Traffic Management Systems for Australian Urban Freeways

Consultancy Report Prepared for

COUNCIL OF AUSTRALIAN GOVERNMENTS

REVIEW OF URBAN CONGESTION TRENDS, IMPACTS AND SOLUTIONS

by

ARRB Consulting
and SJ Wright & Associates

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This document does not necessarily reflect the views of the Commonwealth, State or Territory governments, and has been prepared by ARRB Consulting and SJ Wright & Associates to inform the Urban Congestion Review, which was commissioned by the Council of Australian Governments.

Contract Report

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for SCOT Urban Congestion Management Working Group

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for SCOT Urban Congestion Management Working Group

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Summary

The SCOT Urban Congestion Management Working Group on behalf of the Council of Australian Governments (COAG) has commissioned ARRB Group, through its project manager VicRoads, to prepare this report describing the potential benefits of using traffic management tools to improve performance of the AusLink urban network and associated urban motorways/freeways.

This report forms part of a national review of urban congestion, and examines how traffic congestion impacts on the efficiency of Australia's urban freeways and tollways, and indirectly upon the Australian economy and the transport needs of its people. Its purpose is to highlight the need for a major change in the way that AusLink metropolitan freeways and other urban motorways are managed, and to put forward a process for facilitating this change in all States and Territories.

Whilst acknowledging the future potential of travel demand management, this report is solely focussed on traffic management systems. Although the report emphasises the importance of integrating freeway management with arterial road and public transport systems, it does not separately discuss the management of these other systems.

This report necessarily utilises a significant amount of performance data from Melbourne's urban freeways in order to provide indicative illustrations of Australian urban freeway conditions. The current level of freeway performance data collection in other jurisdictions is not as comprehensive. The authors recognise that urban freeways in other States and Territories will experience levels of congestion of severity and duration that are different to those in Melbourne. However, the nature of the congestion problems and the appropriate solutions will nevertheless be similar.

Background

The need for a change in management philosophy has been highlighted by strong anecdotal evidence that Australian urban freeways are significantly less efficient in handling traffic demand than equivalent, managed overseas freeways. While many overseas urban freeways are actively managed using capacity improvement tools, few Australian freeways make use of these tools. Of those that do, none are installed on a system-wide basis or integrated to the extent found in Europe and the United States.

Most urban freeway funding is focussed on high-cost engineering works that deliver clear strategic and economic benefits, such as better access to ports. The balance of funding goes to maintaining the physical infrastructure, with limited priority being given to improving operational efficiency. Current management effort centres on responding to and clearing congestion caused by incidents and breakdowns. While these were the major cause of congestion in the early 1990's, they now probably account for little more than 20% of all freeway congestion because of the huge growth of capacity-related freeway congestion that has occurred since then.

Most traffic authorities have only limited means of collecting real-time freeway data. Therefore it is difficult to set performance targets because they have no way of determining what these might be and whether they have been met. As a result, the majority of freeway congestion, which is capacity-related, has largely remained unnoticed and untreated, and it has become part of the accepted, daily traffic environment. Installing traffic management systems has the potential to save Australia as much as $500 million annually in avoidable congestion, and billions of dollars in lost return on the national investment in urban freeways.

In Europe and the United States, traffic managers use active management systems aimed at making the best use of their existing freeways. Unmanaged freeways,

operating at or near their design capacity, perform at a level that is typically 20% - 25% below their capability

Allowing this situation to continue is essentially a waste of a major national resource. By using proven management practices, overseas infrastructure managers have been able to recover and 'lock-in' much of the freeway capacity that was previously forgone due to unmanaged congestion.

Current trends in Australian urban traffic

About 20% of all metropolitan vehicle travel occurs on urban freeways. By 2020, metropolitan vehicle travel is expected to increase by about 31%, which is nearly twice the estimated capital city population growth in this period.

A major factor in the disparate growth in travel during this period is an estimated 67% increase in the national capital city freight task, reflecting changes in business practices that result in more trips, such as greater use of 'just-in-time delivery' to reduce inventory costs; greater specialisation of production, which means more factories in different locations; the expanding differentiation of consumer tastes and the concentration of warehousing in outer urban areas. To service the freight task, metropolitan travel by articulated trucks and light commercial vehicles is expected to grow by 89% and 79% respectively by 2020.

Traffic growth has already had a significant impact on urban freeways, with the total length of peak demand periods in Melbourne increasing from 4.5 hours to 6 hours in the last five years alone. As traffic demand continues to grow, many urban freeways will soon be operating at their maximum capacity for most of the day. Overseas freeways are already operating under these conditions.

The causes of freeway congestion

As discussed earlier, most freeway congestion results from unstable traffic flow conditions that can develop when a freeway is operating at or near its design capacity. This instability can cause the traffic flow to suddenly collapse, with a dramatic reduction in speed and volume. Throughput typically drops by an average 25% for periods as long as 7 hours, resulting in severe congestion. As this often happens, it is referred to as recurrent congestion and its causes include:

- Unexpected vehicle movements such as braking or last-minute lane changes which are often the result of trucks and slow vehicles using multiple lanes and changing lanes.
- Too many vehicles trying to use the freeway simultaneously.
- High volumes of entering traffic interfering with the main flow.
- Vehicles weaving over short distances to access closely spaced exit ramps, or traffic queuing on an exit ramp extending back to block the left lane of the freeway or causing freeway traffic to slow down prior to exiting.
- Geometric features that may cause vehicles to slow down, such as transitions from four to three lanes, upgrades, tight curves or width restrictions.

Non-recurrent causes of congestion include vehicle accidents and breakdowns, extreme weather conditions, roadworks and special events. Most recurrent and non-recurrent causes of congestion can be successfully managed through the use of traffic management tools and operational management strategies.

The cost of freeway congestion

A draft, 2006 BTRE report estimating urban traffic and congestion cost trends for Australian cities, suggests that the avoidable social costs of congestion are:

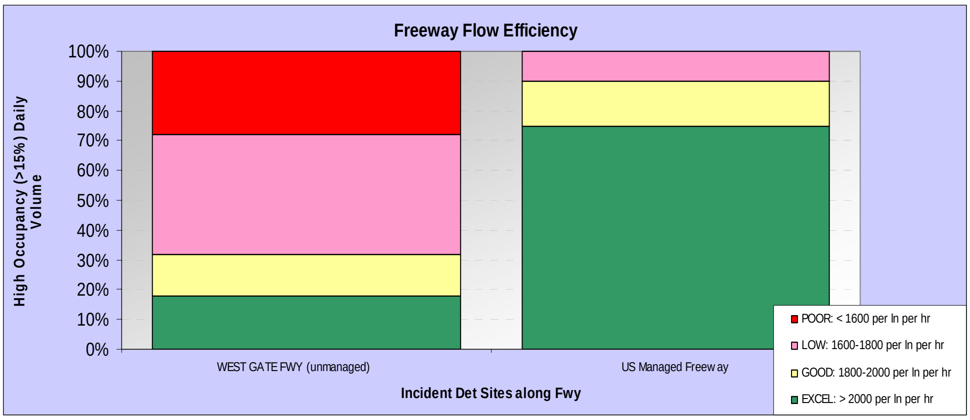
Component	2005 estimate	2020 estimate
Private travel time costs. (losses from trip delay and travel time variability)	**$3.4 billion**	**$7.5 billion**
Business time costs. (trip delay plus variability)	**$3.6 billion**	**$8.9 billion**
Extra vehicle operating costs.	**$1.2 billion**	**$2,4 billion**
Extra pollution damage costs.	**$1.1 billion**	**$1.5 billion**
Total avoidable social cost of congestion	**$9.4 billion**	**$20.4 billion**

On the basis of total metropolitan vehicle travel, about 20% of these avoidable costs could be attributable to urban freeways. This may have amounted to $1.9 billion in 2005, and could double by 2020 if no action is taken.

The relative performance of Australian and overseas urban freeways

The chart below compares unmanaged urban freeways with managed urban freeways by illustrating how effectively managed freeways handle peak traffic flows during the total daily period when demand is sufficient to supply 2000 veh/hr per lane. The colours indicate how well the freeways perform in terms of the number of vehicles carried per hour per lane, ranging from excellent (green) to poor (red).

The bars on the left represent the weekday performance of the West Gate Freeway in Melbourne. The bars on the right represent the performance of an equivalent managed freeway in the United States, showing demand being fully met (green) for better than 70% of the time. It should be noted that the chart is provided for illustrative purposes only and does not necessarily represent all managed and unmanaged freeways. However, the indicated difference in performance does reflect the findings of a number of study tours to the US and Europe.



How managed tools can improve freeway performance

To achieve freeway performances equivalent to those on international freeways, Australian traffic authorities will need to use a range of managed tools. Managed tools are on-road systems that can be controlled via data links to prevent flow breakdowns or implement lane management policies that can temporarily assign particular lanes to certain classes of users such as heavy vehicles. When used on a system-wide basis, managed tools can respond to imminent congestion by altering traffic signal timings on entry ramps, varying freeway lane speeds (via overhead indicators) and advising approaching travellers of current or impending conditions, route alternatives and trip times via a range of information systems.

The principal managed tools used on freeway networks are:

- *Ramp metering*

Ramp metering has been used overseas for many years to prevent traffic flow collapses at entry ramp terminals caused by multiple vehicles competing for gaps while attempting to merge with the main flow. Ramp metering uses traffic detectors linked to signals located part-way down entry ramps to 'drip feed' entering vehicles. The metering system ensures that there is adequate headway between entering vehicles and that there are gaps in the outer lane to accommodate them.

Ramp metering has been used on several Australian freeways, but only to address merging problems at particular ramps. However, a significantly greater benefit can be achieved if all entry ramps are metered, and exit ramp flows are monitored. This can reduce capacity-related flow breakdowns by ensuring that the number of vehicles entering the freeway does not exceed the number of vehicles exiting. However, care needs to be taken to ensure that travellers on metered ramps in uncongested sections are not unreasonably delayed.

The benefits and costs of ramp metering were clearly illustrated in 2000 when the Twin Cities of Minnesota deactivated their freeway-wide ramp metering system for two months as part of a study of their effectiveness, and in response to public concerns about delays at entry ramps. The results of the study vindicated previously claimed ramp metering benefits of increased throughput, reduced travel time, increased reliability of travel time and fewer accidents. The study also indicated a benefit/cost ratio of 15 times the cost of the ramp metering system.

- *Variable speed limits (VSL)*

Most freeways are subject to fixed speed limits that do not take into account situations where faster or slower speeds might result in improved safety or freeway performance outcomes. VSL allows speeds to be dynamically changed to provide the most appropriate speed for the prevailing conditions.

The VSL system relies on real-time measurements of traffic speed and volume provided by pavement sensors to assess current and desirable speeds. It can detect queues resulting from congestion and vehicle incidents. Speed limit adjustments are made via Variable Message Signs (VMS) on overhead or roadside gantries. An example of automatic adjustment is where a VSL system determines that traffic in a particular section has slowed significantly, and sets progressively lower speed limits for upstream sections to ensure that there is a safe differential speed.

VSL was originally introduced as a road safety measure and has achieved worthwhile reductions in accident numbers wherever it has been installed. VSL is also becoming widely recognised as a valuable tool for increasing freeway throughput. Automatic speed reductions made by VSL at the onset of peak flow periods have been found to forestall flow collapses without significantly reducing freeway capacity. VSL can also be used to reduce traffic noise at night, and to implement differential speed limits for lanes restricted to freight vehicles. VSL systems have demonstrated benefit cost ratios of 11 or more.

- *Lane control*

Lane control allows freeway lanes, including shoulders to be more efficiently allocated in response to changing traffic conditions or incidents by providing traffic managers with the ability to open and close particular lanes, prevent overtaking or even reverse the direction of traffic lanes through the use of internationally recognised pictograms displayed on overhead Variable Message Signs (VMS).

Lane controls such as bus lanes and high occupancy lanes are already common on many major arterial roads. Lane controls are being increasingly used on freeways to implement management strategies such as capacity improvement through the use of reversible and contraflow lanes and to prevent overtaking movements during peak flow periods. Lane control has delivered benefits similar to VSL.

- *En-route and pre-journey information systems*

These systems provide drivers with the right information at the right time and at the right location. Pre-journey, motorists who subscribe to an information system can be alerted to changes or conditions on their favoured routes by email, targeted SMS, traffic TV channel or telephoned advice from third-party providers. Transport operators and dispatchers can use this information to modify delivery scheduling and despatching arrangements.

En-route, drivers in their vehicles can receive travel information and make timely decisions about changing or maintaining their route. While much of this information is currently received via drive-time radio or from VMS, emerging information technology will enable drivers to receive more timely and relevant information via Radio Data Service ‘narrowcasts’ on a special FM frequency that can override the current station or directly through interaction with government or third-party information providers via their in-vehicle navigation systems.

The benefits of adequate journey information systems include reduced public and private user costs through improved ability to plan or modify trips; integration of the public transport system into driver trip planning scenarios, and reduced duration of congestion because drivers can be warned to avoid already congested routes.

- *Coordinated use of managed tools*

When managed tools are used interactively across an entire freeway instead of being employed at isolated or grouped ‘hot spots’, the resulting benefit often exceeds the sum of their benefits from being used independently. In the United Kingdom, this process is called Active Traffic Management (ATM).

For example, if a freeway’s data sensors indicate that a capacity-related flow breakdown is imminent, ramp metering can automatically reduce the rate of inflow and the VSL system can automatically lower the speed limit to avert the flow breakdown. The en-route information systems can warn motorists about delays and recommend alternative routes.

In Australia, managed tools are being used to treat congestion problems at individual sites, mainly because there is insufficient funding to do otherwise. By using tools on a piecemeal basis, major benefits are being lost to the Australian community. While the cost of installing system-wide, integrated tools would be significant on any urban freeway, they would be dwarfed by the community costs resulting from the ongoing loss of up to 25% of freeway capacity over half of the working day.

If managed tools are to be applied effectively, particularly at entry and exit ramps and on arterial approaches, freeway management systems will need to be integrated with arterial road management systems to ensure that interactions are co-ordinated, at least in the immediate vicinity of freeway interchanges.

While there is currently close liaison between private and public traffic control centres on incident management, Australian tollways will need to be integrated into seamless, overall motorway and arterial management systems. To achieve this, state road authorities and toll operators will need to agree on operating protocols driven by common objectives.

There is a growing international trend towards integrating all of the diverse transport systems within a corridor rather than simply linking freeway/arterial interfaces or parallel freeways and arterials, and this will be essential in Australia if the full potential of the freeway management initiatives is to be realised.

Managing the allocation of road space

As it is neither feasible nor cost-effective to continue to accommodate the growth of urban traffic solely by constructing additional freeway lanes, overseas traffic managers are devoting more attention to making the most effective use of freeways that have been enhanced by managed tools.

‘Effective use’ means using priority-based lane management systems to facilitate journeys that deliver the greatest benefit to the community, as opposed to achieving traffic throughputs that are as near as possible to a lane’s optimum capacity. (In most cases, both aims can be achieved). By allocating road space in this fashion, priority systems can influence community choices of transport mode, encourage the trend to smaller, more fuel-efficient vehicles and also improve integration of freeway systems into the public transport network.

Priority users can include public transport vehicles (including taxis), freight vehicles, trucks, long distance vehicles, airport or shipping port traffic, 2+ or 3+ car pool vehicles or authorised vehicles such as police and emergency response vehicles. Priority systems can be ‘built-in’ where there is a preponderance of one or more groups, or be dynamically managed to cater to changing needs and goals. The principal strategies for allocating road space are:

- *High-occupancy vehicle (HOV) lanes*

The primary purpose of HOV lanes is to improve the people-carrying efficiency of freeways by encouraging car pooling and greater use of road-based public transport. Strategically located park and ride facilities can assist this process. As fewer vehicles are eligible to use HOV lanes, travel times in them are much shorter during peak periods than in the adjoining lanes. HOV lanes can carry 3 – 6 times the number of people as adjacent general purpose lanes.

Depending upon the extent of HOV demand, these lanes can be physically separated from other freeway lanes and operated as HOV lanes on a permanent basis, or they can be utilised as a general purpose freeway median lane or outer shoulder and operated permanently as HOV, or temporarily during peak flow periods.

While contiguous HOV lanes can be cheap to implement, they can be difficult to enforce. HOV traffic moving to and from ramps on the opposite side of the carriageway can disrupt main flows and also reduce overall peak period capacity because they are frequently under-utilised. As a result, there is a growing view that HOV priority should be limited to providing bypass lanes at ramp metering sites and on exit ramps which also provide signal priority to HOV traffic. This is particularly the case when other freeway management tools have been implemented to improve overall traffic management.

The primary user benefits of HOV lanes are travel time savings and improved travel time reliability – particularly for public transport vehicles operating to fixed schedules. The community benefits are better utilisation of the freeway as a people-moving facility, more effective integration and use of road-based public transport, and reduced congestion and pollution due to fewer vehicles using the freeway during peak periods.

- *High occupancy tolled (HOT) lanes*

HOV lanes often remain considerably under-utilised, even after taking into account the reduced volumes needed to maintain free flows. US traffic authorities are increasingly utilising their spare capacity by allowing low occupancy vehicles to use them, provided they pay a toll to do so. When this happens, the HOV lanes become conditional pay lanes, or High Occupancy Tolled (HOT) lanes.

Tolls vary according to fixed times of day, or in real-time in response to actual traffic conditions to ensure free-flow conditions. Contiguous HOT lanes suffer from the same enforcement difficulties as HOV lanes and can also create problems at exit and entry ramps by blocking traffic entering and leaving the main flow. For this reason, HOV/HOT lanes are probably more effective on longer urban freeways with more widely spaced interchanges.

The benefits of HOT lanes are at least those of un-tolled HOV lanes, with the added benefits of maximising the available lane capacity and thus removing some of the public perception that these lanes are under-utilised. The costs of establishing a completely separate HOT lane can be recovered from the tolls imposed.

- *Freight lanes*

Heavy freight vehicles generally have high journey values, and as such should be considered for priority in the allocation of road space. The main period for freight movement is before and after the peaks and during business hours. Road authorities often ‘top-up’ the volume of freight lanes during the peaks with buses and other HOVs to maximise available capacity. Depending upon the relative levels of HOV and freight vehicles on a route, permanent HOV lanes can also be used as freight lanes.

Dedicated freight lanes suffer from the same ramp conflict problems as HOV and HOT lanes. While some overseas countries cater for very heavy truck volumes by constructing separate, truck-only carriageways with their own interchange ramps, this is probably not a realistic option for many of Australia’s inner-urban freeways. An alternative means of giving priority to freight vehicles is to provide bypasses on ramps as discussed for HOV/HOT lanes and shown in Figure 6.

The main benefits of freight lanes are reduced travel times and increased reliability, particularly for the long-haul freight movements typically using articulated vehicles.

- *Narrower lanes and car-only lanes*

Most freeways are designed on the premise that trucks will operate in all lanes. However, in some cases, freeway space can be more efficiently used by restricting trucks and buses to a full-width (3.5m), outside lane and dividing up the remaining space into narrower car-only lanes. In this way, one or more additional car-only lanes can be created, with a resultant increase in capacity.

The narrower lanes can be added on a permanent basis (if necessary, by widening the pavement in the median area and/or utilising part of the shoulder), or can be implemented during peak demand periods by using ‘intelligent’ pavement markings to temporarily change the width and number of traffic lanes. The latter option would improve freight capacity outside the peak periods (when freight volumes are higher) by allowing trucks to use additional lanes.

Although widths of 2.5m have been considered in Europe for cars only, the current consensus is that car-only lanes should not be less than 3m. The primary benefit of using narrower, car-only lanes is increased capacity where additional lanes are provided, albeit at slightly reduced speeds. The other benefits are effectively the same as those of freight lanes in that traffic flow is improved, and accidents are reduced by removing larger, slower vehicles from the majority of the traffic lanes.

- *Express lanes*

These are lanes whose users are given priority because they are travelling relatively long distances in comparison to the majority of travellers whose journeys might span no more than three to four interchanges. Many long distance users are ‘high-value’ freight vehicles whose cargoes have economic importance and are often time-critical to the ‘just-in-time’ input management schemes of major industries.

Vehicles weaving to enter or exit closely spaced interchanges can cause flow collapses resulting in major bottlenecks. The objective of introducing express lanes is to improve the efficiency of main flow, longer distance traffic by reducing entry and exit movements to a workable minimum. This is achieved by providing physically separate, parallel general purpose lanes (called collector-distributor lanes) that have a minimum number of connections to the express lanes but connect to either multiple interchanges or all of the interchanges along the entire freeway. In this way, most of the weaving movements take place within the collector-distributor lanes, rather than in the express lanes.

A vehicle leaving an express lane might necessarily pass several interchanges via a collector-distributor lane before accessing the desired connection to the local road system.

Express lanes can be achieved at relatively low cost by widening existing carriageways to create a contiguous collector-distributor lane and erecting barriers to achieve physical separation. In cases where contiguous lanes cannot be achieved due to lack of space, the provision of a collector-distributor lane can often involve land acquisition and overpasses of local roads at interchanges. However, collector-distributor lanes can be very effective at improving main flows and removing major bottlenecks, and can provide benefit-cost ratios of 10:1.

- *Reversible and contraflow lanes*

Reversing lane flows is widely considered to be one of the most cost-effective means of increasing peak period capacity because it utilises facilities that have already been constructed. The theoretical increase in capacity can be as high as 59% depending on the number of lanes.

The traditional approach is that flows can be reversed in opposing lanes where peak period traffic in one direction is 65% or more of total traffic and is subject to congestion and delays. However, there is an emerging view that contraflow can still be a cost-effective strategy where the difference between the flows is less than 65% but the duration of the peak in the favoured flow direction is significantly longer than the peak in the contraflow direction. While this can introduce some congestion during the shorter contraflow peak, a benefit/cost ratio in the order of 16:1 can be achieved in these circumstances.

Flows on contiguous lanes of two-way arterial roads are commonly reversed by using overhead lane control signals. Overseas freeways that have completely separate HOV or express lanes located in the median area commonly reverse their flow in the peak hours. When a freeway median cannot accommodate self-contained reversible lanes, some of the lanes of the opposing carriageway can be utilised to provide additional peak period capacity. This is known as contraflow.

Contraflow lanes require specialised transition points at the beginning and end of the contraflow section, and physical barriers are needed to separate contra-flowing traffic from opposing traffic. There is an issue as to whether temporary or permanent barriers should be used, together with their impacts on operating costs and transition arrangements for reversing flows. Permanent solid barriers may need more complex entry transitions to reduce the danger posed to normal traffic at the point where the barrier commences.

Flow reversals in contraflow lanes are usually managed by closing the cross-median connections using boom gates, lane control signals and VMS in conjunction with CCTV to ensure that the lanes are empty before they are closed or opened. To justify the cost of installing and operating contraflow lanes, a significant length of the freeway needs to be congested in one direction during the peak periods, and the downstream network should be capable of handling the additional volumes facilitated by the contraflow arrangements. A study by VicRoads of installing contraflow lanes with fixed lane barriers on Melbourne’s West Gate Bridge indicates a benefit/cost ratio in the region of 16:1.

- *Use of freeway shoulders or emergency lanes*

Freeway shoulders are usually of sufficient width and strength to be capable of use as an additional traffic lane. In theory, converting the emergency lane of a two lane carriageway to a trafficked lane can increase capacity by nearly 50%.

As the use of emergency lanes for general traffic increases accident risk, overseas authorities provide closely spaced lay-by or 'refuge' areas. Shoulder use requires CCTV monitoring, enhanced incident response teams and reduced speed limits enforced via signals and VMS mounted on overhead gantries.

The most efficient use of emergency lanes is as a priority (HOV/HOT and/or freight lane), although speeds are reduced because they are narrower. Utilising the additional capacity as a general purpose lane is likely to result in an immediate short term gain in capacity with congestion re-emerging in a short period of time as capacity is taken up by induced demand.

The primary benefit of using emergency lanes is considerably increased capacity for minimal construction effort and reasonable ongoing costs.

Network intelligence

Network intelligence is the asset represented by enhanced historic and real-time data concerning all aspects of using, operating and improving a transport network. It can provide real-time user and management information such as travel times, delays, alternative routes, performance indicators and warnings of problems. It can be used predictively to anticipate future demands, identify potential problems, analyse proposals and suggest responses to unusual traffic circumstances.

At the most fundamental level, the absence of network intelligence means that most Australian traffic authorities are unable to set freeway performance targets because they have no data that would allow them to determine what these targets should be (based on the measured, realisable capabilities of the freeway). Even if targets were to be nominated on the basis of theoretical performance, there is no effective means of determining whether or not they are being met.

Freeways and arterial roads are complementary transport systems that are often poorly utilised as a whole because they tend to be managed as separate entities. This can result in considerable inefficiencies when available capacity on one of the systems is under-utilised while there is congestion on a parallel route. The reason for this is that most traffic managers have no easy means of determining the status of either facility in real-time, nor can they provide timely alternative route suggestions to road users or predict that routes are about to become congested.

A network intelligence system requires a comprehensive, real-time data collection system; a process to aggregate and transform real-time and historical data into meaningful real-time and predictive content; and systems for timely delivery of this content to traffic managers and road users.

The major benefit of using network intelligence will be a far more effectively planned, managed and integrated transport network. Freeways and arterials will operate in much greater harmony with their users, and funding decisions will be based on better information and be better targeted. The benefits will include the transformation of control centres from manually operated facilities to largely automated facilities that can be operated from any location. Banks of CCTV screens will be replaced by dynamic, map-based display systems showing real time conditions on the entire network.

Road users will benefit enormously from the increased information, which will be delivered via the en-route and pre-journey information systems discussed earlier.

Conclusions

It is clear that:

- Many Australian urban freeways are heavily congested, with the length of the AM and PM peak hours in Melbourne alone increasing by 50% in the last four years alone to about six hours per day. Traffic growth will see some urban freeways operating at their full capacity for the entire working day within ten years or less.
- Australian urban freeways should be capable of carrying 2,200 veh/hr per lane, but often average only 1,600 – 1,700 veh/hr when design capacity is required because there is relatively little control of the causes of flow collapse. By comparison, many overseas freeways consistently carry 2,100 – 2,200 veh/hr per lane because maximum flow is maintained via managed tools.
- Managed tools require an extensive network of data gathering sensors to monitor the operation of the network. As most Australian freeways have limited data gathering capability, managed tools tend to be used on a site-by-site basis rather than on a system-wide basis, and tend to be operated independently of each other.
- While newer freeways and tollways are beginning to incorporate traffic management tools, the bulk of current freeway and tollway management effort goes to responding to incidents and breakdowns, which probably represent little more than 20% of congestion causes.
- In the absence of effective traffic data gathering systems, traffic authorities have difficulty setting realistic performance targets and have minimal awareness of what is happening on their freeways. As a result, freeway congestion has largely remained unnoticed and untreated, because it has become part of the accepted, daily traffic environment.
- Because many of Australia's urban freeways are either unmanaged or only partly managed, up to 25% of their capacity could be unavailable during periods when their full capacity is required. The use of internationally proven traffic management tools and strategies could recover much of this capacity and ensure that it remains 'locked in'.
- Improved management of our freeways could potentially recover Australia $500 million annually in avoidable congestion, and potentially billions of dollars of lost 'return' on the national investment in urban freeways.

The way forward

The report discusses a wide range of traffic management tools and strategies that Australian traffic managers can utilise to improve the performance of their motorway systems. It also emphasises the importance of implementing and interlinking these tools on a freeway-wide basis to provide a unified management system, rather than using them in isolation.

Desirably, the management systems of freeways and the arterial road network should be integrated so that available capacities of both networks can be effectively utilised at all times. Australian road authorities also need to embrace the emerging overseas trend towards total corridor management systems that integrate all transport modes. This will become increasingly important as travel demand consumes the remaining day-time capacity of our transport networks.

At the outset, Australian road authorities need to agree, via the Austroads forum, on fundamental objectives associated with the introduction and operation of urban freeway management systems. This in turn will set the stage for the development of national best practice management policies, implementation guidelines and performance indicators. Of equal importance, it will provide an agreed, national framework for assessing and capitalising the outcomes of several major Australian trial projects of freeway management systems. These trial projects will provide valuable 'test-beds' to assess how traffic management systems function in Australian traffic environments, and will provide a robust basis for:

- Australian research into network-wide control algorithms, driver behaviour and learning in a managed environment, performance metrics and a wide range of other information and control technologies.
- The development of Australian freeway management skills and resources.
- The trialling and development of advanced data collection and reporting systems and network evaluation tools.
- The development of data frameworks, management concepts, data provider linkages and software for local network intelligence systems.
- The development of protocols for control and information exchange between freeway and tollway systems.

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1 Introduction

The SCOT Urban Congestion Management Working Group on behalf of the Council of Australian Governments (COAG) has commissioned the ARRB Group, through its project manager VicRoads, to prepare a report describing the potential benefits of improved traffic management arrangements for the AusLink urban network and associated urban motorways/freeways. The report is intended to contribute to the National Review of Urban Congestion Causes, Trends, Impacts and Solutions, which was endorsed by COAG in February 2006.

The Review reflects growing national concerns about the increasing impact of traffic congestion on the efficiency of Australia's urban freeways, which play a key role in supporting the Australian economy and maintaining the social and employment needs of its people.

While congestion is a world-wide phenomenon, there is strong anecdotal evidence that Australian urban freeways are significantly less efficient in handling traffic demand than equivalent overseas freeways. The reason for this difference is that many overseas traffic authorities actively manage their urban freeways through the system-wide use of capacity improvement tools and their integration into a single freeway management system. By comparison, these tools have only been used to a limited extent on Australian urban freeways, and have largely been deployed on an ad-hoc basis without integration.

The cost to Australia of this potentially avoidable congestion could be as much as $0.5 billion annually, and this could double by 2020.

1.1 Objective

The purpose of this report is to highlight the need for a major change in the way that AusLink metropolitan freeways and other urban motorways are managed, and to outline internationally proven management tools and approaches that can be used to achieve this change.

1.2 Scope

Whilst acknowledging the future potential of travel demand management, this report is solely focussed on traffic management systems. Although the report emphasises the importance of integrating freeway management with arterial road and public transport systems, it does not separately discuss the management of these other systems.

This report discusses:

- How traffic growth is affecting Australia's urban freeways, and why peak hour freeway throughput can drop by up to 25% when freeway congestion is not managed.
- How capacity improvement 'tools' such as ramp metering, variable speed management and lane control can recover and 'lock-in' lost throughput, and why it is important to coordinate the use of these tools and the overall management of freeways, tollways and arterials.
- How implementing a priority user policy can result in more efficient use of freeway road space by facilitating high-benefit journeys. Priority user policies can influence community choices of transport mode and improve road integration with the entire transport network.
- How real-time and historical performance data can be used as network intelligence to facilitate the effective management of the transport network in partnership with its users.
- How the above improvements should be implemented via trial projects, enhanced research, development of nationally consistent objectives and policies, guidelines and performance indicators.

1.3 The focus of this report

This report focuses on AusLink metropolitan freeways and other urban motorways, including tollways, and is primarily drawn from foundational work undertaken by ARRB and other researchers for the Austroads Networks Program. These national research projects are based on the current practices and experiences of practitioners within State and Territory road authorities. A number of reports arising from these projects have been cited in this paper.

This report necessarily utilises a significant amount of performance data from Melbourne's urban freeways in order to provide indicative illustrations of Australian urban freeway conditions. The current level of freeway performance data collection in other jurisdictions is not as comprehensive. The authors recognise that urban freeways in other States and Territories will experience levels of congestion of severity and duration that are different to those in Melbourne. However, the nature of the congestion problems and the appropriate solutions will nevertheless be similar.

1.4 What is congestion?

Congestion occurs when increased demand for the use of a road results in slower than normal speeds. The United States Federal Highway Administration (FHWA) defines road congestion as '… an excess of vehicles on a portion of roadway at a particular time resulting in speeds that are slower - sometimes much slower - than normal or 'free flow' speeds'. There is no standard measurement of congestion. Engineers quantify it in terms of volume versus capacity, or in the percentage of time traffic spends at various 'levels of service' that rank traffic density and speed. Freeway users measure congestion in terms of delays per traveller, travel time, travel time variability and speed. Economists focus on the increasing cost to both users and society as a whole arising from additional vehicles on the network.

The amount of congestion that might be acceptable is also problematic. Some economists believe that there is an 'optimal' level of congestion that should be maintained, in which some road users either do not travel at all, postpone their trips to another day, travel out of peak hours, ride-share or use public transport. At the other end of the spectrum, at least one major German city has declared a long-term goal of eliminating traffic congestion completely.

Notwithstanding the divergence of views, there is wide consensus that the extent of congestion on Australian urban freeways is not only unacceptable, but is increasingly affecting the well-being of this country.

1.5 Congestion management on Australian and overseas urban freeways

In the past, infrastructure managers addressed congestion by building new freeways to provide extra capacity. While upgrading of roads to freeway status will continue for some time into the future, governments are becoming reluctant to build new inner urban routes because up to half of the added capacity is often quickly absorbed by 'induced'[1] traffic. To address long-standing deficiencies in the national transport infrastructure, public urban freeway funding is currently focussed on localised, high-cost engineering improvements that can deliver clear strategic and economic benefits, such as better access to industrial centres, ports and intermodal facilities.

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[1] In this context, 'induced' traffic is traffic that the facility was not intended to accommodate. It includes drivers who previously used alternative routes to avoid traffic, switching back to the improved route; drivers who previously avoided peak travel switching back to travelling at closer to peak hours and drivers who previously used alternative transport modes returning to cars. (VCEC)

Traditionally, the balance of freeway funding has been (and remains) focussed on maintaining the physical infrastructure.

Because of these emphases, relatively little priority has been given to improving the efficiency of the existing urban freeway network. Much of the current effort in this direction is via the use of control centres to monitor and address congestion caused by incidents. While this cause of congestion was relevant in the late 1980's and early 1990's, the subsequent, huge increase in capacity-related congestion means that incidents probably account for little more than 20% of all current congestion. Some authorities have begun to implement low-cost congestion reduction measures such as ramp metering and variable speed limits to address capacity-related congestion. However, these have only achieved limited benefits because they have been applied on a piecemeal basis. Overall, the extent to which Australian freeways are managed is minimal when compared to international practice.

In Europe and the United States, the change to proactive freeway management has been called 'the Big Shift'[2], because it has focussed considerably more attention on making the best use of the existing freeway infrastructure. This change acknowledges the fact that unmanaged freeways, operating at or near their design capacity, do so at a level that is typically 20% - 25% below their capability, and that allowing this situation to continue is essentially a waste of national resources. By using proven management practices, infrastructure managers in Europe and the United States have been able to recover and 'lock-in' much of the freeway capacity that was previously forgone due to unmanaged congestion.

1.6 Current national approach to congestion management

1.6.1 The AusLink national network

The Australian Government formally recognised the importance of urban freeways in its 2004 *AusLink* White Paper, which heralded the establishment of a National Network funding program. One of the key strategic directions in *AusLink* is to address congestion on urban and outer metropolitan sections of the National Network. The adoption of the 'Big Shift' as a major policy component of the national freeway management process would deliver worthwhile improvements in the efficiency of the metropolitan sections of the AusLink network at a relatively modest cost.

1.6.2 Austroads

Austroads is the association of Australian and New Zealand road transport and traffic authorities which undertakes strategic research, facilitates collaboration in the interest of improved road transport outcomes. A number of issues regarding network performance and road use data have been identified by Austroads, and form part of the current research in the Network, Asset and Freight program areas of Austroads. Much of the current work involves desk based research and market surveys of road users, industry and practitioners. The development of policies, systems and associated testing and refinement of traffic management tools will require closer collaboration between Austroads and AusLink as research and development progresses towards implementation on the AusLink network.

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[2] CEDR 2004

2 Current trends in Australian urban traffic

2.1 Factors influencing the growth in metropolitan traffic

About 20 per cent of all metropolitan vehicle travel occurs on urban freeways. By 2020, metropolitan vehicle travel is expected to increase by about 31% compared to estimated[3] capital city population growth of 15.9 per cent in this period. Key factors contributing to this additional growth are:

Economic growth	**This stimulates the demand for freight travel. The national capital city freight task is predicted to increase by 50% between 2006 and 2020 to nearly 57 billion tonne kilometres.**
Structural changes in the economy	**These also contribute to future growth in the road freight task. Changes in transport patterns include: the increasing popularity of just-in-time delivery as a replacement for point of sale inventory; greater specialisation of production (more factories in different locations), making manufacturing in particular more transport-intensive; expanding differentiation of consumer tastes making retailing more transport-intensive, and with the concentration of warehousing in outer urban areas, resulting in more and longer trips.**
Income growth	**ABS data indicates that higher income groups tend to spend more on travel, suggesting that income growth will lead to greater personal travel. Metropolitan car travel per person, which is currently about 7,900 km per year is expected to plateau at around 8,300 km by 2020, after which further increases in car travel will more closely follow the rate of population increase.**
Working age	**The number of people of age 60 or older who are still working or holding a licence and simply enjoying increased mobility (often in the absence of alternative public transport) is expected to increase by a factor of four[4] by 2031.**
Employment growth	**Employment is predicted to increase by about 18% over the next 14 years[5], with much of this concentrated in inner city areas in the business and services sector. This growth is considered likely to increase travel in peak times.**
Public transport availability and service quality	**Although public transport mode share has remained relatively constant, its potential for increased patronage (and hence less commuter vehicles on the road) is limited by the non-availability of rail links in many urban areas and the fact that many bus and train services are already operating close to capacity and have restrictive timetables that do not accommodate extended working hours.**

2.2 Growth in car and freight traffic

Cars	**About 79% of vehicles travelling on Australia's roads are cars. Based on BTRE indicators for these factors, car travel in Australian cities is estimated to increase by an average 23% in the 14 years between 2006 and 2020.**
Trucks	**Trucks represent about 3.2% of the national vehicle fleet. There is an ongoing shift to larger, articulated vehicles which offer greater efficiency, and this is expected to moderate the growth in truck traffic overall. Although metropolitan articulated truck travel is predicted to grow by 89% by 2020, it is based on a very small number of vehicles (0.5% of the fleet), and the impact on total traffic growth is expected to remain relatively small. The increasing preference for articulated vehicles is reflected in the much lower predicted growth rate (29%) in**

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[3] Based on figures from the Bureau of Transport and Regional Economics (BTRE).

[4] VCEC P.51

[5] Based on VCEC P 52

the metropolitan travel of rigid and other trucks in this period.

Light commercial vehicles

Light commercial vehicles represent about 15% of the vehicle fleet, and their travel is predicted to grow by 79%. This very large growth rate reflects the transport consequences of an ongoing shift in consumer preferences, driven by increased incomes, longer working hours (which decrease time for shopping in person) fuelling the on-line purchasing boom, and the desire to have things immediately. It has resulted in larger numbers of consumer items being delivered within hours of order to homes and businesses, and the consequent expansion of courier services to support this market. The projected growth also reflects the increase in vehicle-based home and business services.

2.3 How will urban freeways handle traffic growth?

The growth in traffic on Victorian urban freeways over the four years between 2001 and 2005 is probably typical of freeways in most Australian capitals. Figure 1 shows how Victorian peak periods have increased from a total of 4.5hrs in 2001 to 6hrs in 2005, and that the traffic volume between the peaks is rising rapidly. As demand continues to increase, urban freeways will be operating at peak capacity from 5.30 AM to 6.30 PM, and the rate of increase in traffic suggests this will happen long before 2020. Many freeways in the United States are already operating under these conditions.

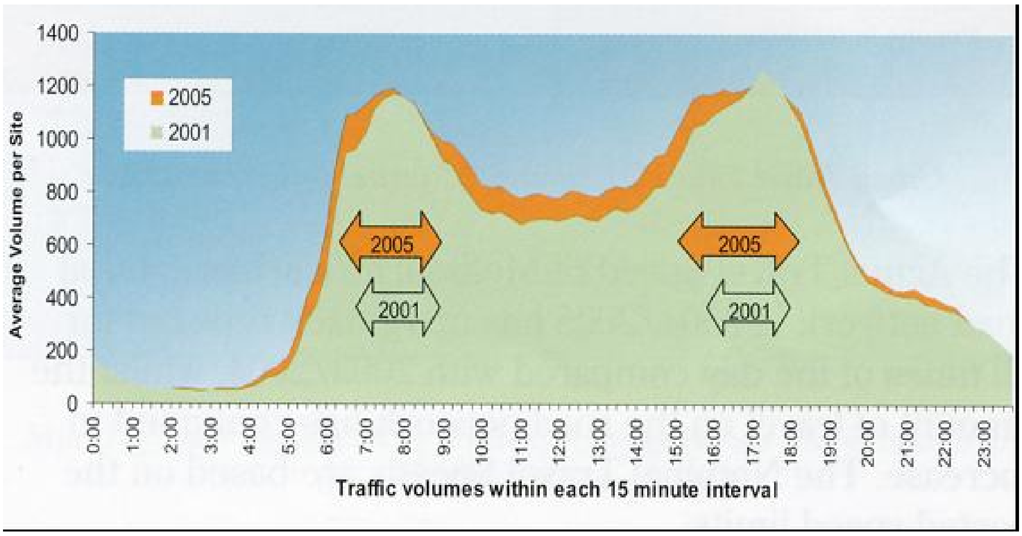

Figure 1: Duration of peak periods 2001 to 2005.
Source: VicRoads Traffic System Performance Monitoring 2004/2005 Information Bulletin

2.4 What happens when urban freeways operate at capacity?

In simple terms, freeways handle increasing traffic volumes fairly well until demand eventually requires them to operate at or near their design capacity[6]. When this happens on an unmanaged freeway, traffic does not continue to flow at or near the design capacity. Instead, freeways become prone to sudden collapses in flow volume and speed, and their throughput typically drops by an average 25% for long periods, resulting in severe congestion, often for several hours a day.

The reasons for traffic flow breakdown are complex but are related to drivers' perceptions of what is an acceptable minimum distance between their vehicle and the one they are following.

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[6] Freeways are designed to carry a maximum number of vehicles per hour (volume) at a predetermined speed that reflects the physical and road safety capabilities of the freeway. This volume is referred to as the design capacity of the freeway.

On an open road, drivers unconsciously increase their following distance as their speed increases. However, on a congested freeway, drivers are required to maintain their position in the moving stream while accepting ever decreasing following distances as more and more vehicles join the stream. This happens because the road space available to each vehicle decreases when the traffic volume increases without an increase in speed.

When the traffic volume exceeds about three quarters of design capacity, drivers begin to slow down slightly in an effort to restore an acceptable following distance. When the volume reaches the design capacity, many drivers are in an advanced state of alertness, and the traffic flow becomes extremely vulnerable to perturbations. Perturbations can be as simple as a vehicle changing lanes or somebody touching their brake pedal, but can suddenly ‘collapse’ the freeway flow to less than 50% of design capacity, with a proportionate reduction in speed. When this happens, the flow can remain at a reduced level for long periods, or the traffic momentarily stops for no apparent reason and then gains speed only to stop again 200m further along.

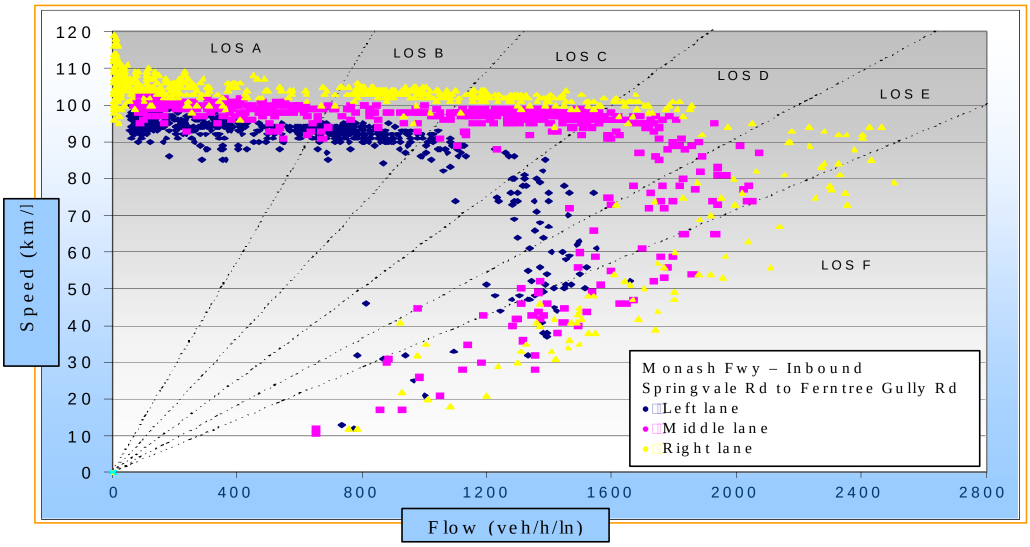

Figure 2: Traffic flow breakdown

Source: VicRoads. Guidelines for managing freeway operating with ramp metering, Nov 2005

Figure 2 illustrates how freeway flow can collapse and the effect this has on volume and speed. The coloured dots are speed/volume ‘snapshots’ of traffic in three lanes recorded on a Victorian urban freeway. Flow in the median lane or fast lane (yellow dots) has the least interference and is stable at 100 km/hr until it reaches a volume of about 1800 veh/hr. The centre and outer lanes (pink and blue dots), which have more ‘friction’ from traffic weaving to exit upstream, are less stable and their flows collapse when their volumes reach 1500 and 1000 veh/hr respectively.

The outer (slow) lane often collapses first because of its interaction with merging and diverging traffic, however this collapse can propagate to all other lanes in a matter of seconds because of the interference caused by vehicles attempting to move into the faster lanes. When the flow collapses, lane volumes fall to 700 veh/hr and speed drops close to zero. The figure shows Levels of Service (LOS) which describe the density of the traffic in terms of vehicles per lane per km, and hence the level of congestion. LOS ‘A’ is effectively no congestion and LOS ‘F’ is worst level of congestion.

2.5 Causes of freeway traffic flow collapse

There are two main groups of causes for freeway flow breakdown and congestion. This section discusses these causes and raises possible methods for treating them that are discussed in more detail in the following sections of the report.

2.5.1 Recurring causes of congestion

More than half of all congestion is recurring congestion, which is demand-related and generally occurs on a daily basis. The flow breakdowns giving rise to this congestion can occur at a ramp merge, between interchanges or near an exit ramp. Factors include:

(a) Traffic volumes at mid-block[7] *exceeding the freeway's critical throughput capacity.*

This primary cause of freeway congestion results from too many vehicles entering the freeway within a given period. Its occurrence or severity can be significantly reduced by controlling entry ramp volumes (ramp metering), reducing lane speeds (variable speed limits), and using other congestion tools. A variety of messaging technologies can be used to warn freeway users of severe congestion or breakdowns before they leave home or enter the freeway.

(b) Uncontrolled vehicle entry during high volume operation interfering with main flow traffic.

This is also a primary cause of flow breakdown. When multiple vehicles simultaneously attempt to merge with the main flow, the outer lane can stop completely, and this quickly results in flow collapsing in the adjoining lanes. By 'drip feeding' traffic onto the freeway, ramp metering can significantly reduce the number of flow collapses at merge areas.

(c) A reduction in the number of freeway lanes that requires traffic to merge to a section having lower capacity.

This congestion is caused by a combination of reduced freeway capacity and flow disturbance caused by vehicles moving across from the outer lane. The incidence of flow collapses can be reduced through the use of variable speed limits during peak periods.

(d) Vehicles weaving over short distances to access exit ramps, or traffic queuing on an exit ramp extending back to block the left lane of the freeway and causing freeway traffic to slow down prior to exiting.

Many of these movements arise from entry and exit ramps being too closely spaced or from insufficient vehicle storage on exit ramps. Auxiliary lanes can be constructed to physically separate multiple entry and exit movements from the main flow and thus reduce the number of points where merging and diverging traffic can result in flow breakdown. Lower cost treatments include changing signal timing on arterial roads to prevent exit queuing, or using the freeway shoulder to store exiting traffic.

(e) Traffic interactions between interchanges

When freeways are operating close to capacity, sudden or unexpected vehicle movements such as braking or last-minute lane changes can result in complete flow breakdown. Many of these perturbations are caused by trucks and slow vehicles using multiple lanes and changing lanes. Their low speed disrupts free flow, and their size can block visibility and intimidate other users when they operate at freeway speeds. Because of this, their presence can generate high numbers of sudden overtaking manoeuvres which can trigger flow collapse. This cause of flow breakdowns can be reduced by restricting trucks and slow vehicles to specific lanes.

2.5.2 Non-recurring causes of congestion

Non-recurring congestion usually arises from:

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[7] 'mid-block' is used to describe the sections of freeways between interchanges.

(a) Accidents and breakdowns

Major accidents can cause multiple lane closures that can result in peak hour traffic being stalled for hours. Overseas experience shows that advanced messaging systems can warn road users before they leave home or enter the freeway, and emphasises the importance of control room staff having access to senior police decision makers when accidents occur well outside normal working hours.

(b) Extreme weather conditions such as heavy rain, fog and snow

Congestion can occur during these conditions because of the generally slower speeds that result. However, some users maintain their 'normal' speeds and create a heightened potential for accidents due to skidding and rear-end collisions. Some overseas countries use automatic weather detectors in conjunction with variable speed limits to temporarily reduce legal speeds under these circumstances.

(c) Roadworks or maintenance activities

These activities often result in flow breakdown because a lane is temporarily closed off to become a work zone. The use of variable messaging signing and variable speed signals can reduce the possibility of flow breakdown in these areas.

(d) Special events

Events such as the Olympic or Commonwealth Games, or major, end-of season sporting events can result capacity restrictions for long periods. Variable messaging signing and variable speed signals in Australia can change traffic priorities, suggest alternative routes and generally prevent flow breakdown during these events.

2.6 The consequences of congestion

2.6.1 Loss of freeway capacity = lost return on investment

The most immediate effect of flow collapse is its effect on the overall capacity of the freeway. On unmanaged freeways (eg, virtually all Australian urban freeways) the flow can remain collapsed for periods of four to six hours, with an average loss of capacity of 20% to 25% compared to normal, free-flow conditions. This is clearly illustrated in Figure 3, which plots vehicle speed, traffic flow rates and time of day on an unmanaged Californian freeway.

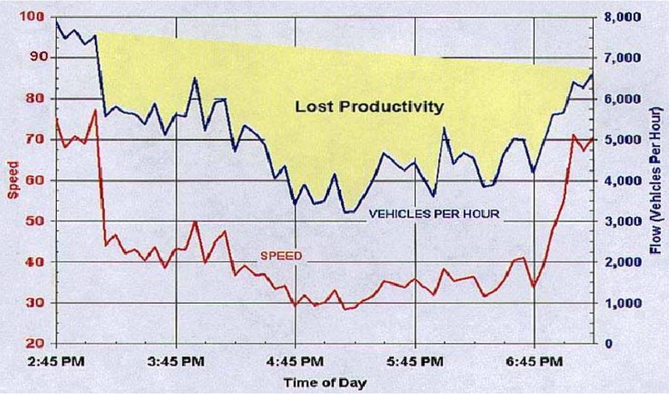

Figure 3: Lost productivity due to reduced capacity.
(Source: CalTrans)

The 'lost' capacity, increased travel time and poor travel reliability has major implications for the future of Australia's urban freeways. If, as predicted, the growth in traffic demand ultimately results in urban freeways operating at peak capacity for most of the day, then unless there is a major change in freeway management philosophy, these freeways will only operate at 75% of their achievable capacity.

If freeways were to be considered as business assets belonging to the community, then the loss of productivity, considered as a lost return on community investment would amount to billions of dollars annually before any other costs of congestion are considered.

2.6.2 Current and future social costs of congestion

Part of the difficulty in preparing any estimate of congestion costs is establishing a realistic base condition. Traditional measures of congestion have been made on the basis of the value of excess travel time compared with travel under uncongested conditions. For obvious reasons, these estimates are unrealistic because uncongested conditions are unattainable under real-world, daytime traffic conditions. A draft, 2006 BTRE report, which estimates urban traffic and congestion cost trends for Australian cities, has departed from this approach and has prepared more meaningful estimates, based on the avoidable social costs of congestion.

The avoidable social costs of congestion give an estimate of how much the total social costs of congestion could be reduced if traffic volumes were reduced (either by appropriate pricing mechanisms or other demand management techniques) to the economically optimal level (i.e. to traffic volumes where the average generalised travel cost is equal to the marginal travel cost)[8]. The draft BTRE report estimates the potentially avoidable social costs of congestion in 2005 as being:

Table 1: Avoidable social costs of congestion

Component	2005 estimate	2020 estimate
Private travel time costs. (Losses from trip delay and travel time variability)	**$3.4 billion**	**$7.5 billion**
Business time costs. (Trip delay plus variability)	**$3.6 billion**	**$8.9 billion**
Extra vehicle operating costs.	**$1.2 billion**	**$2,4 billion**
Extra pollution damage costs.	**$1.1 billion**	**$1.5 billion**
Total avoidable social cost of congestion	**$9.4 billion**	**$20.4 billion**

Source: BTRE 2006

On the basis of total metropolitan vehicle travel, about 20% of these avoidable costs would be attributable to urban freeways. This amounted to $1.9 billion in 2005, and will increase to $4.1 billion by 2020 if no action is taken.

It would be tempting to simply attribute a 20% – 25% saving of these amounts to a reduction in congestion resulting from a shift to managed freeways. However, while a more focussed and detailed financial analysis would be needed to determine a more reliable figure; it seems possible that savings of this magnitude could be achieved.

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[8] During urban travel at times of peak demand, the time costs that motorists will personally incur is the *average generalised travel cost*. The costs of the extra delay and other wasted resources that a motorists' entry onto the already congested traffic stream imposes on other motorists is the *marginal generalised cost for current traffic levels*. If motorists were required to not only base their travel decisions on their own costs but also the difference between their costs and the marginal costs, the number of peak hour and road-based trips would decrease, and a lower traffic density would result, although it would be far from free-flow conditions. This level of congestion is referred to as the *economically optimal level*.

2.6.3 Personal impacts

Delays in peak hour traffic not only impact on drivers in the way of added stress but also reduce the time available for family life. A US study[9] noted that: ‘Parents are increasingly missing events with their children, friends and families are finding it hard to spend time together and civic participation is being negatively impacted. Evidence suggests that each additional 10 mins in daily commuting time cuts involvement in community affairs by 10%.’

2.6.4 Road safety impacts

Urban freeway congestion results in avoidable deaths, injuries, repair and emergency service costs due to traffic accidents. When the traffic flow breaks down during peak demand, drivers in the stalled lanes attempt to move into the lanes that are still flowing. This often results in rear-end and side-swipe collisions, which in turn results in further congestion, particularly if there are injuries, and/or the damaged vehicles need to be cleared from the carriageway. While these incidents contribute to delays, the immediate costs of accidents are not included in the BTRE estimate of the social costs of congestion.

2.6.5 Impacts on other transport modes

Congestion on urban freeways can impact on the public transport vehicles that use these facilities by way of reduced speed and reliability. As freeways become increasingly congested during the extended peak hours, a growing percentage of vehicles are abandoning them in favour of the arterial road network. This not only increases congestion levels on arterial roads, but also interferes with public transport scheduling by delaying trams and buses. The increasing diversion of freeway traffic onto the arterial network encourages greater use of shortcuts through suburban streets and thus, interferes with urban amenity through added emissions and noise.

2.7 The relative performance of Australian and overseas urban freeways

In the context of assessing the need for efficiency improvements, freeway productivity could be expressed as the percentage of time that a freeway is able to operate at its maximum achievable capacity under stable conditions, when a demand exists for that capacity.

At present, the maximum achievable capacity of a freeway lane under stable conditions is somewhere between 2,200 and 2,400 veh/hr. In the future, as intelligent, in-vehicle headway management systems become commonplace, lane capacities could feasibly rise to 2,600 veh/hr.

A reasonable, achievable capacity for a freeway lane is currently around 2,100 veh/hr, which is the service level required by Caltrans[10] in the United States for its freeway lanes. The Minnesota Department of Transportation requires its freeways to provide and maintain a carriageway operating capacity of at least 2,000 veh/hr per lane, based on the outer lane carrying 1,800 veh/hr and each of the other lanes carrying 2,100 veh/hr. Anecdotal evidence gained from study tours in both Europe and the United States strongly indicates that managed freeways are providing these free flow rates for a high percentage of peak demand periods.

The absence of definitive studies comparing the performance of Australian un-managed freeways with that of overseas managed freeways is largely due to the fact that few Australian urban freeways have the necessary data gathering capability to establish a reasonable estimate of the extent to which design capacity is achieved during periods of high demand. The most comprehensive data available comes from VicRoads which uses an extensive network of pavement loop detectors to gather freeway volume, speed and density data.

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[9] US Department of Transportation. May 2006
[10] The California Department of Transportation

The chart below compares unmanaged urban freeways with managed urban freeways by illustrating how effectively they handle peak demand flows during periods of high demand (i.e. flows capable of supplying 2,000 veh/hr per lane) The full height of the vertical axis represents the total period of high demand as determined by data from loop detectors along the freeways. The colours indicate how well the freeways perform in terms of the number of veh/hr per lane, ranging from excellent (green) to poor (red).

The bars on the left represent the weekday performance of the West Gate Freeway and this is probably typical of many of Australia's unmanaged, inner urban freeways. It suggests that maximum capacity is achieved for less than 20% of that time during periods of peak demand. The bars on the right represent the performance of an equivalent managed freeway in the United States, showing maximum capacity being achieved for better than 70% of the time of peak demand.

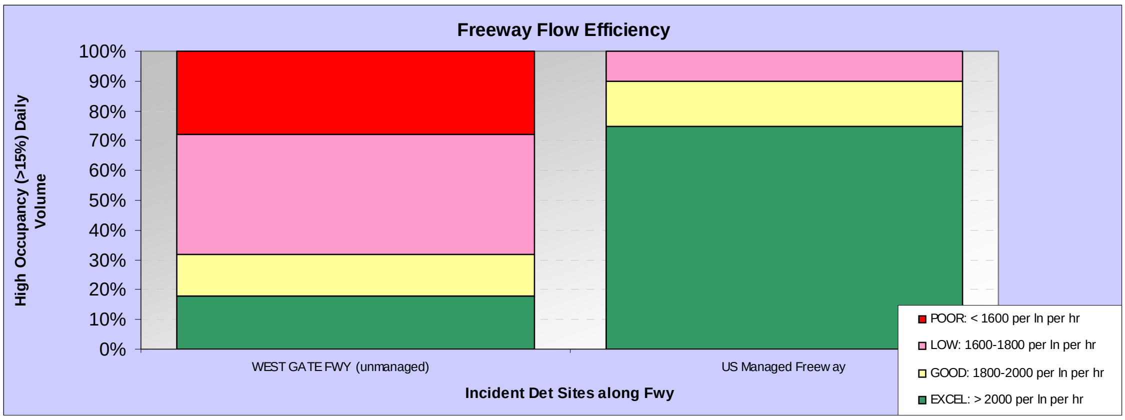

Figure 4: Unmanaged versus managed freeway performance

It can be seen that for about 80% of the peak demand periods, the performance of an unmanaged freeway is either poor or low, whereas the equivalent figure for managed freeways is probably less than 20%. It must be stressed that the above chart is provided for illustrative purposes only and as such does not necessarily represent all managed and unmanaged freeways. However, the indicated difference in performance does reflect the findings of a number of study tours to the US and Europe.

Capacities above 2,100 veh/hr per lane are often achieved on unmanaged freeways, but this happens only briefly before flow collapses. On average, peak period flows of Australian freeways appear to be closer to 1,600 - 1,700 veh/hr per lane, representing a throughput loss of between 20% and 25% during the combined six hour period of peak AM and PM demand. As the demand for maximum capacity increases, so will the overall loss of capacity if left unmanaged.

3 Managed elements and traffic management integration

3.1 What are managed tools?

Managed tools are so-called because they are systems that can be controlled via data links to address some of the causes of flow breakdowns, or to implement lane management policies that can temporary assign particular lanes to certain classes of users such as heavy vehicles.

To effectively use managed tools, comprehensive on-road systems are needed to detect and report a wide range of events and conditions, such as accidents, traffic speed and density, queue lengths and weather conditions. To operate in an integrated fashion with the entire road system, an adequate system of detectors and linked control and advice tools must also be in place on the complementary arterial road network, particularly in the vicinity of freeway interchanges.

When used on a system-wide basis, managed tools also require a centralised system to evaluate reported real-time data in terms of system-wide needs and to determine and deliver appropriate responses such as altering traffic signal timings on entry ramps, varying freeway lane speeds (via overhead indicators) or advising approaching travellers of current or impending conditions, route alternatives and trip times via a range of information systems.

3.2 Why are managed tools needed?

The need for managed tools can be illustrated by comparing the management of Australia’s arterial road networks with that of its urban freeways. Urban arterial road networks achieve high traffic flows because their entire signal detector loop systems are linked to centralised control systems. The real-time performance data these loops provide allows signals to be used proactively to manage peak flows and incidents. While the arterial network might seem to be congested, removing these controls would result in complete chaos and gridlock, as is sometimes seen with a major power failure.

By comparison, most Australian freeways have no real controls on access via entry ramps or on their carriageways. Other than video cameras, there is no freeway equivalent of the arterial road performance data collection system. More importantly, there are few mechanisms that traffic control centres can use proactively if such data were to be made available. In other words, our freeways are in the same situation as the urban arterial road systems would be if they were to operate without managed signals.

The principal managed tools used on freeway networks are shown below.

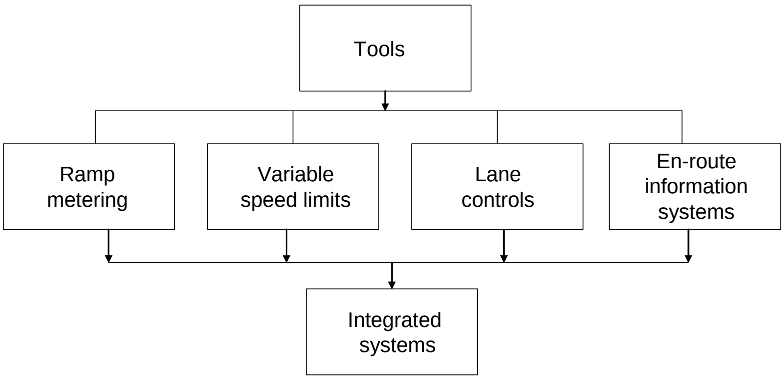

Figure 5: Range of managed tools

3.3 Access control using ramp metering

Ramp metering has traditionally been used to limit the interference that entering vehicles cause to flows on freeway carriageways, but is now becoming increasingly important as a system-wide tool to optimise freeway flows.

3.3.1 How ramp metering works

The principle of ramp metering is similar to that of an urban flood retarding basin. These basins temporarily store sudden, local downpours that would otherwise overwhelm downstream channels that are running near capacity. The storage area, which might be a sports oval that can be safely flooded, has a dam with an outlet that releases the water at a reduced rate that can be safely accommodated by the downstream drainage system.

Figure 6: Two-lane ramp metering with truck bypass

With ramp metering, vehicles entering from the arterial network or from another freeway, are temporarily ‘stored’ on the entry ramp and released at a ‘metered’ rate by a set of signals just upstream of the merge area. The signals operate on very short cycles to allow between 4 and 30 veh/min (depending upon the number of ramp lanes) to join the main flow. Vehicle sensors on both the ramp and the freeway carriageway measure the relative flows, and algorithm-based processors use this data to continuously adjust the rate of entry via the signal timing.

Successful ramp metering requires integration of the freeway detection and control systems with the arterial road control system on the approaches to entry ramps, and the provision on the entry ramp of priority bypass facilities for buses and freight vehicles and potential for high-occupancy vehicles (HOV) with two or more occupants (T2 and T3).

3.3.2 Why ramp metering is needed

Ramp metering is needed to prevent freeway flow collapses that would otherwise occur at the end of the ramp when entering traffic is unable to smoothly merge with traffic on the main carriageway. Peak freeway flows are particularly vulnerable to collapse when multiple vehicles compete for limited gaps in the outer lane while attempting to merge with the main flow. Ramp metering ensures that there is adequate headway between entering vehicles, and that they can be accommodated without undue disturbance to the main flow.

A secondary but increasingly important use of ramp metering is to ensure that, during peak flow periods (eg. freeway at or near capacity), the number of vehicles being added to a freeway does not exceed the number of vehicles leaving. Vehicles entering at a particular, uncontrolled ramp might not interfere with the flow at that location, but the effect on overall volume can cause the overall capacity to be exceeded, with a resultant flow breakdown elsewhere on the freeway. Use of ramp metering for this purpose requires real-time monitoring of all entry and exit ramps, together with the arterial road system at freeway interchanges, via vehicle detection sensors.

3.3.3 Implementation options for ramp metering

Overseas traffic managers have used traffic signals to regulate entry ramp flows since the early 1960's. However, Australian traffic managers have only recently begun to use this tool to prevent flow breakdowns in particular merge areas (in Victoria, Queensland and NSW), and have yet to employ it on a coordinated or system-wide basis to prevent overall capacity-based flow breakdowns and to balance queues on entry ramps. There are two main implementation options for ramp metering:

(a) Local or isolated ramp metering

Individual metered entry ramps manage entering traffic solely on the basis of the local freeway traffic conditions in their immediate vicinity. Although a number of ramps may be locally metered along a freeway, each operates independently of the other and without regard to the global traffic situation on the freeway. Local ramp metering can work well to reduce local congestion, and while they can be used to improve local freeway flow, they have only limited ability to ameliorate congestion related to other bottlenecks along the route.

(b) Coordinated ramp metering

With this option, the primary objective of ramp metering is to optimise freeway flows over a wider area in addition to controlling merging movements. Multiple metered ramps are controlled as a co-ordinated system using freeway and traffic measurements taken over a wide area. Coordinated systems can range from managing several entry ramps to controlling every entry ramp in an entire freeway system. While the development of algorithms[11] to properly manage large, coordinated ramp metering systems is an extremely complex task, and is the subject of significant transport research, the majority of benefits can be obtained with relatively simple algorithms.

Because coordinated ramps respond to a wider traffic environment rather than the immediate, local environment of particular ramps, they are more prone to queuing problems on the entry ramp in which traffic can be delayed for up to 5 minutes during the peak. Similar problems can also occur where ramp metering has been retro-fitted. Options for addressing the queuing issue range from storing vehicles on the freeway ramp to making special provision for storing vehicles on the arterial network.

By integrating freeway and arterial road management systems, arterial road traffic signals used in conjunction with variable message signs, can be used to prevent excessive queuing and to either divert traffic away from the site or provide advance indication of the likely delay for traffic entering the freeway.

3.3.4 Public perceptions of ramp metering

The nature of ramp metering is to subject users to a short delay upon entry, and in doing so spare them the effects of much longer delays that would otherwise result from flow breakdowns. Although overall travel time is shortened, this is not readily perceived by users queuing on ramps. In a coordinated ramp metering system, queued users waiting to enter a seemingly lightly trafficked, upstream section of the freeway are even more prone to believing that their time is being wasted. While traffic management algorithms can be fine tuned to evenly distribute queues and minimise waiting and trip times, comprehensive public education programs are an essential adjunct to the successful introduction of ramp metering schemes.

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[11] An algorithm is a step-by-step problem-solving procedure, especially an established, recursive computational procedure for solving a problem in a finite number of steps.

3.3.5 Benefits and costs of ramp metering

The benefits and costs of ramp metering were clearly illustrated in 2000 when the Twin Cities of Minnesota deactivated the 430 ramp metering sites on their 340 km freeway network for a two month period as part of a study[12] of their effectiveness. The study was carried out in response to a legislative mandate ordering the traffic authority to address public concerns about delays at entry ramps and to determine whether the benefits of ramp metering outweighed the impacts and costs.

On the basis of extensive data collected immediately before and during the shutdown, it was concluded that ramp metering was a cost-effective investment of public funds. The study concluded that:

- Freeway mainline throughput in the peak hour declined by an average of 14% when ramp metering was switched off.
- Time saved by eliminating metered ramp delays was more than offset by the decline in freeway travel speeds. Switching off ramp metering resulted in additional user travel time estimated at 25,121 hrs annually.
- Without ramp metering, freeway travel time was more than twice as unpredictable. Ramp metering was therefore estimated to have reduced unexpected delays by 2.6 million hours annually.
- Without ramp metering, and after accounting for seasonal variations, peak period crashes on previously metered freeways and ramps increased by 26%. Ramp metering was therefore estimated to have resulted in 1,041 fewer crashes annually.
- Without ramp metering, emissions increased by 1160 tonnes annually, but fuel consumption decreased by 10.8 million litres of fuel, which was the only observed disbenefit of ramp metering[13].

The benefit/cost ratio developed in the study indicated that benefits are approximately five times greater than the cost of the entire congestion management system and over 15 times greater than the cost of the ramp metering system alone.

3.4 Variable speed limits (VSL)

Most freeways are subject to fixed speed limits that do not take into account situations where faster or slower speeds might result in improved safety or freeway performance outcomes. Research has shown that when drivers are not subject to a posted limit they will travel at speeds near to the facility’s design speed, and that when the fixed speed limit is set below this limit, drivers frequently exceed it. In areas where speed limits have been varied realistically in accordance with prevailing conditions, and are appropriately enforced, drivers have shown a higher level of speed compliance, adopt more consistent vehicle spacings or headways and change lanes less frequently. Most importantly, there are fewer accidents, and during peak periods, fewer flow breakdowns.

3.4.1 How speed limiting works

As a managed tool, VSL relies on pavement detectors to detect queues resulting from vehicle incidents, speeds and volumes, and on other roadside sensors (including CCTV) to detect rain and fog. The data from these detectors is linked to processors which use algorithms to continuously assess the appropriateness of the current speed limit and implement appropriate speed limit adjustments via Variable Message Signs (VMS). Alternatively, the limit can be manually changed by traffic control centre staff to respond to special circumstances. An

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[12] Minnesota DoT. Twin Cities Ramp Meter Evaluation 2001.

[13] This outcome may be applicable to the US vehicle fleet. However, European modelling shows a reduction in fuel consumption with ramp metering.

example of automatic adjustment is where a VSL system determines that traffic in a particular section has slowed significantly, and sets progressively lower speed limits for upstream sections to ensure that there is a safe differential speed when following traffic encounters the rear end of the queued or slower group.

Figure 7: Variable speed limit signs

3.4.2 The uses of VSL

Variable speed limiting is commonly applied in conjunction with a range of other visual en-route regulatory and advice systems to achieve the following outcomes:

(a) Improving road safety

VSL was originally developed as a means of improving road safety by reducing traffic speed on particular freeway sections where there was a clear connection between differential vehicle speeds and variable conditions such as peak period operation or fog. On the Western Ring Road in Melbourne, which had a particularly bad reputation for accidents, before and after studies by VicRoads showed that the introduction of VSL reduced all types of accidents by up to 34% and rear-end collisions in particular by up to 39%. Road safety can also be improved at worksites via VSL.

VSL systems can also detect incidents such as accidents and breakdowns, and quickly implement appropriate speed reductions to maintain traffic safety.

(b) Increasing freeway throughput

There is encouraging evidence that the improved lane discipline associated with the use of VSL may result in reduced turbulence from fewer overtaking manoeuvres and hence fewer flow collapses during peak period operation. The lower numbers of speed-related accidents also reduces the instance of prolonged flow breakdowns.

Studies of freeway flow collapse data indicate that by slightly lowering the traffic speed via VSL before the volume/capacity ratio reaches a critical point, which can be identified through flow monitoring, traffic managers may be able to either prevent or delay flow collapses. During the 2005 Austroads Study Tour, the Austrian road authority indicated that the VSL starts to harmonise speeds when volumes reach 70% of capacity. Both the Austrian and German authorities claim that the maximum volume (2,500 veh/hr) is obtained at speeds between 60-80 km/hr.

(c) Reducing freeway noise

The Austrian motorway system incorporates a noise algorithm that automatically reduces motorway speed via VSL when vehicles produce unacceptable noise levels (60dB during the day and 50dB at night). The algorithm is claimed to reduce noise by 7-8 dB[14].

(d) As an adjunct to lane control

VSL can be used to apply differential speed limits to lane management initiatives such as freight-only lanes and 'hard shoulder' running.

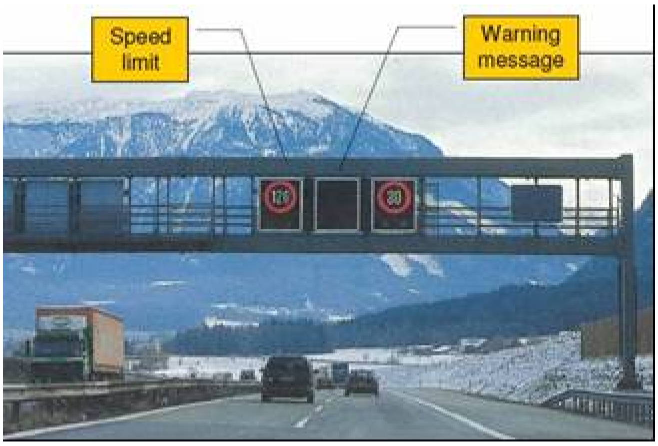

Figure 8: Differential speed limits

3.4.3 Benefits and costs of VSL

The main benefit of VSL systems are fewer flow breakdowns and shorter durations of flow breakdown. An example of the benefits and costs of VSL and VMS systems is the Wellington – Ngauranga advanced traffic management system, which involved the installation of variable message signs, CCTV, environmental monitoring, automatic incident detection, variable speed limit signs, loop detectors, optic fibre cabling and other roadside control equipment at a cost of $4.25 million and an annual operating cost of $125,000. The estimated savings from reduced crashes and vehicle operating cost and reduced travel time were estimated as having a NPV of $23m for the motorway, and a NPV of $56.7m for arterials. A benefit/cost ratio of between 4.7 and 11.4 has been estimated for the scheme.

3.5 Lane control

Lane control is a dynamic process by which freeway lanes, including shoulders can be more efficiently allocated in response to changing traffic conditions or incidents by providing traffic managers with the ability to open, close, lock or even reverse traffic lanes through the use of overhead Variable Message Signs (VMS).

Lane control signals comprise the lane allocation and lane regulation component of a hierarchy of VMS indicators that include speed control, danger warnings and advice and information. Lane control signs are mandatory in terms of actions required or restrictions imposed. Lane control signals provide road users with current and advance information of lane availability, and can indicate the required diverge direction when the lane ahead is closed. In particular, lane control can also be used to enforce lane 'discipline' by banning overtaking movements for all vehicles or for heavy vehicles only.

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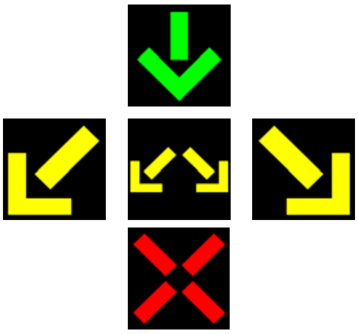
[14] Austroads European Study tour 2005. P 12

3.5.1 How lane control works

Lane control is achieved via VMS indicators mounted above each lane that indicate lane requirements downstream. In Europe, the basic lane control lights as standardised by the Vienna convention are:



The lane is open. (Where VSL is used, the green arrow is often replaced by the speed limit in a red circle).

The lane will be closed further down; go in the direction of the arrow(s).

The lane is closed; you should not continue.

Figure 9: Lane control symbols

Other pictograms not shown can be used to indicate overtaking bans and restrictions of use such as dedicated lanes for target groups, buses, trucks, carpools etc.

3.5.2 The uses of lane control

(a) Incident and work zone management

Traffic managers can temporarily close lanes in which a breakdown or accident has occurred, or in which maintenance or construction work is proceeding. Lanes can also be closed to facilitate access to accident and breakdowns by emergency and incident management vehicles.

(b) Capacity management

Lane control signals can be used to indicate the availability of the freeway shoulder for all traffic or freight vehicles only during peak periods. By banning overtaking movements, lane control signals can also improve capacity by removing one of the major triggers for flow breakdown during peak flows. Under controlled circumstances, lane signals can also be used to accommodate tidal flows by reversing some traffic lanes during the peak hour.

(c) Merge facilitation

The 2005 Austroads Study Tour noted:

> *'A unique and innovative application of lane control signals was found in Germany at merges of two freeway mainlines or merges of two multilane freeway entrance ramps, where the number of downstream lanes beyond the merge point is less than the total number of lanes upstream of the merge'. Lane control signals are installed over both upstream approaches, well in advance of the merge, and are operated with variable displays at different times of the day. The lane control signals are used to close a lane on whichever approach has the lesser volume during a given time period, and keep all lanes open on the higher volume approach. As the relative volumes of the two approaches change throughout the day, the lane closure is switched from one approach to the other. This system makes most efficient use of the available roadway infrastructure and improves safety by making the lane reduction take place where drivers do not have to contend with merging traffic.'*

3.5.3 Benefits and costs of lane control

Lane control is invariably used in conjunction with a range of other traffic management tools such as VSL and VMS, and it is difficult to isolate benefits and costs for lane control alone. However, the capacity and road safety improvement capability of lane control would be similar to that of VSL, which delivers benefit cost ratios of between 4.7 and 11.4.

3.6 En-route information systems

En-route information is about providing drivers with the right information at the right time and at the right location. Pre-journey and en-route information completes the loop between the traffic management system and the users. The desired outcome is that private drivers and the transport industry are well informed at all times and make better choices that more closely align with the day to day strategies of the traffic management system, and with the broader aims of the overall transport system.

The provision of en-route information for drivers is becoming an integral part of modern traffic management systems on both arterials and freeways, and is continuously broadening in scope as traffic managers embrace new information and communication technologies. As traffic authorities employ more dynamic tools to manage traffic demand, drivers will increasingly realise that decisions based on historic travel experience are less reliable than those made using dynamic information received either just before they commence their journeys or en-route.

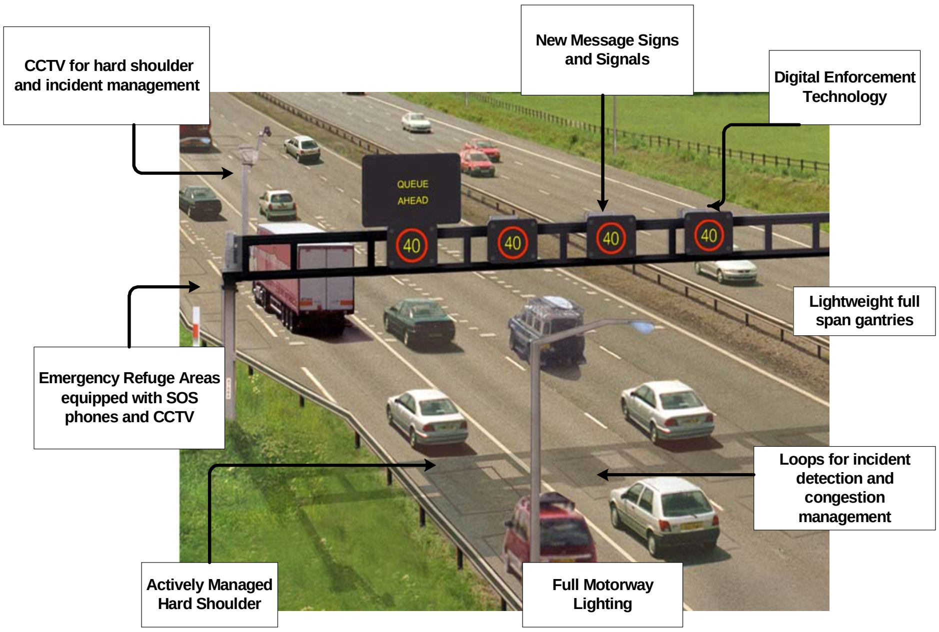


Figure 10: Gantry sign showing en-route information

3.6.1 How en-route information systems work

En-route information systems apply at two fundamental levels:

(a) Tactical and operational level

Drivers in their vehicles receive information about impending congestion, travel times, accidents and breakdowns, construction and maintenance work, weather conditions and hazardous road conditions such as oil spills or flooding. With this information, drivers can make appropriate and timely decisions about changing or maintaining their route. Most of this information arrives via drive-time radio or from variable message signs (VMS) on the freeways and their arterial approaches. However, with emerging information technology, drivers will also be able to:

- Receive traffic advice via Radio Data Service – Traffic Message Channels (RDS-TMC) which 'narrowcast' on a special FM frequency and can override the current station with locally relevant information.
- Interact with government and third-party information providers via direct means or automatically via their in-vehicle navigation systems to assess possible or suggested alternatives. The role of third party en-route information service providers is crucial to this initiative, and there are a number of organisations emerging such as Intelematics, Road Angel and Road Pilot.
- Receive radio or telephone advice in their commercial vehicles from transport dispatchers who in turn have been alerted of global traffic conditions by traffic information centres.

(b) Strategic level

Decisions can be made on the basis of en-route advice *before* travel by both private drivers and commercial vehicle operators. Before leaving home, private operators who subscribe to an information system could be alerted by email, targeted SMS, traffic TV channel or telephoned advice from third-party providers to changes or conditions on their favoured routes. Drive-time already radio provides a broader, less detailed information service along the same lines. If the driver's decision is to use an alternative transport mode such as 'park and ride using a bus or train service, Internet services already provide details of public transport timetables and routes. For commercial transport operators and dispatchers, information received from information providers via the Internet can be used to modify delivery scheduling and despatching arrangements. Credibility is crucial in accepting the advice and thus the reputation of the provider is crucial.

3.6.2 Benefits and costs of en-route information

There are no specific analyses of these information systems operating in isolation, but it is clear that they are important components of other installed dynamic management systems such as variable speed limits, lane control and incident detection systems that have demonstrated significantly positive benefit/cost ratios. The benefits include:

- Reduced public and private user costs through improved ability to plan or modify trips.
- Integration of the public transport system into driver trip planning scenarios.
- Improved road safety through provision of advance warnings of incidents, hazardous conditions and sudden weather changes.
- Reduced duration of congestion because approaching traffic is warned before it enters the freeway, or can exit to the arterial system or another freeway before the congested area is reached.
- Reduced duration of congestion due to improved access for incident management teams.

3.7 Coordinating the use of managed tools

When managed tools are used interactively, the resulting benefit often exceeds the sum of their benefits from being used independently. An example of this is the improved traffic flow that results when ramp metering for two or more interchanges is coordinated. However, a significantly greater benefit arises when managed tools are used interactively to manage an entire freeway instead of being employed at isolated or grouped ‘hot spots’. In the United Kingdom, this process is called Active Traffic Management.

With Active Traffic Management, every ramp and carriageway is monitored and controlled via managed tools. This allows the entire freeway to be ‘fine-tuned’ in real time to maximise throughput and safety. For example, if a freeway’s pavement loops detect volume/speed data that suggests a capacity-related flow breakdown is imminent, ramp metering can automatically reduce the rate of inflow, the VSL system can automatically lower main carriageway speed to avert the flow breakdown, and en-route information systems can warn motorists about delays and recommend alternative routes.

In Australia, managed tools are being used to treat congestion problems at individual sites, mainly because there is insufficient funding to do otherwise. While tools such as ramp metering and VSL have provided some worthwhile local capacity improvements, the fact that they work in isolation means that their improvements are often diminished by lack of capacity on unmanaged upstream or downstream sections. The current use of VSL to reduce flow breakdown is dependent on manual intervention based on historic traffic patterns or CCTV observations instead of real-time data and automatic intervention. As a result, VSL can be under or over-utilised because there is no real-time feedback loop.

By using tools on a piecemeal basis, major benefits are being lost to the Australian community. While the cost of installing system-wide, integrated tools would be significant on any urban freeway, they would be dwarfed by the community costs resulting from the ongoing loss of up to 25% of freeway capacity over half of the working day.

3.8 Coordinating freeway and arterial road management systems

Most of the tools discussed in this section rely on data and information on both the freeway and arterial road networks. If these tools are be applied effectively, (as indicated in the previous example) particularly at entry and exit ramps and on arterial approaches, freeway management systems will need to be integrated with arterial road management systems.

3.9 Coordination of freeway and tollway management

Many major urban motorways have adjoining tolled and un-tolled sections. The tolled sections are separately managed via the private operators’ control centres. Depending on the number of private operators, there can be multiple, privately operated control centres in addition to the road authority’s overall traffic control centre. Apart from incident control and isolated sections subject to active traffic management, most Australian tollways are largely unmanaged, although this is beginning to change.

While Melbourne CityLink’s management focus has been on increasing daily throughput and handling incidents, it has recently acknowledged that, despite increasing patronage, their facility is not achieving its potential at times of highest demand because of unmanaged congestion. CityLink has already installed one metered ramp on its tollway and proposes as part of a wider, joint project with the Victorian Government, to install ramp meters at the remaining interchanges together with speed, lane control and en-route information systems.

It would be in the commercial interest of other toll operators throughout Australia to adopt active traffic management systems. Some new tollways are currently being constructed with provision for these systems. A significant portion of the Sydney motorway network is operated by the private sector under deed arrangements. While there is currently close liaison between private and public traffic control centres on incident management, the integration of traffic management into seamless, overall motorway and arterial management systems would provide the best overall outcome for toll operators and road users. To achieve this, road authorities and toll operators will need to agree on operating protocols driven by common objectives.

3.10 Urban corridor traffic management

There is a growing trend towards integrating all of the diverse transport systems within a corridor rather than simply linking freeway/arterial interfaces or parallel freeways and arterials, and this will be essential in Australia if the full potential of the freeway management initiatives is to be realised.

The development of the principles, practices and technology needed to marry these diverse systems with dynamic freeway management systems is a complex task that is the subject of major research effort and a number of pilot schemes in Europe and the United States. As yet, there is no 'killer application' or agreed processes for achieving this.

As recently as March 2006, the United States Federal Highway Administration put out a call for US State Departments of Transport to submit proposals for Urban Corridor Traffic Management (UCTM) initiatives[15]. The following excerpt from the FHWA invitation eloquently captures the size and complexity of the task, and the need to focus on corridor management:

> *'Much of the congestion is in critical metropolitan corridors that link activity centres and carry high volumes of people and goods. These corridors are typically comprised of independent transportation networks, such as freeways, arterials, bus routes, and rail transit lines. The current state-of-the-practice in corridor management is highly disaggregated.*
>
> *To date, efforts to reduce congestion have focused on managing transportation networks within corridors individually. The ability to shift travel demands between facilities and modes (networks) during traffic incidents, roadway work zone activity, adverse weather, or simply unusually large traffic demands is severely hampered by lack of information about current conditions and lack of standardized technical means for sharing that information.*
>
> *The lack of institutional collaboration and coordination and the lack of integrated operational strategies and procedures further impede optimizing the performance of the corridor. It is envisioned that integrating the management and control of the individual transportation networks and optimizing the corridor transportation system as a whole would greatly improve the movement of people and goods through corridors, resulting in reduced delays and increased travel time reliability.'*

It is clear from the US imperative that the integration of all corridor transportation management systems will be a critical national task in improving the management of Australia's urban motorways and the broader transport networks.

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[15] US DoT(c). March 2006

4 Managing the allocation of road space

4.1 Introduction

Managing the allocation of road space is an important concept that is becoming increasingly relevant as communities realise that it is neither feasible, nor cost-effective nor desirable to continue to accommodate the growth of urban traffic by constructing additional freeway lanes.

While the previous section discussed the use of managed tools to reduce congestion and introduce greater travel reliability during peak capacity freeway flows, this section is concerned with making the most effective use of freeways that have been enhanced by managed tools.

‘Effective use’ means using priority-based, lane management systems to facilitate journeys that deliver the greatest benefit to the community, as opposed to achieving traffic throughputs that are as near as possible to a lane’s optimum capacity. (In most cases, both aims can be achieved). Deciding which journeys deliver the greatest benefit to the community and how they should be accommodated within the freeway cross-section requires the nomination of classes of road users that are to be given priority within particular lanes, and the specification of minimum levels of service for these users.

Priority users can include public transport vehicles (including taxis), freight vehicles, trucks, long distance vehicles, airport or shipping port traffic, 2+ or 3+ car pool vehicles or authorised vehicles such as police and emergency response vehicles. Priority systems can be tailored to individual freeways and corridors where there is a preponderance of one or more groups. These needs and goals can change over time; hence it is important that the systems for managing them are sufficiently flexible to embrace new priorities. By allocating road space in this fashion, these policies can influence community choices of transport mode, encourage the trend to smaller, more fuel-efficient vehicles and also improve integration of freeway systems into the public transport network.

The principal strategies for used for optimising freeway efficiency are shown below.

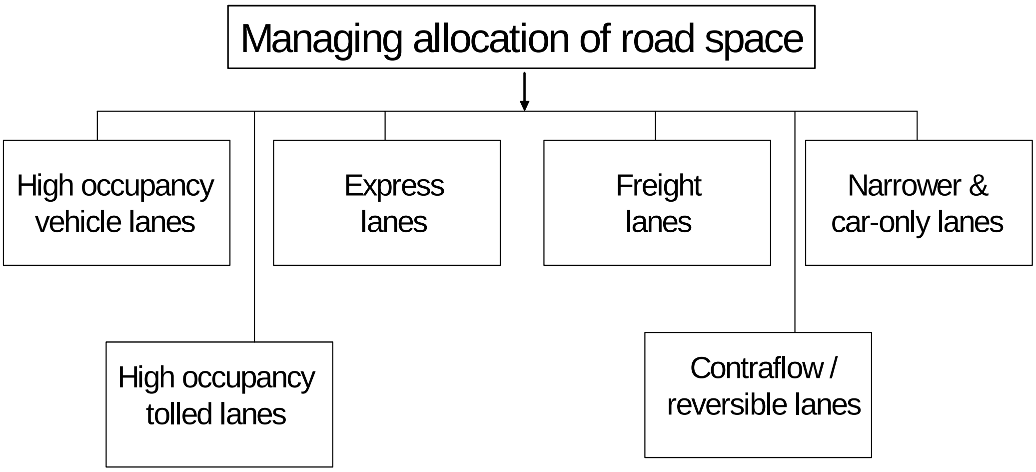

Figure 11: Road space allocation strategies

4.2 High occupancy vehicle (HOV) or transit lanes

High-occupancy vehicle lanes are lanes that are usually restricted to buses, taxis and private vehicles carrying two or more people[16]. Depending upon the extent of HOV demand, these lanes can be physically separated from other freeway lanes and operate as HOV on a permanent basis, or they can utilise a general purpose freeway median lane or outer shoulder and operate permanently as HOV, or only during peak flow periods. Temporary HOV lanes are currently used in Melbourne, Sydney and Perth.

The primary purpose of HOV lanes is to improve the people-carrying efficiency of freeways by encouraging car pooling[17] and greater use of road-based public transport - especially via park and ride facilities. Because fewer vehicles are eligible to use HOV lanes, travel times in them are much shorter during peak periods than in the adjoining lanes. Slightly under-utilising the capacity of HOV lanes is a deliberate strategy to maintain free-flowing conditions and hence provide an incentive/reward for high-occupancy vehicle travel. The overall payoff is that the additional passengers carried will more than compensate for the reduced numbers of vehicles carried by the freeway. Some overseas transit lanes are carrying 3 – 6 times the number of people as adjacent general purpose lanes. Victoria's Eastern Freeway transit lane has a people throughput of about 800 people per hour higher than the adjacent general purpose lanes.

HOV operation can be further facilitated by allowing HOV traffic to bypass ramp metering signals when entering freeways and by providing dedicated turn lanes and signal priorities for exiting HOV traffic at arterial road interfaces.

Dedicating an existing lane for HOV can (for example) reduce the overall capacity of a four lane freeway carriageway by at least 5.4%, assuming that the HOV is fully utilised[18]. Where HOV lanes are under-utilised, they can increase congestion in the remaining general purpose lanes and also tempt ineligible road users to use the HOV lane. Preventing misuse can be difficult and in some cases self-defeating because on-site enforcement can cause delays and congestion that the HOV lane was intended to avoid. Compliance can be low where there is no obvious risk of detection and/or the HOV lanes are not physically separated from the other lanes. The need for HOV traffic to move to and from ramps on the opposite side of the carriageway can cause disruption to main flows. As a result, there is a growing view that HOV priority should be limited to providing bypass lanes at ramp metering sites and on exit ramps which also provide signal priority to HOV traffic.

The primary user benefits of HOV lanes are travel time savings and improved travel time reliability – particularly for public transport vehicles operating to fixed schedules. The community benefits are better utilisation of the freeway as a people moving facility, more effective integration and use of road-based public transport, and reduced congestion and pollution due to fewer vehicles using the freeway during peak periods. The physical cost of establishing a HOV lane can be minimal (eg. signs, line-marking and public education) if an existing lane or shoulder is used. However, not all shoulders are of sufficient width or strength to accommodate a HOV lane, and it may be necessary to firstly widen the carriageway or strengthen the shoulder. Also, some shoulders are used by cyclists with no viable alternative route available.

Ongoing costs can include requiring a regular police presence to reinforce compliance and detect offenders, or alternatively mounting and demounting temporary barriers to physically separate the HOV lane from the adjoining general purpose lane.

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[16] Where there is a high demand, private vehicle access to HOV lanes can be restricted to vehicles carrying three or more people, or the number of vehicles carrying only two people can be restricted by various means.

[17] Off-freeway incentives such as concessional parking arrangements can be used to further encourage private HOV usage.

[18] Better utilisation of motorway infrastructure. Booz Allen Hamilton, Aug 2005

4.3 High occupancy tolled (HOT) lanes

Because HOV lanes are usually implemented as a long term transport policy initiative rather than as a response to a quantified demand, they often remain considerably under-utilised, even after taking into account the reduced volumes needed to maintain free flows. US traffic authorities are increasingly utilising the spare capacity of HOV lanes by allowing low occupancy vehicles to use them, provided they pay a toll to do so. When this happens, the HOV lanes become conditional pay lanes, or High Occupancy Tolled (HOT) lanes.

The operation of HOT lanes would be most effective from a compliance and enforcement viewpoint when all users have electronic tags, offenders are recorded by cameras and there is a graduated charging system based on vehicle occupancy. (Some US authorities station police officers on HOT lanes for 12 – 16 hours a day to catch or deter offenders). High occupancy vehicles would either travel free or pay a minimum toll, with low occupancy vehicles paying the highest toll. Tolls would be varied in value according to fixed times of day, or be varied in real time in response to actual traffic conditions to ensure that traffic flow in the HOT lane is always maintained at free-flow conditions.

With HOT lanes, it is even more important to prevent misuse, and this is frequently achieved by using temporary or permanent barriers to provide separation from the un-tolled lanes. However, with contiguous HOT lanes, gaps in the barriers are required in the vicinity of exit and entry ramps. The need for HOV traffic to move to and from ramps on the opposite side of the carriageway can disrupt main flows. For this reason, HOV/HOT lanes are probably more effective on longer urban freeways with more widely spaced interchanges.

The benefits of HOT lanes are at least those of un-tolled HOV lanes. However, HOT lanes have the added benefits of maximising the available lane capacity and thus removing some of the public perception that these lanes are under-utilised. The costs of establishing a completely separate HOT lane (usually in the central median area) can be considerable, but can be recovered from the tolls imposed. In some US cities, separate HOT lanes are funded, constructed and operated on behalf of the traffic authority by private operators. Completely separate HOT lanes can be capable of being reversed to handle AM and PM peak flows.

4.4 Freight lanes

Heavy freight vehicles generally have high journey values, and as such should be given priority in the allocation of road space. Providing a freight-only lane not only benefits the economy by reducing the trip times of these vehicles, the reduction (or even exclusion) of heavy vehicles from the remaining lanes can also deliver improvements to traffic throughput by reducing the incidence of flow collapse during the peak periods.

As a rule, the outer lane or even the shoulder is designated as a freight lane because this involves the least number of cross-carriageway movements of heavy vehicles at entry and exit points. However, as truck volumes increase in these lanes, so does the risk of conflict with other traffic entering or leaving the freeway. While some overseas countries cater for very heavy truck volumes by constructing separate, truck-only carriageways with their own interchange ramps, this is probably not a realistic option for many of Australia’s inner-urban freeways.

The main period for freight is not during the peaks but in the periods before and after the peaks and during business hours. The volume of freight vehicles typically drops during the AM and PM peak periods, and traffic authorities may ‘top-up’ the volume of freight lanes during the peaks with buses and other HOVs to maximise use of the available capacity. Depending upon the relative levels of HOV and freight vehicles on a route, permanent HOV lanes can also be used as freight lanes. Also, the ramp metering bypass lanes and exiting HOV lane signal priority used by HOVs can also be extended to freight vehicles.

Where freight lanes are provided, trucks can have the option of using them or be prohibited from using the other lanes. As with HOV lanes, non-compliance can be a problem, with some studies indicating non-compliance rates of up to 10%. Automated enforcement systems using height or mass-based detectors in association with camera-based evidence can be used to detect light vehicles in freight lanes or vice versa, however this can require extensive gantry and sensor systems.

The main benefits of freight lanes are reduced travel times and increased reliability, particularly for the long-haul freight movements typically using articulated vehicles. Opinions vary as to whether freight only lanes reduce road accidents. However, as freight vehicles are a common factor in flow breakdowns, which result in rear-end and sideswipe accidents, some reduction in road accidents could reasonably be attributed to the use of freight lanes.

4.5 Narrower lanes and car-only lanes

Most freeways have been designed on the premise that trucks will operate in all lanes. However, in some cases, freeway space can be more efficiently used by restricting trucks and buses to a full-width, outside lane and dividing up the remaining space into narrower car-only lanes. In this way, one or more additional car-only lanes can be created, with a resultant increase in capacity.

The narrower lanes can be added on a permanent basis (if necessary, by widening the pavement in the median area and/or utilising part of the shoulder), or can be implemented during peak demand periods by using ‘intelligent’ pavement markings to temporarily change the width and number of traffic lanes. The latter option would improve freight capacity outside the peak periods (when freight volumes are higher) by allowing trucks to use additional lanes.

In Australia, trucks have a maximum allowable width of 2.5m, although mirrors, reflectors and other devices often project beyond this width. By comparison, most cars are less than 2m wide. While the most widely adopted ‘standard’ lane width is probably 3.5m, a lane width of 3.35m is generally considered to be the desirable minimum for heavy vehicles moving at 100 km/hr. At widths less than 3.35m, accident rates increase in proportion with heavy vehicle use, and drivers tend to decrease their speed in proportion with decreasing lane width.

Although widths of 2.5m have been considered in Europe for cars only, the current consensus is that car-only lanes should not be less than 3m. Nevertheless, there is a growing trend in highly urbanised areas towards the use of motorcycles and smaller motor vehicles that might see lanes narrower than 3m used in the future. This trend reflects a growing consumer preference for fuel-efficient, personal mobility vehicles that are easier to park in crowded environments - as opposed to larger vehicles used for transporting family members.

The primary benefit of using narrower, car-only lanes is increased capacity where additional lanes are provided, albeit at slightly reduced speeds. The other benefits are effectively the same as those of freight lanes in that traffic flow is improved, and accidents are reduced by removing larger, slower vehicles from the majority of the traffic lanes.

4.6 Express lanes

The term ‘express lane’ is often used in the United States to encourage and promote use of HOV lanes by car poolers. However, in the context of allocating road space, express lanes are lanes whose users are given priority because they are travelling relatively long distances in comparison to the majority of travellers whose journeys might span no more than three to four interchanges. Long distance journeys can include cross-urban journeys and outer-urban to inner-urban journeys. They can also include inter-capital and inter-regional journeys when urban freeways incorporate a major interstate or inter-regional route. Many long distance users are ‘high-value’ freight vehicles whose cargoes have economic importance and are often time-critical to the ‘just-in-time’ input management schemes of major industries.

One of the significant triggers of freeway flow collapse is interference to main flows caused by vehicles weaving to enter or exit the freeway. This can result in major bottlenecks where interchanges are closely spaced, such as inner urban areas. The objective of introducing express lanes is to improve the efficiency of main flow, longer distance traffic by reducing entry and exit movements to a workable minimum. This is achieved by providing physically separate, parallel general purpose lanes (called collector-distributor) that have a minimum number of connections to the express lanes but connect to either multiple interchanges or all of the interchanges along the entire freeway. In this way, most of the weaving movements take place within the collector-distributor lanes, rather than in the express lanes.

Figure 12: An express lane

A vehicle leaving an express lane might necessarily pass several interchanges via a collector-distributor lane before accessing the desired connection to the local road system.

Express lanes can be achieved at relatively low cost by widening existing carriageways to create a contiguous collector-distributor lane and erecting barriers to achieve physical separation. In cases where contiguous lanes cannot be achieved (usually due to lack of available space on or under freeway bridges), the provision of a collector-distributor lane can often involve land acquisition and overpasses of local roads at interchanges. However, collector-distributor lanes can be very effective at improving main flows and removing major bottlenecks. In Melbourne, extensive retro-fitting of collector-distributor roads is proposed on sections of the Monash Freeway to eliminate current inner-city bottlenecks caused by closely spaced interchanges.

The primary benefit of express lanes is increased throughput. VicRoads has estimated a benefit cost ratio of 10: 1 for the provision of express lanes on the Monash Freeway.

4.7 Contraflow and reversible lanes

During the AM and PM peak periods, most urban freeways exhibit significant directional flow imbalances, which occur on a daily basis. The traditional approach is that where peak period traffic in one direction is 65% or more of total traffic and is subject to congestion and delays, a significant improvement in throughput can be achieved by reversing the flow of one or more lanes in the opposing direction. However, Victorian studies of contraflow proposals for the West Gate Bridge suggest that contraflow can still be a cost-effective strategy where the difference between the flows is less than 65% but the duration of the peak in the favoured flow direction is significantly longer than the peak in the contraflow direction. While this can introduce some congestion during the shorter contraflow peak, the VicRoads study suggests that the overall benefit/cost ratio from catering to the longer peak can be as high as 16:1.

Reversing lane flows is widely considered to be one of the most cost-effective means of increasing peak period capacity because it utilises facilities that have already been constructed, and is not subject to physical constraints that major bridges and tunnels normally impose on widening. The theoretical[19] increase in capacity, ranges from 49.2% from converting 8 equally shared lanes to 6 and 2 lane facilities, to a 59.1% capacity increase from converting 10 equally shared lanes to 8 and 2 lane facilities.

Flow reversal is commonly achieved by the following means:

4.7.1 Reversible lanes

The two major forms of reversible lanes are:

- Contiguous lanes on undivided sections of freeways and major arterials that are subject to overhead lane control signals which indicate the permitted direction of flow. These lanes can either be separated by pavement markings or by temporary, moveable barriers. There are differing opinions about the need for physical separation of these lanes to reduce the risk of head-on collisions. The Road Traffic Authority of NSW 20 year experience with reversible lanes on the Sydney Harbour Bridge suggests that containment barriers are unnecessary, provided a speed management regime is in place. However, in Auckland, the implementation of a reversible lane using only overhead signs resulted in 11 deaths from head-on collisions over three years, resulting in the implementation of concrete, moveable barriers. The reversal process can involve initially banning access from both directions using overhead lane signals, and after a safe, short period, changing the signals to indicate permitted movement in the opposite direction.

Figure 13: Portable safety barriers, Europe
(Note the use of the left-hand shoulder)

- Permanently separated lanes that are usually located in the median area for the purpose of handling HOV, HOT and/or freight traffic (as distinct from HOV/HOT lanes located on both sides of the freeway). HOV flows tend to be highly directional because of the preponderance of commuters. As a consequence, separate HOV/HOT lanes are usually reversed between the AM and PM peaks to maximise their capacity.

The reversal process involves using signals to stop further access from the current direction, and using CCTV to ensure the lane is clear before permitting access from the opposing direction.

4.7.2 Contraflow lanes

When a freeway median cannot accommodate self-contained reversible lanes, some of the lanes of the opposing carriageway can be utilised to provide additional peak period capacity. These lanes are referred to as contraflow lanes because their travel direction is ‘contra’ to the carriageway’s normal flow during periods of peak demand in the opposite direction. For

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[19] Based on the US Highway Capacity Manual, 2000

example, a median lane on the outbound carriageway will function as a contraflow lane during the morning peak but will function normally for the rest of the day, including the evening peak when the equivalent lane on the opposite carriageway will operate as the contraflow lane.

Contraflow lanes require specialised transition points at the beginning and end of the contraflow sectio. It is highly desirable to use a physical barrier to separate contra-flowing traffic from opposing traffic because the speed differential is often much greater under contraflow arrangements.

Figure 14: Sydney contraflow lanes

The lane separation barriers can be fixed or moveable, or solid or visual, and there are differences of view as to which type of barrier delivers the best outcome in terms of vehicle safety and operational costs. Concrete barriers provide the best protection from head-on collisions, and can either be permanently fixed to the pavement or interlinked and moved by a special machine when contraflow is no longer required. Lightweight, flexible systems that form visible barriers rely on driver behaviour and do not prevent vehicles crossing, but have been successfully used for contraflow lanes in Sydney for a number of years without a significant accidents record.

The costs of mounting and demounting moveable lane separation barriers can be considerable over a period of time, and solid, fixed barriers are often favoured for this reason. However, solid barriers need to provide regular gaps or emergency openings to allow traffic to be re-routed during accidents and breakdowns in the contraflow lanes, and to facilitate rapid access by emergency vehicles. Permanent solid barriers may need more complex entry transitions to reduce the danger posed to normal traffic at the point where the barrier commences. Flow reversals in contraflow lanes are usually managed by closing the cross-median connections using boom gates, lane control signals and variable message signs in conjunction with CCTV to ensure that the lanes are empty before they are closed or opened.

To justify the cost of installing and operating contraflow lanes, a significant length of the freeway needs to be congested in one lane during the peak periods, and the downstream network should be capable of handling the additional volumes facilitated by the contraflow arrangements. Contraflow arrangements may have limited life-spans as the spare capacity in the opposing lanes is progressively reduced by traffic growth and/or changes in commuter travel patterns. A study by VicRoads of installing contraflow lanes with fixed lane barriers on Melbourne’s West Gate Bridge indicates a benefit/cost ratio in the region of 16:1.

4.8 Use of freeway shoulders or emergency lanes

The extreme outer lanes of freeways are shoulders which are usually designated as emergency lanes. Driving vehicles along them is normally forbidden. The intent of emergency lanes is to allow disabled to move out of the through lanes, and to provide access for emergency vehicles. Emergency lanes are also used to answer or make mobile phone calls safely.

Figure 15: Hard shoulder use, UK

Figure 16: Lay-by area, M42, UK

Because most emergency lanes are three metres wide and are capable of carrying normal traffic loads, they are also capable of being used as an additional traffic lane. In theory, converting the emergency lane of a two lane carriageway to a trafficked lane can increase capacity by nearly 50%. This can be an attractive option when additional capacity is needed for badly congested roads and there is insufficient space beside the freeway in which to widen the carriageway. Some international studies suggest that using emergency lanes for general traffic can increase accident rates. However, this risk can be reduced through the provision of closely spaced lay-by areas equipped with emergency phones, CCTV monitoring, enhanced incident response teams and reduced speed limits enforced via signals and VMS mounted on overhead gantries.

The most efficient use of emergency lanes is as a priority (HOV/HOT and/or freight lane). Because emergency lanes are narrower than general purpose lanes, their capacity is lower and they need to operate at a lower speed limit to maintain safe conditions. When emergency lanes are used as priority lanes, the higher person throughput obtained should more than compensate for the reduced speed and capacity. Utilising the additional capacity as a general purpose lane is likely to result in an immediate short term reduction in congestion with congestion re-emerging in a short period of time as capacity is taken up by induced demand.

If there are high daytime volumes of heavy freight vehicles, emergency lanes can be used as full time freight lanes and be topped up during the peaks with HOV/HOT traffic when freight volumes normally drop. Alternatively, the emergency lanes could be used as priority lanes only during the peak periods and be restored to emergency use only between those periods. This latter type of operation requires careful CCTV surveillance to ensure that there are no broken-down vehicles in the emergency lane before it is activated for priority use. Overhead gantries and lane control signals are essential to this type of operation.

Figure 17: Use of hard shoulder with lighted studs

The primary benefit of using emergency lanes is considerably increased capacity for minimal construction effort (eg. lay-bys and overhead gantries with VMS) and additional ongoing costs (CCTV monitoring and provision of efficient incident response teams). Where emergency lanes are used as priority lanes, there are further benefits due to the fact that person throughput is increased with a commensurate reduction in vehicles, and capacity in the remaining lanes improves because slower, heavier vehicles can be removed from the main stream, with a corresponding reduction in flow breakdown. All of the benefits applicable to HOV/HOT lanes also apply.

5 Network intelligence

5.1 What is network intelligence?

Network intelligence is the asset represented by enhanced historic and real-time data concerning all aspects of using, operating and improving a transport network. The enhanced data can provide real-time user and manager information such as travel times, delays and performance indicators. It can be used in a predictive sense to anticipate future demands, analyse improvements and provide suggested responses to unusual circumstances.

5.2 Why is it needed?

Freeways and arterial roads within a corridor are complementary transport systems that are often poorly utilised as a whole because they tend to be managed as separate entities. This can result in considerable inefficiencies when available capacity on one of the systems is under-utilised while there is congestion on a parallel route.

The reason for this is that traffic managers have no easy means of determining the status of either facility in real-time, nor do they have an effective mechanism to provide timely suggestions to road users to avoid congested routes or divert to less congested routes. More importantly, traffic managers do not have the tools to detect that an uncongested route is about to become congested, and thus be proactive in activating real-time interventions and providing traveller advice, rather than reacting to the congested situation.

On a more fundamental level, the absence of network intelligence means that most Australian traffic authorities are unable to set freeway performance targets because they have no data that would allow them determine what these targets should be (based on the measured, realisable capabilities of the freeway). Even if targets were to be nominated on the basis of theoretical performance, there is no effective means of determining whether or not they are being met.

5.3 How is network intelligence implemented?

A network intelligence system requires:

- The collection of real-time performance data for freeways and arterial roads.
- A process to aggregate real-time and historical data and to analyse and transform it to develop meaningful real-time and predictive content for traffic managers and road users.
- Systems for delivering this content to traffic managers and transport users in real-time.

5.4 Network intelligence in Australia

Australian authorities have gone some distance towards implementing network intelligence, but to a lesser extent to that seen in overseas countries. For example, the Victorian *Drive Time* system uses freeway detector loops to assess traffic conditions, and uses VMS to advise motorists on arterial roads that freeway traffic is either ‘light, medium or heavy’, and to warn when ramps are closed due to major incidents. *Drive Time* also uses VMS at points along the freeway to provide motorists with visual estimates `of travel time to key interchanges. However, the Victorian system does not have the capability of suggesting alternative arterial routes nor is it used in a predictive capacity.

Western Australia is proposing to implement a similar form of network intelligence in its Freeway Performance Management and Traffic Information System (FPMTIS) on the Mitchell and Kwinana Freeways in Perth. The FPMTIS, which includes ramp metering and VSL is expected to provide a benefit/cost ratio in the range of 7.1 to 8.4 as a result of increased route diversion during incidents, reduced numbers of incidents and reduced vehicle operating costs.

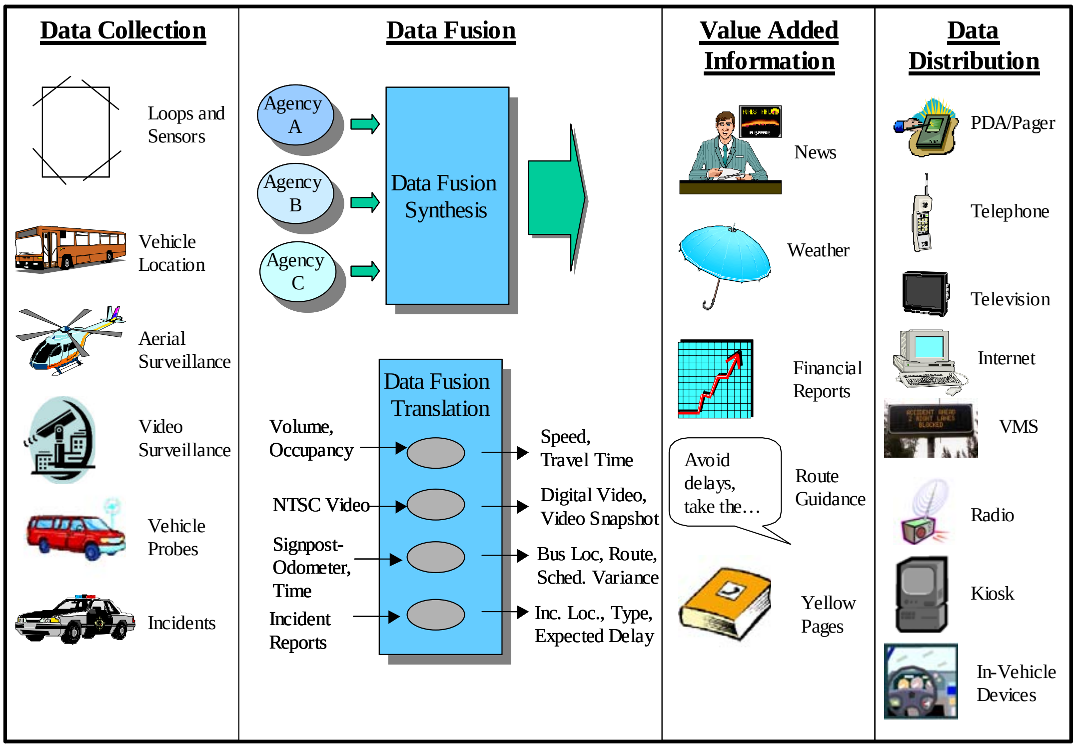

Figure 18: General concept of network intelligence

5.5 The importance of network data collection

A network intelligence system requires a data collection capability for both freeways and arterial roads that will allow authorities to make real-time assessments of the health of the network. Without this data there can be no meaningful network intelligence.

5.5.1 Freeway data collection

Few Australian urban freeways have systems for collecting high-quality, real-time performance data that would support a network intelligence system. While there is good public information about freeways, it is not necessarily gathered or provided in real-time. Much of it originates from drivers using mobile phones and video cameras, or via the control rooms of emergency or roadside assistance services, drive-time radio stations, private aerial traffic surveillance and CCTV traffic cameras.

The bulk of high-quality real-time freeway performance data comes from pavement-based inductive detector loops[20] which can collect speed, occupancy (length of time a vehicle spends on a loop) and flow data for each lane. Only Victoria has a comprehensive system of loop detectors on most of its urban freeways. The few tolled systems that exclusively use electronic tags, can also collect performance data via their gantry sensors.

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[20] Pavement loops collect speed, occupancy (length of time a vehicle spends on a loop) and flow data per lane.

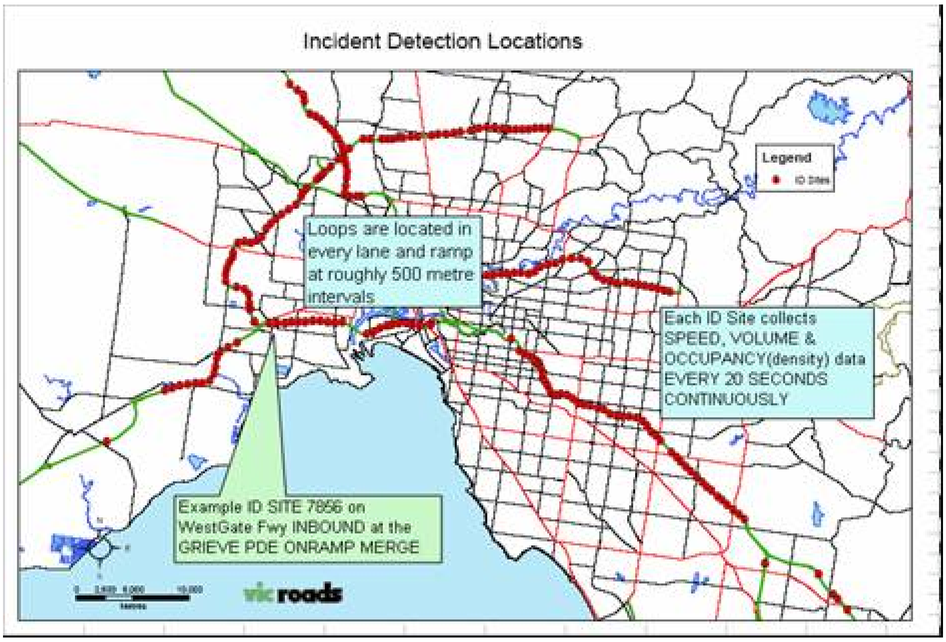

Figure 19: Melbourne freeway traffic detector network

Low cost, light-weight gantries are becoming popular on overseas freeways as a platform for performance-measuring detectors including microwave, noise and infra-red. These can be installed and serviced on a gantry without the need to close a lane. However, pavement-based detectors are likely to remain because of the cost of installing gantries. There is promising research suggesting that more cost-effective, wireless intelligent pavement ‘studs’, capable of measuring a variety of performance and environmental data, will supersede inductive pavement loops.

Another method traditionally used to obtain real-time performance is to utilise fleets of probes[21]. However, these do not provide the frequency of input needed for a network intelligence system. Another possibility is to monitor the movement of large numbers of vehicles equipped with electronic-tags. However, there are social equity issues involved, and further research is needed to resolve issues such as the adequacy of data refresh rates and what constitutes a critical mass of vehicles on which to base intervention strategies.

Other non-pavement in-vehicle detector systems being investigated include the use of roadside equipment to detect GPS receivers, and mobile phones. The Intelligent Access Program to monitor heavy vehicles will use this technology. Automatic Number Plate Recognition (ANPR) technology is another probe option and the Queensland Department of Main Roads is trialling a scheme. The NSW Safe-T-Cam system uses ANPR and has been operational in NSW as a heavy vehicle tracking system for over 10 years. The cost of ANPR technology has declined dramatically in recent time as evidenced in the range of toll products that do not require tags.

5.5.2 Arterial road data collection

A robust data gathering system will also be required for arterial roads to facilitate the operation of network intelligence.

Unlike freeways, there is little public information available concerning the hour-to-hour operation of arterial roads. However, there is a wealth of potential performance data that can be made available from the traffic signal loop detector system, which is linked to traffic control

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[21] Probes are specially equipped vehicles that are driven along the freeway in a consistent manner intended to mimic freeway traffic.

rooms and operated via specialised management systems such as SCATS (Sydney Coordinated Adaptive Traffic Management System), or similar systems such as STREAMS or BLISS. Because most arterial road performance data is currently associated with intersections, it will be necessary for traffic managers to install additional detectors between intersections to provide a performance measuring system for arterial traffic that will be adequate for use in a network intelligence system.

Currently, a number of road authorities are developing models which utilise loop detector data to provide information on the performance of the network. This information, including travel times for road sections, is then able to be used by both road managers and road users. Further refinements have included travel times for buses in priority lanes and a freight travel time model has recently been proposed.

These early arterial models will soon be enhanced with data from other sources. There are proposals to install additional detectors between intersections that can both classify vehicles as well as collect traffic data. This will not only help to improve the accuracy of the current models but as a result of classification, provide additional information that could support signal priority for freight and public transport vehicles.

A companion paper will be addressing the developments in arterial roads.

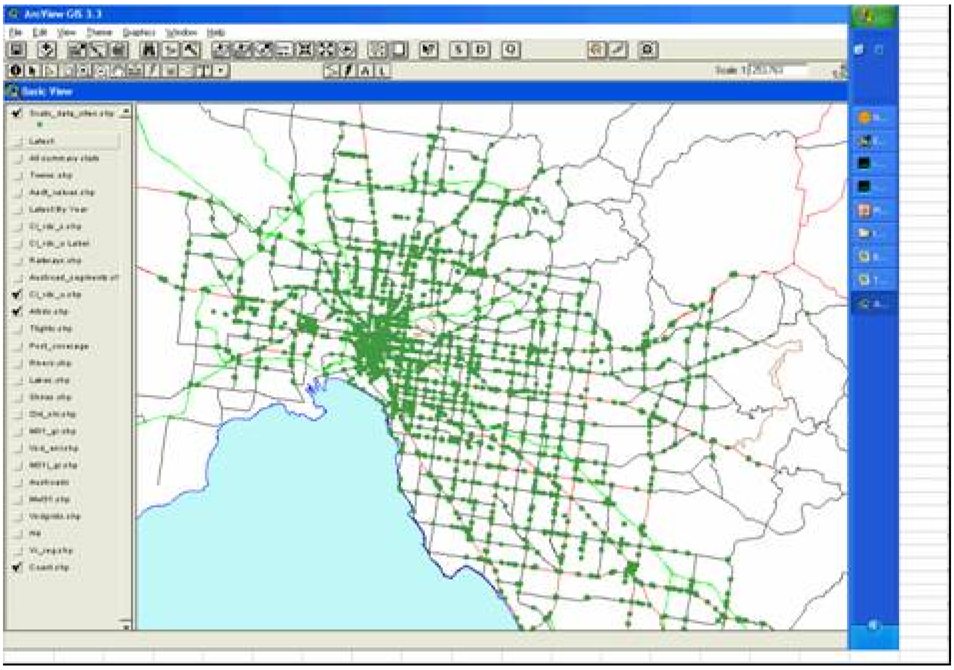

Figure 20: Melbourne arterial detector network

5.6 Processing data and information

Road authorities already gather and aggregate a huge amount of 'static'[22] data such as traffic volumes and composition, accidents and road infrastructure properties. The common use of Geographical Information Systems[23], means that this data can be integrated into network intelligence systems and combined with other real-time data to provide useable content.

Road authorities have traditionally used static data (in the form of origin and destination surveys) in mathematical network models to predict how traffic will utilise road links in

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[22] Static data is historic data because it does not reflect current conditions.

[23] These are databases that link data to geographical locations via coordinates.

response to route changes. Although modelling has become a highly refined process, the lack of real-time traffic performance data means that models cannot be calibrated against current conditions, nor can their predictive outputs be validated. Obviously, access to comprehensive, real-time data would considerably enhance and broaden the role of these models, which could then become part of the network intelligence system.

Australian road authorities and research organisations are well advanced with the development of software[24] to convert raw, real-time traffic data from arterial and freeway pavement detector loops into useable information. The major challenge for road authorities will be in developing data fusion software to combine and process all of the other relevant historic and real-time data discussed in the preceding section, and to convert this refined content into useable ‘metrics’ that have value and meaning to both traffic managers and travellers.

In a network intelligence system, the fusion software would also interpret data into meaning. For example, if loop detectors indicate a dramatic reduction in vehicle speeds, then rather than simply reporting this data, the system could indicate that an accident has potentially occurred and this adds to the information that is available. Current situations could also be extrapolated into the future to draw inferences about network conditions, traveller behaviour and opportunities for operational improvements.

The increasing amount of real-time data originating from private sources suggests a future scenario in which road authorities will utilise private data sources to better manage their road networks. This already occurs in most Australian Capital cities where private aggregators share their information with traffic authorities.

5.7 Delivering and using network intelligence

5.7.1 Traffic managers

Traffic managers can use network intelligence to measure actual freeway performance in both the short and long term, and by doing so establish agreed network performance indicators such as optimum speeds, reliability and capacity. Road managers can then easily compare actual performance against these indicators to identify areas requiring improved management or physical improvement.

In Europe and Japan, the use of network intelligence has revolutionised the operation of traffic control centres. Dynamic, map-based systems visually display network performance and depict performance anomalies as they occur. Traffic control centres are also using network intelligence to identify emerging flow breakdown scenarios, based on automatic access to historic data, and are taking pre-emptive action via managed tools, and monitoring the results of their interventions in real-time.

When major incidents occur, control centre managers are better able to assess the available capacity of alternative arterial routes, and to make real-time changes to facilitate the operation of diversions along these routes. On public holidays and special occasions, road managers will be able to use historical traffic patterns to predict capacity gaps and plan necessary interventions and user advice.

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[24] Companies such as ARRB, Transmax, ARTIS, Advantech Design, VicRoads Freeway Analysis Tool and Custom Traffic have been involved in developing these software packages.

Figure 21: Control room in Germany, showing map-based systems

5.7.2 Road users

The means by which network intelligence will be delivered to road users have been discussed in Section 3.6 of this report, dealing with en-route information. Network intelligence will provide road users with the most timely and effective advice of conditions and/or alternative route choices, based on real-time knowledge of the performance and available capacity of the freeway and arterial networks and the public transport system.

Recent Australian studies have found that road users in Melbourne, Sydney and Brisbane favour prescriptive, predictive and quantitative real-time dynamic information over more static direction such as alternative routes. The studies also show that road users are primarily concerned about the time their trip will take, the reliability of that travel time, and to a lesser extent, the cost of their trip.

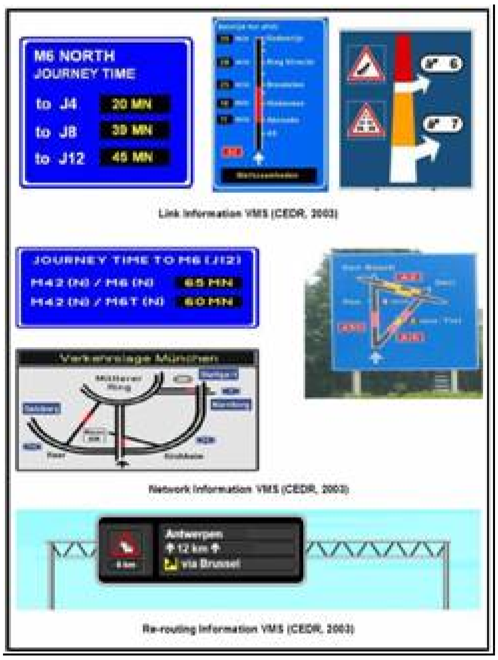

Figure 22: German en-route information display

There is a host of other road user information that is becoming available on the Internet, such as the availability and location of road-user services such as fuel, restaurants, windscreen replacement, medical attention etc. It is likely that private providers will make this information available to travellers in partnerships with road authorities.

As the use of GPS navigation systems becomes more widespread, road users will increasingly seek data on the best and quickest means of reaching these services. In the future, it is feasible that in-vehicle navigation and vehicle telematics[25] systems will automatically interface with private data system providers.

5.8 Benefits

The major benefit of using network intelligence will be a far more effectively planned, managed and integrated transport network. Freeways and arterials will operate in greater harmony with their users, and improvement funding will be based on better information and be better targeted. Road users will benefit enormously from the increased information, which will be delivered via the en-route and pre-journey information systems discussed earlier.

5.9 Challenges

The challenges for road authorities will be to:

- Implement comprehensive, real-time network performance data collection systems.
- Form partnerships with private providers of other real-time data and information.
- Develop information technology to manage the diverse flows of information and data.
- Identify information markets and their data preferences and delivery mechanisms.
- Deliver this product in a manner that optimises use of the overall transport system by satisfying user needs in conjunction with proactive freeway management.

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[25] The science of sending, receiving and storing information via telecommunication devices.

6 Conclusions

It is clear that:

- Many Australian urban freeways are heavily congested, with the length of the AM and PM peak hours in Melbourne alone increasing by 50% in the last four years alone to about six hours per day. Traffic growth will see some urban freeways operating at their full capacity for the entire working day within ten years or less.
- Australian urban freeways should be capable of carrying 2,200 veh/hr per lane, but often average only 1,600 – 1,700 veh/hr when design capacity is required because there is relatively little control of the causes of flow collapse. By comparison, many overseas freeways consistently carry 2,100 – 2,200 veh/hr per lane because maximum flow is maintained via managed tools.
- Managed tools require an extensive network of data gathering sensors to monitor the operation of the network. As most Australian freeways have limited data gathering capability, managed tools tend to be used on a site-by-site basis rather than on a system-wide basis, and tend to be operated independently of each other.
- While newer freeways and tollways are beginning to incorporate traffic management tools, the bulk of current freeway and tollway management effort goes to responding to incidents and breakdowns, which probably represent little more than 20% of congestion causes.
- In the absence of effective traffic data gathering systems, traffic authorities have difficulty setting realistic performance targets and have minimal awareness of what is happening on their freeways. As a result, freeway congestion has largely remained unnoticed and untreated, because it has become part of the accepted, daily traffic environment.
- Because many of Australia’s urban freeways are either unmanaged or only partly managed, up to 25% of their capacity could be unavailable during periods when their full capacity is required. The use of internationally proven traffic management tools and strategies could recover much of this capacity and ensure that it remains ‘locked in’.
- Improved management of our freeways could potentially recover Australia $500 million annually in avoidable congestion, and potentially billions of dollars of lost ‘return’ on the national investment in urban freeways.

7 A way forward

This report has discussed a wide range of traffic management tools and strategies that all Australian traffic managers can utilise to improve the performance of their motorway systems. It has also emphasised the importance of implementing and interlinking these tools on a freeway-wide basis to provide a unified management system, rather than using the tools in isolation as is currently done on Australian freeways.

To enhance the performance of Australian freeways, their management systems will need to be integrated with the management systems of the arterial road network. Only in this way can the available capacities of both networks be effectively utilised at all times.

While these tools and strategies can be used to encourage greater use of road-based public transport systems through lane priority systems, Australian road authorities need to anticipate the emerging overseas trend to total corridor management systems that integrate all urban transport modes. Corridor management will become increasingly important as travel demand consumes the remaining day-time capacity of our transport networks.

7.1 Development of agreed objectives and policies

The fact that Australian traffic managers have barely begun to embrace urban freeway traffic management, as practiced in some parts of the United States and Europe, presents a valuable opportunity to develop and introduce nationally consistent freeway management practices that best suit the Australian traffic environment.

At the outset, Australian road authorities need to agree, via the Austroads forum, on fundamental objectives associated with the introduction and operation of urban freeway management systems. This in turn will set the stage for the development of national best practice management policies, implementation guidelines and performance indicators. Of equal importance, it will provide an agreed, national framework for assessing and capitalising the outcomes of several major Australian trial projects of freeway management systems.

7.2 Trial projects

Several jurisdictions, namely Victoria and Western Australia are already proposing to introduce performance management systems on a freeway-wide basis[26]. These trial projects will provide a valuable ‘test-bed’ to assess how traffic management systems function in Australian traffic environments, and will provide a robust basis for:

- An enhanced level of Australian research into network-wide control algorithms, driver behaviour and learning in a managed environment, performance metrics for road managers and road users and a wide range of other information and control technologies.
- The development of Australian freeway management skills and resources.
- The trialling and development of advanced data collection and reporting systems and network evaluation tools.
- The development of data frameworks, management concepts, data provider linkages and software for local network intelligence systems.
- The development of protocols for control and information exchange between freeway and tollway systems.

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[26] Namely the Monash, CityLink and West Gate motorways in Melbourne and the Mitchell and Kwinana freeways in Perth.

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