MONASH-CITYLINK-WEST GATE FREEWAY UPGRADE FREEWAY MANAGEMENT SYSTEM

P. WALSH & A SOMERS
VicRoads, Australia
phillip.walsh@roads.vic.gov.au
andrew.somers@roads.vic.gov.au

ABSTRACT

The Monash–CityLink–West Gate (M1 Freeway) Upgrade is a A$1.39 billion project to improve traffic flow and safety. It is arguably Melbourne's most vital road transport corridor, incorporating sections of the Monash Freeway, CityLink, the West Gate Freeway, and sections of the Princes Freeway West. The project is being implemented in partnership with Transurban, operator of the CityLink toll road.

The M1 Freeway carries about 160,000 vehicles per day, linking major manufacturing and warehousing centres, ports, the CBD and other business activity centres, and linking communities across Melbourne and to regional Victoria.

Along the M1 Freeway, since 2002 and prior to commencement of the upgrade, there has be a 25 percent decline in daytime traffic capacity. The objectives of the M1 Upgrade were to:

- reduce peak hour travel times;
- improved travel time reliability;
- crash reductions of up to 20 per cent;
- improve freight performance and reliability; and
- reduced peak traffic on feeder roads.

The project includes a A$102 million Freeway Management System which will help maintain efficient and safe traffic operations, today and for the future transforming the M1 as one of Australia's leading examples of managed freeways. The system will manage traffic across 75 kilometres of urban freeways and includes:

- coordinated freeway ramp signals
- lane-use management signs
- a control system; and
- a dedicated communications system.

This paper will present the benefits of implementing a managed freeway to manage congestion and improve business performance/outcomes. It will focus on:

- The results of how intelligent transport systems, in particular coordinated freeway ramp signals can improve freeway performance during construction;
- The results showing increased performance of the freeway following commissioning of the freeway management system on the M1 Freeway;
- The innovations implemented to operate lane use signs within a traffic management centre in a complex road environment, with particular focus on improved response times to implement a traffic management plan;

- Improved availability rates of a freeway once suitable management technologies are installed.

Sections of the upgrade have been progressively opened since mid 2009 showing the following traffic improvements:

- travel time reductions of approximately 40 per cent and 15 percent during the PM peak and AM counter-peaks respectively;
- increased travel speeds from 50km/h to 85km/h in the PM peak, and 79km/h to 87km/h during AM counter-peak;
- average peak period traffic volumes up by 10 per cent despite overall daily traffic volumes remaining static pre and post opening.

A significant reduction in the afternoon weekday peak period is being experienced generally from four hours to less than two hours in a section.

1. INTRODUCTION

Making best use of the road network is a key objective of all road authorities. This paper outlines how VicRoads, the State Road Authority in Victoria, Australia, in partnership with key stakeholders, is achieving significant improvements on freeways (motorways). This incorporates use of advanced intelligent transport systems that align with business objectives.

VicRoads is responsible for managing Melbourne's road network which consists of over 3,400 kilometres of roads. This road network has more than 12 million vehicles trips per day. Melbourne has a population of approximately 3.8 million and is forecast to pass 5 million well before 2030.

A significant infrastructure improvement has recently been completed along sections of the Monash Freeway, CityLink, the West Gate Freeway, and sections of the Princes Freeway West. The Monash–CityLink–West Gate (M1 Freeway) Upgrade project is a A$1.39 billion investment to improve traffic flow and safety along Melbourne's most vital road transport corridor. The project has been implemented in partnership with Transurban, operator of the CityLink toll road.

Figure 1 below show key project sections, including the West Gate Freeway (orange), the CityLink Southern Link Toll Road (blue) and the Monash Freeway (yellow). These three coloured sections received civil infrastructure improvements as well as ITS; the green sections received only ITS treatments.

Figure 1 – M1 Freeway Upgrade Project Map

The M1 Freeway Upgrade aligns to key initiatives to maximise the use of the transport network, such as SmartRoads. SmartRoads is VicRoads strategy for network operations, which 'sets out an approach for managing the many competing demands for limited road space'. Partnerships with key stakeholders who make transport decision, such as those relating to freight or public transport, assist with supporting a sustainable vision for Melbourne.

The M1 Freeway carries about 160,000 vehicles per day, linking to our manufacturing and warehousing centres, ports, the CBD and other business activity centres, and linking communities across Melbourne and to regional Victoria.

The objectives of the M1 Freeway Upgrade were to:

- reduce peak hour travel times;
- improve travel time reliability;
- reduce crashes by up to 20 per cent;
- improve freight performance and reliability; and
- reduce peak traffic on feeder roads.

This paper focuses on the use of intelligent transport systems implemented as part of the M1 Freeway Upgrade. For information, the civil infrastructure upgrades can be summarised as:

- adding an additional lane on the Monash Freeway, between the CityLink tunnels and Heatherton Road;
- separating weaving and merging movements between the West Gate Bridge and the CityLink tunnels; and
- increasing the number of lanes in the peak direction on the West Gate Bridge from four lanes to five.

2. FREEWAY MANAGEMENT SYSTEM

There are multiple ways to manage congestion. Managed freeways (motorways) are evolving around the world in various forms based on local transport demands. VicRoads, similar to many road authorities, has seen a decline in the performance of freeways in urban areas, resulting in longer peak periods due to inefficient use of infrastructure and peak demand greater than the capacity provided.

The M1 Freeway has experienced similar changes in traffic patterns to other freeways in Melbourne, such as:

- Daily volumes growing around five percent per annum;
- Peak hour traffic throughput declining, with some sections as much as 25 percent; and
- Congestion (or flow breakdown) occurring at locations that are not expected.

The M1 Freeway Upgrade project included a A$102 million Freeway Management System which helps maintain efficient and safe traffic operations, today and for the future. This has transformed the M1 Freeway into one of Australia's leading examples of managed freeway. The system manages traffic across 75 kilometres of urban freeway and includes:

- coordinated freeway ramp metering at 63 interchanges;
- lane-use management signs along 18 kilometres of freeway, including on Southern Link, which forms part of the CityLink Toll Road;
- a dedicated communications system; and
- a control system to operate all devices along the M1 Freeway..

The Freeway Management Systems aims to:

- Maximise performance across the 75 kilometre;
- Maximise capacity of the existing key bridge and tunnel infrastructure;
- Improve efficiency by reducing travel times and enhancing travel time reliability;
- Improve safety; and
- Provide equitable access to the freeway for all road users.

The sections below describe key elements implemented as part of the M1 Freeway upgrade.

2.1. Coordinated Motorway Ramp Metering

The use of ramp metering has increased in Victoria since 2002 to regulate traffic flow entering the freeway network. Prior to the M1 Upgrade, ramp metering in Victoria was limited to fixed time installations at isolated locations to manage congestion at those locations. However, further analysis and research showed that coordinated ramp metering was needed to optimise the utilisation of existing infrastructure, plus provide equity of access by 'managing demand across multiple ramps on the freeway network'

As part of the M1 Freeway Upgrade 63 ramp meters have been installed across 75 kilometres of freeway, including five on Southern Link (Toll Road).

2.2. Lane Use Management/Traveller Information

Lane Use Management (LUM) provides the road operator with an ability to dynamically manage the available road space along the freeway, which can be achieved by either closing lanes and/or changing speed limits.

LUM has been installed across 18 kilometres of the freeway network including the West Gate Bridge. The LUM that has been installed on each road operator's network is linked so that operators can request changes along the entire route rather than just their own sections of the road network. This provides the road user with seamless information regardless where they are driving.

Signs integrate variable speed limits and lane control, reducing the number of signs on the network by approximately 60%. LUM is being used to:

- Make the best use of road space, and provide improved travel time and reliability by managing traffic speeds for stable flow and by reducing interruptions resulting from incidents;
- Improving safety by providing advance information to road users, which will reducing the potential for secondary incidents; and
- Provide road space for emergency service vehicles at various times of the day to attend incidents.

Figure 2 shows how LUM works in conjunction with traveller information such as Variable Message Signs (VMS) to both inform drivers and control use of the freeway.

Figure 2 – Lane Use Management (LUM) and Variable Message Sign (VMS)

2.3. Communications Network

The Freeway Management System provides extensive benefits to managing the route, including congestion and safety outcomes. To support this VicRoads has installed a robust and reliable communications system to enhance interactions with the Traffic Management Centre and other VicRoads offices.

Linking the in-field devices is a hybrid high-speed fibre optic and wireless communication system. The system has physically diverse paths and redundant connections to the Traffic Management centre.

The communications system is predominantly VicRoads (as shown in Figure 3) owned and therefore obviates the need to use public networks with their associated ongoing costs. Continuous operation of in-field devices from the control room is available as the communications system has built in redundancy.

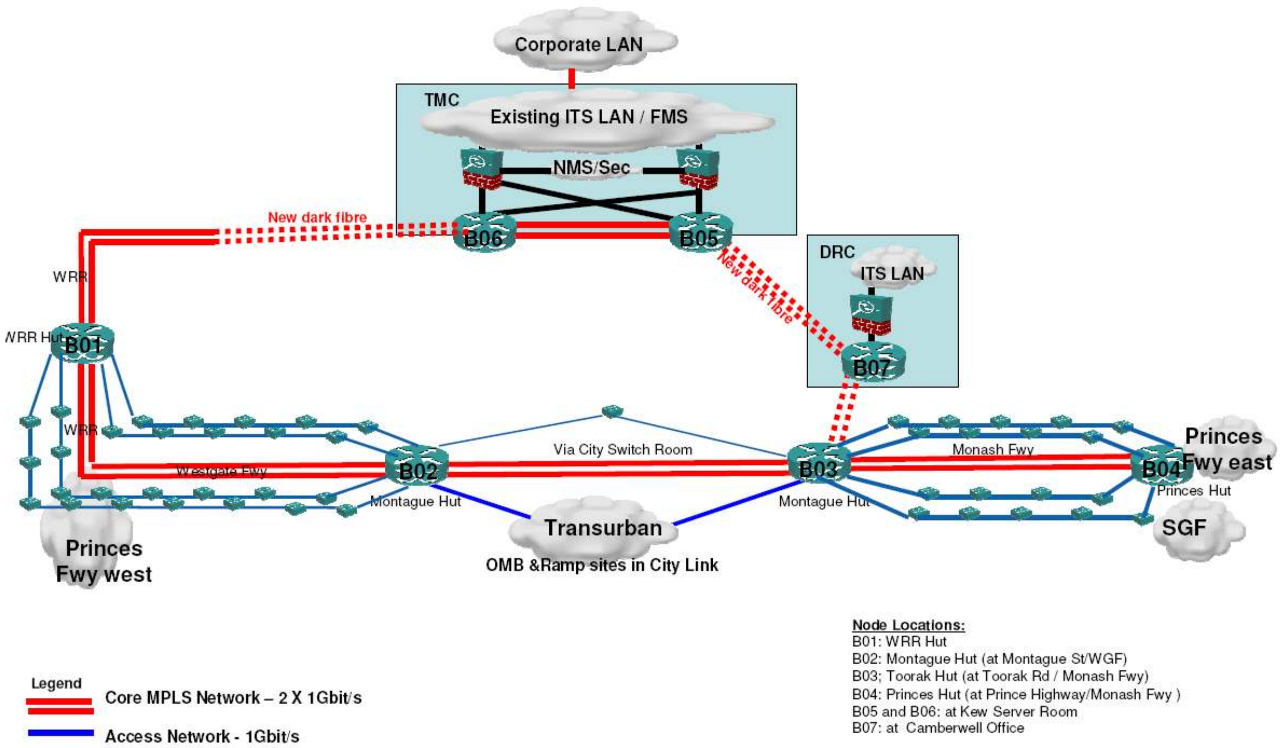

Figure 3 – Communications System, showing redundancy for high reliability performance

2.4. Control System

The control system deployed as part of the M1 Freeway Upgrade is called STREAMS, which is provided by Transmax Pty Ltd. VicRoads has previously had a disverse range of systems to manage in-field devices. STREAMS enables VicRoads to manage all in-field devices along the M1 Freeway from a single system and also provides the basis for an organisation-wide ITS platform.

New in-field devices can be added to the system easily and be available to all users within minutes.

3. INNOVATIONS

VicRoads has implemented a world class managed freeway system. Fundamental to the development of this system was a particular focus to align system requirements with the primary objective of the project. Decisions on in-field devices and their operation, the configuration of the communications network and functionality provided in the control system were all aligned to meet the project objectives.

The following sections briefly outline some of the innovations implemented as part of the M1 Freeway. The innovations vary from better use of existing technologies/deployments through to creating world-leading practice.

3.1. Coordinated Ramp Metering

VicRoads undertook an evaluation of various ramp metering algorithms used around the world. The European algorithm HERO, designed by Prof Markos Papageorgiou and Associates, was selected as the core algorithm for coordination freeway ramp metering.

VicRoads implemented and improved the world's best practice in control logic. It includes:

- Dynamic start up and shut down of ramp signals based on traffic demand;
- The ability to balance queue lengths on entry ramps, therefore providing improved equity; and
- Ability to manage available road space resulting from lane closures;

3.2. Rules-based Traffic Management

VicRoads required a smarter way of operating LUM along the M1 Freeway when compared to traditional methods for plan based traffic management, which were cumbersome and time consuming. An assessment of potential growth of the system meant that LUM may be deployed widely across the freeway network in future years, extending to more than 250 kilometres.

Preliminary investigations identified that given the complex road layout on the West Gate Freeway, hundreds or thousands of plan based responses would be required to be created and maintained simply to cover the first 18km of LUM. To mitigate the above VicRoads adopted and refined 'rules-based traffic management', which defined the requirements to operate LUM into 23 simple rules. These rules allow the control system to dynamically generate responses that cover even highly complex road layouts through interchanges and separated weaving sections. Transmax developed the engine to implement this approach and incorporated it into their STREAMS control system.

Figure 4 shows a schematic of the LUM system deployed.

3.3. Traveller Information

The use of Variable Message Signs (VMS) is commonly seen around the world to provide up-to-date information to road users. As part of the M1 Freeway variable message signs have been installed primarily at two locations to serve two complementary purposes:

- Along the main-line of the freeway, which provides re-assurance information to road users on the freeway; and
- On the main roads prior to entering the freeway, which enable road users to be informed about freeway conditions at the point where they are able to choose not to enter the freeway.

Figure 4 – Schematic of Lane Use Management Operations

Pictograms have been utilised on the variable message signs, which broadens the meaning of information being provided to road users, allows faster comprehension of complex messages and assists with language differences. Prior to the M1 Freeway Upgrade, pictograms had not commonly been used on VMS in Australia, although they are well established in practice for fixed signs.

Figure 5 illustrates the types of variable message signs deployed on the M1 Freeway. The sign on the left provides information to road users at the decision point before they are committed to entering the freeway. The sign on the right provides information to road users already on the freeway.

Figure 5 – VMS implemented on the M1 Freeway

4. NETWORK BENEFITS

The freeway management system has been progressively completed since 2008 before final completion in December 2010. As a result road users have been able to enjoy some of the network benefits, both improve travel times and greater safety.

In assessing the network benefits, particular focus has been placed on coordinated ramp metering. This analysis has been undertaken in three parts as outlined below:

- A pilot of coordinated ramp metering undertaken in 2008;
- Road opening of an additional lane and completion of the freeway management system along a 20 kilometre section of freeway undertaken in December 2009; and
- A brief review of freeway performance undertaken in January 2010.

Each section below discusses in more detail the above points. The positive outcome of the analysis clearly shows that coordinated ramp metering can provide a sustainable solution.

4.1. Pilot of Coordinated Ramp Metering

A pilot of coordinated ramp metering commenced in 2007 to determine the performance benefits which could be achieved. The pilot occurred on the Monash Freeway, between Jacksons Road and Warrigal Road, a 15 kilometre inbound section of freeway. This section of freeway has six ramp metering sites which were previously operated by a fixed time ramp metering system, which operated in the morning peak period.

During the pilot period, road works were occurring as part of the M1 Freeway Upgrade. Figure 6 shows a speed contour plot for the AM peak period, which had the original fixed time ramp metering operating. It is noted that three bottlenecks form during the peak period for a number of reasons including a large number of lane changes and downstream congestion.

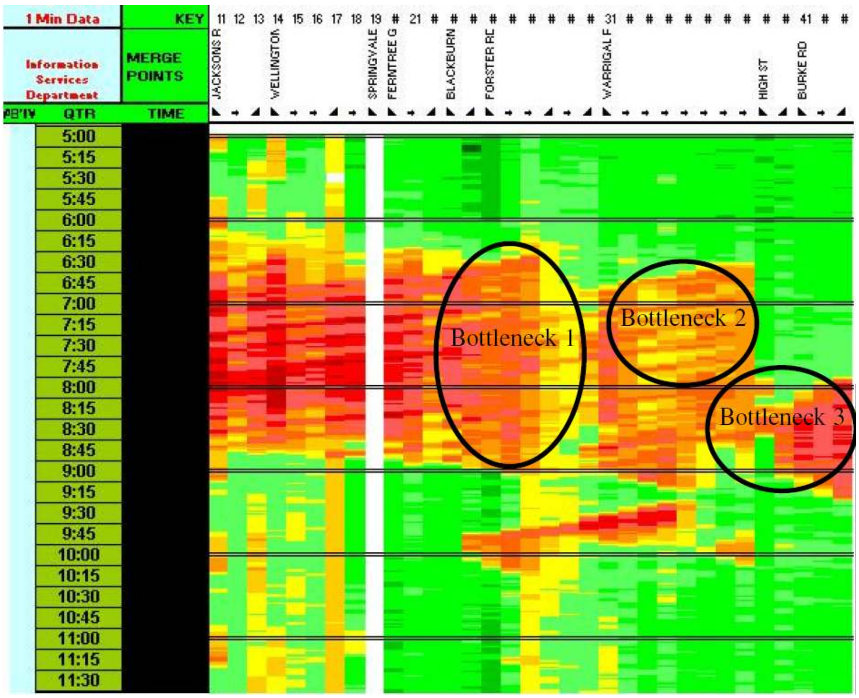

Figure 6 – AM Peak (Fixed Time) on a Typical Day

Figure 7 shows improvement in freeway performance by effectively managing Bottleneck 2, which results in increased flow and speeds in this area. It is considered that due to the small (six) number of sites being trialled, Bottleneck 3 could not be effectively managed.

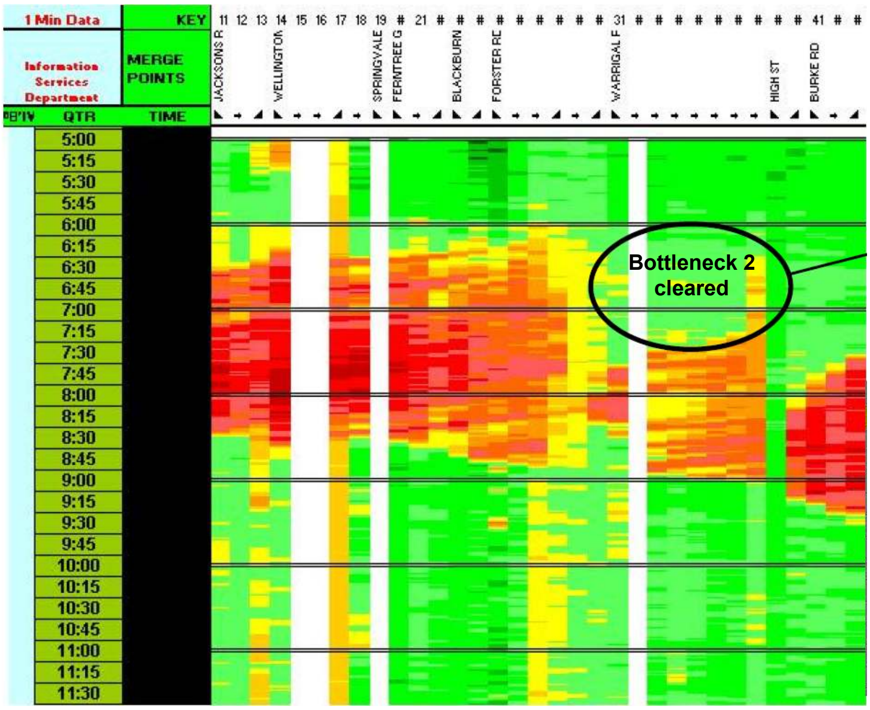

Figure 7 – AM Peak (HERO) on a Typical Day

The pilot was then extended to the afternoon peak period following further evaluation of traffic data, which showed:

- Congestion formed around 5:30pm near Blackburn Road and Forster Road entry ramps; and
- Congestion formed around 6:30pm near Warrigal Road; and

The results of the pilot showed that coordinated ramp metering aligns to the objective of the upgrade. In particular:

- Increased throughput by 5% in the AM peak and 8% in PM peak, reaching 2165 pcu/hr/lane;
- Improved travel speed by 25% in AM peak form 64.5 km/h to 80.3 km/h; and
- Improved travel speed by 59% in PM peak from 50.2 km/h to 79.6 km/h.

4.2. Findings from Initial Road Opening

As outlined in VicRoads submission to the Australian Smart Infrastructure Awards 2010, since progressively opening sections of the M1 Freeway from mid 2009, outbound traffic improvements have been recorded between Toorak Road and Jacksons Road include:

As outlined in VicRoads submission to the Australian Smart Infrastructure Awards 2010, benefits include:

- Travel time reductions of approximately 40% and 15% during the PM peak and AM counter-peak respectively;
- Increased travel speeds from 50 km/h to 85 km/h in the PM peak and 79 km/h to 87 km/h during the AM counter-peak; and

- Average peak period traffic volumes up by 10% despite the overall daily traffic volumes remaining static pre and post opening.

4.3. Measurement against Austroads National Performance Indicators

There are various measures to determine network benefits. In Australia, national performance indicators are available. Austroads is the association of Australian and New Zealand Road Authorities. Austroads first established a set of National Performance Indicators (NPIs) for the road system and road authorities in 1993. This paper uses the new NPIs for Network Operations, which are in their final stages of development.

The two NPIs used in this paper are:

- Productivity (Speed and Flow) – this indicator is based on the product of speed and flow.
- Reliability (Travel Speed) – measures the variability of speeds by calculating the coefficient of variation.

There are three further Network Operations NPIs which have not been used in this paper as they were not suitable or not required:

- Traveller Efficiency (Travel Speed)
- Traveller Efficiency (Variation from Posted Speeds)
- Traveller Efficiency (Arterial Intersection Performance)

Performance data in this section of the paper was first reported in Somers and Ramalingam (2010) and is from the month of May 2010 for the M1 Monash Freeway in Melbourne, between Wellington Road and Toorak Road, a distance of 15.5km. This is the first Australian managed freeway section for which comprehensive performance data is available, in this case from data stations approximately 500m apart.

4.4.1 *Reliability Performance Indicator*

The reliability performance measure is based on the co-efficient of variation for particular route and time of day, categorised into variability bins and aggregated across the network under assessment.

This indicator is a good measure of the level of variation between actual speeds and the average speed for that route and time of day. This average speed value aligns with reasonable road user expectations – that conditions will be similar to "normal" conditions for that route and time of day.

Table 1: Peak Period (6-10am, 3-7pm), Warrigal Rd to Toorak Rd (Inbound)

Austroads Reliability Value	Preliminary Performance Target	Measured Performance
0.2 (very low variability)	(not specified)	55%
0.4 (low variability)	80%	69%
0.6 (moderate variability)	95%	86%

Table 2: Outside Peak Period, Warrigal Rd to Toorak Rd (Inbound)

Austroads Reliability Value	Preliminary Performance Target	Measured Performance
0.2 (very low variability)	80%	96%
0.4 (low variability)	95%	99.8%
0.6 (moderate variability)	(not specified)	100%

Reliability outside peak periods (Table 2) significantly exceeds the preliminary performance target. This indicates that there is very little variation from average speeds for that route segment and time of day.

Reliability during peak periods (Table 1) falls marginally short of the preliminary performance target. This does not necessarily indicate poor performance, as it could either reflect the impact of continued roadworks on the corridor or that the preliminary target was overly optimistic.

As stated in Somers and George (2010), this initial assessment of managed freeway data is intended to assist refine the reliability performance targets as more actual performance data becomes available.

4.4.2 *Productivity Performance Indicator*

The productivity measure is the product of the speed x flow over the normalisation speed x normalisation flow. In this case we are interested in when full productivity is being achieved, and so the normalisation speed becomes the critical threshold.

The selection of 65km/h as the normalisation speed for a Managed Freeway performance target represents a convergence of freeway flow theory and road user expectations. This normalisation speed represents the lower bound of acceptable conditions – shown as green or "light" in VicRoads *DriveTime* traffic conditions displays.

The preliminary performance target has been set at 95-98% achievement of full productivity on a 24/7 basis. The M1 Monash Freeway performs favourably against this target, particularly given the impact of continuing roadworks downstream of Toorak Road.

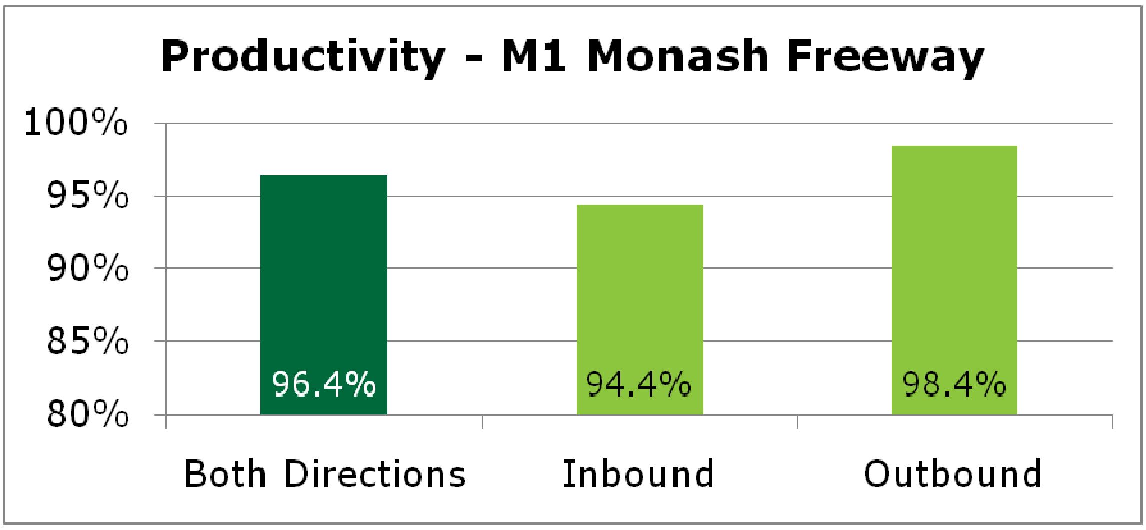

Figure 8: Productivity Performance, showing both inbound and outbound directions

The freeway has achieved 96.4% productivity for May 2010, lower for the inbound direction (94.4%) and higher for the outbound direction (98.4%). This compares favourably with the preliminary performance target of 95-98%. These preliminary results are based only on weekday data, and could be expected to rise slightly when weekend data was included.

The inbound result is affected by continued roadworks to the west, associated with finalising the fourth lane. The effect of these roadworks on performance becomes more evident when results are broken into sections (Figure 9 below). The result nearest the roadworks (High St to Toorak Rd) is considerably lower than other sections. It is noted that the impact of the roadworks cannot be isolated, and other factors may also be contributing to this lower performance.

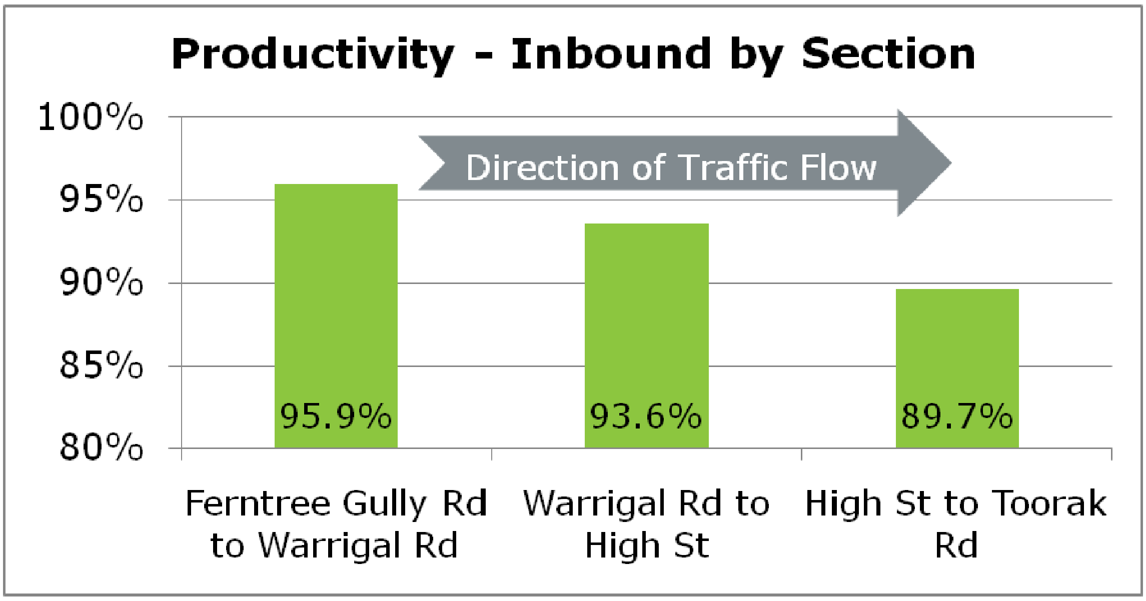

Figure 9: Inbound Productivity Performance, showing difference between sections

Analysis of the data showed that resulted differed noticeably by days. This means that the assessment of performance is dependent of the selected timeframe, at least with respect to shorter periods. Figure 10 below shows the variance in performance between four different days, selecting Tuesday as a consistent day of week.

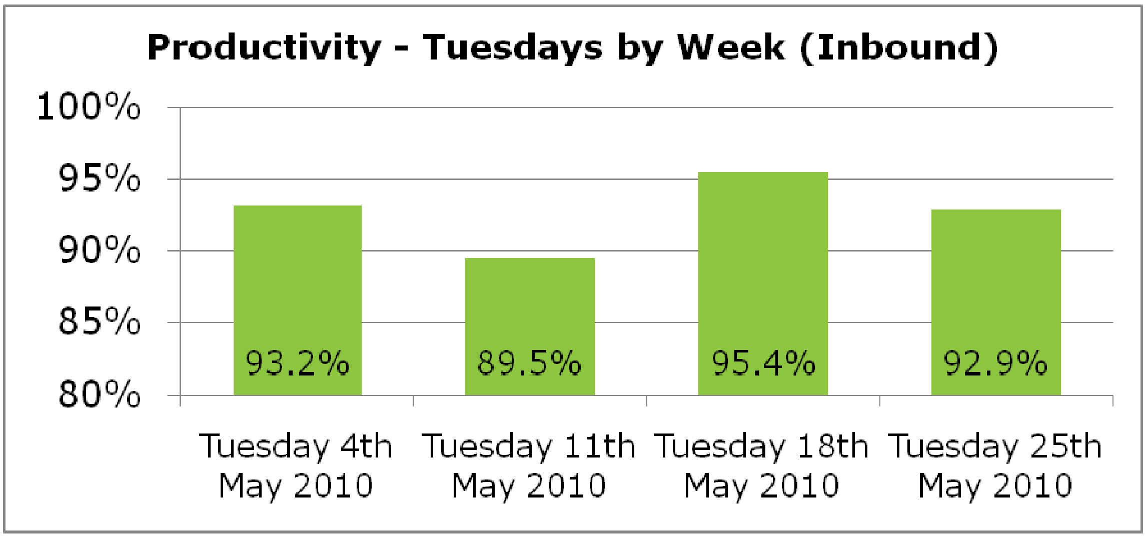

Figure 10: Inbound Productivity Performance, illustration of variation between days

5. CONCLUSION

The M1 freeway Upgrade is an exceptional example of how infrastructure and technology can be used together to maximise the performance of existing infrastructure to manage road user demand. There are further opportunities to broaden the use of technology to seek additional benefits in managing the use of available road space as well as retrofit on other freeways to achieve similar goals.

Further analysis of the work that has been done on the M1 Freeway in relation to network performance will be undertaken in 2011 to substantiate the overall network benefits. This analysis will also be able to indicate sustainable benefits that road users have experience since 2008 when the pilot for coordinated ramp metering was commenced.

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