>
<tr><td></td><td>Scheme: London Works
Site: London, UK
Description:
• LondonWorks (LW) is a tool for facilitating the planning, co-ordination and permitting of road and street works by London's 35 streetworks authorities. It is a mapping database, which will show the locations and types of works planned and being undertaken on all of London's roads. Such visibility allows the expected traffic impacts to be properly considered in the context of other planned and on-going works, and opportunities for joint working can be identified.
Source: FaberMaunsell, 2006</td><td>Strengths
• A particular strength of PlannedWorks is that it will facilitate the co-ordination of works by many operators, for example scheduling small works into the shadow of larger ones.
• The automated mapping also assists highways inspectors to plan their routes, and the system is designed to facilitate other aspects of the registers' administration. It takes its input from data provided by the Electronic Transfer of Notices (EToN) to streetworks registers.
Weakness
• Ensuring all stakeholders are aware of the system and update their information to ensure the data set is complete can be difficult.</td><td>Applicable
• Can be used on urban arterial roads
• Supply measure
• Already being applied in Australia</td></tr>
<tr><td colspan="4">d) Use of processed historical data to enable historical review of network performance against expected roadway speed, reliability and capacity measures and agreed network performance indicators</td></tr>
<tr><td></td><td>No references found</td><td></td><td></td></tr>
<tr><td colspan="4">e) Description pf the new tools that will be required by Traffic Management Centres and system analysts in order to operate road system efficiently.</td></tr>
<tr><td></td><td>No references found</td><td></td><td></td></tr>
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