

Managed Motorway Design Guide

Volume 2: Design Practice

Part 1: Managed Motorway – Design Principles and Warrants

October 2019



Managed Motorway Design Guide

Volume 2: Design Practice

Part 1: Managed Motorway – Design Principles and Warrants



Volume 1 - Managed Motorway - Role, Traffic Theory and Science

- Part 1 - Introduction to Managing Urban Motorways
- Part 2 - Traffic Theory Relating to Urban Motorways
- Part 3 - Motorway Capacity Guide
- Part 4 - Road Safety on Urban Motorways
- Part 5 - Linking Investment and Benefits Approach



Volume 2 - Managed Motorway Design Practice

- **Part 1 - Managed Motorway - Design Principles and Warrants**
- Part 2 - Managed Motorway - Network Optimisation Tools
- Part 3 - Motorway Planning and Design
- Part 4 - LUMS, VSL, Traveler Information (*Update Under Development*)

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Foreword

Managed Motorway Design Guide – Designing for Optimised Operations

Overview of the Guide

The Motorway Design Guide is to be used as the primary reference for planning and design of urban motorways in Victoria. The Guide includes two volumes that include a number of parts.

Best urban motorway performance outcomes can only be achieved with a holistic and multi-disciplinary understanding of traffic analysis, road design principles and traffic engineering theory. This must then be combined with accurate and reliable data, advanced control systems, Intelligent Transport Systems (ITS) and electrical and electronic devices supported by Information and Communication Technologies (ICT). These tools and disciplines are integrated to provide a single optimised system to manage motorway traffic flows (mainline, entry ramp access, exit ramps and interchanges) in near real-time, as well as speed limits, lane use and traveller information. This ensures motorway infrastructure and assets deliver their intended economic and strategic performance.

Over recent years there have been considerable advances in motorway traffic theory and operational understanding which has now been validated by empirical and statistical evidence. This has led to refinement of mainline and coordinated ramp metering analysis, design and operational principles. The Guide is the result of innovation associated with the Monash-CityLink-Westgate (M1) Project, other managed motorway projects in Melbourne, and the investigations and research of the Motorway Optimisation Team in VicRoads Road and Traffic Design Division and sharing of knowledge and valuable contributions of a number of international experts in the field.

Rather than a focus on isolated treatments to address localised problems, all elements documented in the Guide have a role to play in supporting a holistic, whole-of-network management approach. This includes route-based motorway analysis and design, as well as management of traffic across the broader arterial road network.

In summary, Managed Motorways is a holistic system approach that spans across all phases of asset management from planning to design to operations that combines:

- advanced traffic theory;
- improved and/or appropriate design standards,
- state of the art electronic devices;
- telecommunications systems and intelligent control system(s);
- utilisation of advanced statistical techniques and detailed data analysis;
- enhanced traffic operations tools; and
- a high level of specialist expertise and capabilities, within and across disciplines.

All of these elements must work together in real time to collectively enable VicRoads to provide optimal levels of service to the community. The resulting outcome is extracting significantly improved safety, efficiency and increased utility from the road infrastructure asset (the community's investment) through delivering higher sustainable flows (servicing more journeys each hour), at higher speeds (reduced delays), with significantly reduced crash risk (improved safety) and in so doing provide greater reliability of travel times (travel certainty).

Part 1: Managed Motorway – Design Principles and Warrants

This Guide supersedes VicRoads Freeway Ramp Signal Handbook and Managed Freeway Guidelines (Traffic Engineering Manual Volume 3 Part 2.03). The Guide represents the Victorian Supplement to the Austroads Guide to Smart Motorways for use within Victoria. A standardised system is essential to ensure that motorists use the road system in a safe and efficient manner. In the interests of uniformity, other Victorian road authorities are encouraged to apply the principles and requirements contained within this Guide to motorways (including privately managed facilities) under their control.

Endorsed by:

Date:

15/10/2019.



Con Stasinos

Director Road and Traffic Design

Engineering and Road Management

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1 Introduction to Managed Motorway Design

Volume 1 of the Managed Motorway Design Guide focuses on the role of motorways as well as traffic theory and science. Volume 2 of the Managed Motorway Design Guide focusses on motorway design for safe and efficient system operations. Volume 2 incorporates various aspects of planning, analysis and design as part of a comprehensive performance-based design methodology (refer to Volume 1, Part 5: Section 2 and Volume 2, Part 3). The principles and practical methodologies embrace and build on the contemporary traffic theory and operational principles contained in Volume 1 to enable application to achieve optimum urban network performance by maximising resilience and operational flexibility.

This Part outlines the principles, processes and reference documents that need to be applied to Managed Motorway design. This Part also outlines the warrants, guidelines and road agency requirements for various components of Managed Motorway (physical infrastructure and ITS devices, tools and systems) that are expected to be incorporated in new and upgraded motorway facilities across Victoria. The requirements for approvals and endorsements are outlined to ensure project scope considers and delivers the necessary elements that will allow the road operator to optimise the performance of the motorway network for many years after project completion.

The following sections summarise the key sections in this Part which contribute to the basis of the design principles and concepts in Volume 2.

- Section 2, provides an overview of the VicRoads policy and relevant guidelines and specifications and other relevant reference documents;
- Sections 3 and 4 provide an overview of the managed motorway principles and design process, outlining required considerations and expectations at each stage to adequately inform a base understanding to develop an operational design;
- Section 5 highlights the considerations, overlapping interactions and required integration of the many components within the managed motorway domain;
- Section 6 outlines the necessary project scope documentation, including endorsement and approvals to be obtained;
- Sections 7 and 8 outlines VicRoads design warrants and criteria for foundational, intervention and optimisation technologies and supporting control strategies.

The guidance is intended to inform the design development of managed motorway projects and is not intended to be an exhaustive check-list for all types of projects. The level of detail, analysis and design development will vary based on the problem needing to be solved and the project context. Regardless, project decision making needs to consider a whole of corridor/network context.

‘Planning and designing for Operations’ is the key principle behind this guideline, focussing on improving traffic flow reliability. The principle is achieved through:

- understanding network demands;
- understanding network capacity and constraints;
- considering lane balance and configuration principally relative to segment level demands;
- adopting designs that allow for future installation of Managed Motorway tools;
- adopting additional design features to support highest likely operating speed;
- adopting design features that accommodate different traffic patterns across the peak, day or week, season or traffic event (sustainable and resilient networks);
- providing sufficient queue storage where entry-ramp demand is restrained;

- providing enhanced travel information;
- affording priority to special users;
- understanding the safety, community and economic priorities for trip types, mode and access;
- developing and testing operational strategies; and
- identifying local constraints and limitations that warrant the provision of additional road space or infrastructure works.

The principles and concepts discussed in this guide are relevant to transport planners, strategic modellers, transport economists, project managers, traffic engineers, road designers and traffic managers who may be involved at any time in the overall process of bringing a motorway from conception to operational phase. It is noted that few designers will be across all aspects and stages of a project and may only be involved in discrete parts of the design process. Therefore, development of the design report and efficiency audit documentation, discussed in Section 6, is critical to assist in communicating and reporting throughout the design development process.

1.1 Justification for a Managed Motorway Approach

Motorways play a key role in the transport network providing high-capacity routes connecting people, employment, industry and other transport nodes. Urban motorways are critical road assets which are expensive to provide and maintain. They represent significant public investment to support community and economic activity.

Efficient motorways are essential in providing a safe and reliable level of service that aims to maximise the productivity of the asset and provide optimum operation in relation to throughput and travel time. Actively managed motorways achieve optimal outcomes for both road users and road managers by providing a reliable and high performance operating environment. It is important that motorways are well designed and adequately maintained. Post opening, it is essential that control systems are regularly tuned and traffic flows actively managed for the benefit of the community.

When motorway flows break down, significant losses in traffic throughput are experienced, increasing travel time and trip variability and often result in a high safety risk. These losses mean that the expected benefits on which delivery of these assets were planned, budgeted and committed were not realised. Further detailed discussion around justification and benefits realisation for investment is provided in Volume 1, Parts 1 and 5.

1.2 Managing Demands to Optimise Utilisation

Transport demand has increased over time placing more stress on critical transport assets. When the demands regularly result in a motorway exceeding its carrying capacity this will result in flow breakdown and congestion reducing productivity ($\text{Flow} \times \text{Speed}$) by as much as 50%, which occurs typically on many urban motorways for increasingly longer periods of the day, along with an increasing number of fatal and serious casualty crashes (refer Volume 1, Part 4: Section 4). Historically, the lack of control on urban motorways allows recurrent flow breakdown to occur. When demands exceed capacity (temporal – sub one-minute flows) they must be managed to provide the best safety and economic outcomes for the community.

Melbourne's motorway network comprises interconnected motorway routes with some sections managed by private road operators. Getting the best performance outcomes for road users from this network requires decisions to be made at the network level so that the actions of individual operators work to achieve network outcomes (VicRoads, 2016).

In 2016, the Metropolitan Melbourne motorway network represented 7% of the urban arterial road lane kilometres yet carried approximately 40% of the urban arterial road travel measured in vehicle

kilometres travelled (VKT). Reliance on the motorway network to provide arterial road travel is trending upwards, with a 50% share likely in the near future.

The shift in road use and increase in overall demand has extended peak periods on all arterial roads, especially urban motorways. Periods between the traditional morning and afternoon peaks are now heavily trafficked (refer to Figure 1-1) and various locations within the road network now experience peak period type demands, variable congestion and reduced performance throughout the day. This is especially true on some urban motorway corridors in Melbourne where more than 50,000 trips per hour are serviced all day reaching 60,000 veh/hr in peak periods. As shown in Figure 1-1 the daily number of trips on this day as measured by the sum of entering flows is more than 900,000 trips.

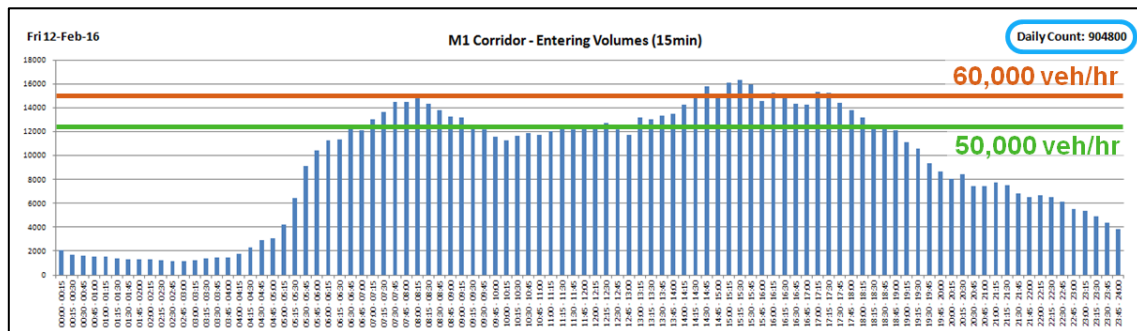


Figure 1-1: Total System Flows Entering the M1 corridor over 24 Hours – 15min Periods

1.3 Managing Bottlenecks and Flow Breakdown

MMDG Volume 1, Parts 1 and 2 extensively discuss the traffic science and complexities related to “uninterrupted flow”. Motorways generally break down based on the mix of micro traffic conditions encountered at the sub one-minute level of traffic flow (e.g. point densities, lane changing and vehicle mix etc) with different micro conditions occurring every day. These triggers may occur anywhere and at any time in the motorway network. These conditions may not be restricted to bottleneck locations, although these locations are often where congestion settles and symptoms become more evident.

The conditions for triggers of flow breakdown can now be understood (stochastically) and determined statistically for every location in the motorway system (refer to Volume 1, Part 3). In the absence of advanced system wide demand management control systems, it is not possible to adequately control the traffic flow towards bottlenecks to manage the micro-conditions that lead to the majority of flow breakdown events, which typically reduce the motorway productivity (Flow x Speed) by 40-50%.

It may not have been as necessary to manage traffic demands 20 to 40 years ago as the majority of flow break down events were caused by incidents. Road Authorities invested heavily in Traffic Management Centres primarily focussed on incident management functions. However, over the past 20 years or so, most congestion (as discussed in Volume 1, Part 2) is related to excess demand resulting in long delays, unreliable travel and low traffic throughput which in turn leads to increased numbers of incidents and casualty crashes (refer Volume 1 Part 4). As has been learnt many times throughout industrial history when any system reaches its capacity it must be redesigned and managed within certain limits to ensure efficiency (minimise waste and delays) and maximum productivity (output). Urban motorway networks are no different.

1.3.1 Bottlenecks

The critical bottleneck is the segment which governs the capacity of the motorway system, i.e. the “weakest link” along the route. The operating condition at the critical bottleneck segment controls the capacity and performance of significant proportions of a route. Figure 1-2 shows a typical motorway system with various bottlenecks at entry ramp merges. Often there can be multiple bottlenecks in close proximity of varying strengths, not all necessarily critical, impacting traffic flow.

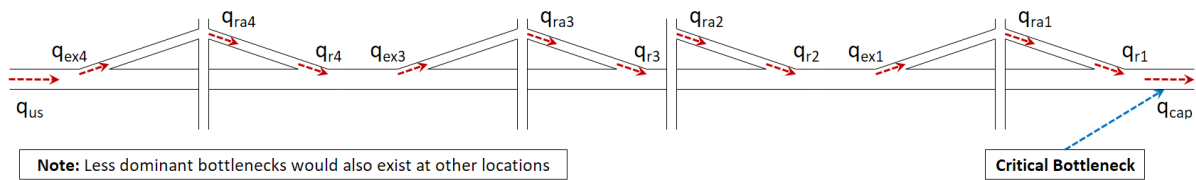


Figure 1-2: Example of a critical bottleneck on a motorway

Causes of critical bottlenecks may not be simply a physical change in cross section or a ramp merge location but may be due to a variety of different geometric or operating conditions, and often a changing mixture of many factors over time. (Refer Volume 1, Part 3: Tables 1-2 and 1-3) It is not possible to build a system with perfectly balanced supply relative to demand since traffic demands and associated patterns can be highly variable across space and time (including within sub-1-hour periods).

Volume 2, Part 3: Section 4 provides guidance on identifying and evaluating these critical bottleneck locations. Focus on these areas ensures higher sustainable flows are achieved across motorway networks for extended time periods.

The likelihood of flow breakdown can be significantly reduced, as well as earlier and faster flow recovery, by focussing on critical bottleneck locations during design, of both the physical infrastructure and control system features. Critical bottlenecks as discussed in Volume 1, Part 2: Sections 2 and 3, are predictable during the design process.

Flow breakdown may also occur on a managed motorway with an inadequate control system lacking application of contemporary traffic science, with an un-tuned motorway control system or when there are traffic incidents or other events.

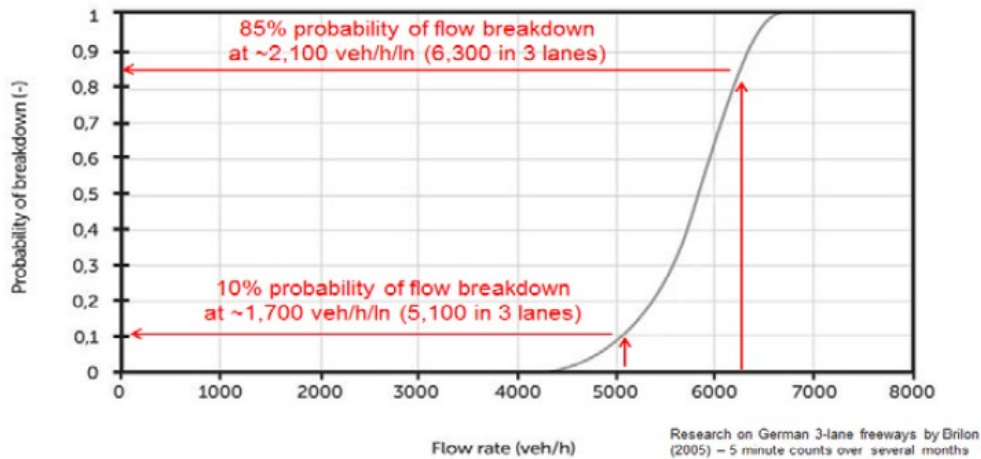
The consequences of regular breakdown and congestion not only affects the localised area at a single point (generally the 'weakest links' in the design – refer Figure 1-2), but the system losses (flow, speed, safety and productivity) upstream, downstream and on the connected broader road network are also significant. Refer Volume 1, Part 1: Section 3, and the scale of system losses in Volume 1, Part 2: Section 3). With the right suite of tools and appropriate, regular tuning, higher average speeds and flows can maintained even under high demands or with mild congestion.

VicRoads holistic approach to motorway design and management means that flow breakdown and congestion can be minimised or avoided and better managed, even in the event of an incident.

1.3.2 Stochastic Nature of Flow Breakdown

Motorways may still breakdown after control systems are installed or bottlenecks are treated with physical changes. This can be due to the stochastic nature of traffic and the inevitable presence of lower capacity points (i.e. "weakest links") in any system. That is the probability of flow breakdown due to partially random nature of traffic demand as well as variability in capacity (refer to Volume 1, Part 2: Section 5). This is especially evident where unusual outlier traffic conditions occur.

Figure 1-3 shows that a flow of 1,700 veh/h/ln on a 3 lane unmetred motorway in Germany has a 10% probability of flow break down over a 5 minute interval, whereas 2,100 veh/h/ln has a very high (85%) chance of breakdown. It is also noted that these values are significantly less than values which have typically been used in modelling and capacity analysis design. As a result, VicRoads adopts design volumes in the Motorway Capacity Guide (Volume 1, Part 3 of this Guide) for use in Victoria which provides the Maximum Sustainable Flow Value rather than a higher measured but unsustainable value.



Source: based on (Brilon, Geistefeldt, & Regler, July 2005)

Figure 1-3: Probability or Risk of Flow Breakdown

1.4 Sustainable Network Management

The active management of urban motorways requires a commitment to ongoing operational efforts to manage and optimise the performance of the motorway. These operational efforts are central to sustaining and building upon the benefits achieved through the application of managed motorway tools.

Integrated network management and coordination at the network level, not just locally or project based, needs to include information to travellers, interventions to change network characteristics, optimisation of traffic flow and the management of demands across the network.

An actively managed motorway may incorporate a number of traffic management tools to provide a range of benefits. These may include:

- City Wide Coordinated Ramp Metering (CWCRM);
- Exit Ramp Management (ERM);
- Congestion management;
- Traveller information including travel time;
- Incident detection and management;
- Lane Use Management (LUMS);
- Dynamic Variable Speed Limits (DVSL).

Not every motorway needs to have every component of managed motorways, for instance lane use management may not be required on some sections of motorway in the short and medium term. There are many dependencies between managed motorway ITS tools, particularly with regards to a common real-time data source and its availability, which are set out in the relevant sections of this document. The availability of accurate real time data is the essential foundation to any form of managed motorway development.

The provision of field infrastructure for managed motorways needs to prioritise management tools to locations where most needed. For existing motorways, it is recognised that the addition of management tools is constrained by available funding. Prioritisation of rollout of the field infrastructure should be based on maximising the return on available funding.

Sustainable asset management is essential for the ongoing success of a managed motorway. In specifying assets and their installation, whole of life costs need to be considered in both financial and

economic (road user impacts) dimensions. Whole-of-life costs need to include resourcing for tuning of control systems, traffic operations and asset maintenance. This must include tuning of control systems, traffic operations resourcing and maintenance. Occupational Health and Safety also needs to be considered as part of the design of a safe workplace for maintenance staff.

Project costs associated with managed motorways must include resourcing, and ongoing operational and maintenance costs for the life of the infrastructure.

2 VicRoads Policy and Guidelines

Project for new or upgraded projects shall incorporate managed motorway tools as set out in VicRoads Managed Freeway policy (2014) and VicRoads Guidelines (outlined in this document). The policy and supporting guidelines set out the minimum requirements for consideration in the scope development and approval process. Sections 7 and 8 provides guidance of minimum requirements for control and optimisation tools relative to Maximum Sustainable Flow Rate (MSFR). Table 7.1 also provides guidance for additional ITS management tools, systems and devices that are to be considered for implementation. These are categorised under control, foundation and support.

Where the ITS device, system or tools requirements in the policy and these guidelines differ, the most recent document shall take precedence.

VicRoads requires adherence to design approval and governance requirements for managed motorway schemes due to the potential large network impacts, high cost and high risk associated with motorway infrastructure, technology and control and monitoring systems. These are outlined within this Part and relevant detailed sections with Volume 2, Part 3.

The various documents discussed below describe the guidance and practice for Managed Motorway applications in Victoria. The order of the documents discussed below does not imply any specific order of document hierarchy.

2.1.1 VicRoads Managed Freeways Policy

The Managed Freeway Policy sets out the policy position that new freeway projects (including upgrade projects) shall incorporate managed freeway tools and that additional management tools will be implemented on existing freeways on a prioritised basis as funding allows. The minimum scope requirements in the Managed Freeway Policy cover the main control and information tools described throughout this Guide including but not limited to LUMS, VSL, coordinated ramp metering, exit ramp management and traveller information.

2.1.2 Transport for Victoria (TfV) Policy – Operational Control of the Motorway Network

Melbourne's motorway network connects key freight gateways and centres, and links major residential and lower density employment areas. Motorways are part of an interlinked network that includes arterial roads and need to be managed as such. People's journeys occur in spite of operational boundaries, road classification or asset ownership. Therefore, managing the network as one network is necessary by a single operator under the principles and objectives of the TIA without commercial influence on operations.

It needs to be recognised that there are multiple road operators acting across the broader Melbourne Motorways network. The operational control and management of motorways amongst a number of private road operators and VicRoads needs to enable optimum performance and utilisation of the motorway network as part of the overall transport network.

The operational control policy recognises VicRoads as the overall Network Operator with the responsibility to optimally manage the network, principally utilising ramp metering, lane control and variable speed limits, under both normal and emergency conditions. This has some implications on the design, provision, connection and control of various managed motorway systems and devices used for control and optimisation.

Operating the network in this way is the optimal approach to achieving the objectives set out in the Transport Integration Act 2010 (TIA) and the Network Development Strategy, particularly with respect to ensuring that the network operates efficiently, and that best use is made of existing and new assets. Road users (including those who pay tolls), and the community in general, expect that the motorway network will be optimally managed to ensure efficient and reliable travel.

2.1.3 VicRoads Managed Motorways Framework

The Managed Motorways Framework includes operational principles and technical requirements for devices and systems to enable the active management of Victoria's motorway network along with the supporting rationale and evidence.

The Managed Motorways Framework establishes that the Victorian active management approach is:

- Outcomes-driven, with operational success measured by network performance outcomes;
- Focussed on improving operational connectivity between motorway routes and the arterial road network, as well as between multiple road operators, to maximise productive use of the asset at all times;
- Based on the understanding that technology is an enabler, but it is the operation and optimisation of multiple control tools and technologies working together that creates the benefits;
- Moving towards an ultimate goal of multi-modal network optimisation and journey management; and
- Adopting a safe system approach to the design and management of motorways to reduce the incidence and severity of crashes.

The Managed Motorways Framework also introduces the concept of multiple concurrent types of control of the motorway network:

- **Traffic management and control interventions** – discrete traffic control actions on the road network that are initiated in response to incidents, congestion and planned network activities;
- **Route optimisation** – continuous and automated fine-level adjustments to dynamic algorithms that tune performance of a route towards a defined objective target; and
- **Multi-modal network optimisation with journey management** – Simultaneous optimisation across network links and different user groups to achieve a 'one network' optimum that also optimises user journeys.

These multiple concurrent types of control include ramp metering control to manage density and actions on LUMS signs to change lane availability and/or adjust speed limits. The overlap of concurrent control actions is a key driver of the complexity this Guide seeks to address. There is always the potential for some control actions to work against each other and result in sub-optimal or unsafe outcomes (e.g. changing speed limits and/or closing and opening lanes also change traffic densities and influence optimum targets in real time).

In addition to control actions, the Managed Motorways Framework includes the active management element of *traveller information* as the provision of information to road users on motorway travel times and conditions that can support their travel choices on the motorway and even before they reach it, thereby also helping road operators to manage demand to the motorway network particularly during incidents and congestion. The use of traveller information to support the control actions means that this is also an area of competing demands.

The Managed Motorways Framework also includes *network monitoring and intelligence* as the essential foundation of active management. This element includes the collection of data on network conditions and issues that is used to trigger traffic control interventions, provide critical inputs for dynamic optimisation control algorithms and support calculations of travel times for traveller information, as well as support network performance reporting. The *network monitoring and intelligence* needs to provide data that satisfies the needs to each of the other layers (multi-modal network optimisation with journey management, route optimisation, traffic management and control interventions and traveller information).

2.1.4 VicRoads Managed Motorways Design Guide

The Managed Motorway Design Guide (MMDG) supersedes and incorporates various pre-existing VicRoads guides and handbooks in to a suite of volumes and parts. The following sections refer to parts of the MMDG that provide design direction and guidance which replace previous VicRoads publications.

MMDG Volume 2, Part 1: Managed Motorway – Design Principles and Warrants (*this document*)

This Part of the MMDG supersedes the VicRoads Managed Freeway Guidelines (VicRoads, 2014) with updates to the information for the selection of treatments and devices on motorways. Further guidance and information is provided regarding the principles and design processes that apply to developing motorway enhancement and upgrade projects.

This Part supports the VicRoads Managed Freeways Policy (VicRoads, 2014).

MMDG Volume 2, Part 2: Managed Motorway – Network Optimisation Tools

MMDG Volume 2, Part 3: Motorway Planning and Design

These two parts of the MMDG supersede the Freeway Ramp Signal Handbook (VicRoads, 2013).

Part 2 provides an overview of the coordinated ramp metering system as the principal network optimisation tool used to optimise motorway performance and safety. Other operational tools and principles for managing motorway conditions are also outlined and support planning and design application in Part 3

Part 3 provides planning and design information for motorway configuration and design (for carriageways and interchanges) with the aim of operating urban motorways in an optimised and fully integrated manner. Aspects for the application of the primary optimisation control tool, freeway ramp signals, are covered for both surface road entry ramps (service interchanges) and motorway to motorway connections (system interchanges). Management of exit ramps and arterial road interface consideration are included. The integration and design of other supporting tools for managing motorway performance are also outlined. As the operation of ramp signals includes some supporting actions for traveller information, LUMS and VSL, Part 3 is the source guide for this approach.

VicRoads Managed Freeways Handbook (for LUMS, VSL, TI)

The Managed Freeway Handbook for Lane Use Management, Variable Speed Limits and Traveller Information (LUMS/VSL/TI Handbook) (VicRoads, 2013) is VicRoads' primary reference for planning, designing and operating lane use and incident management, variable speed limits and traveller information tools on motorways. (A planned update will see the handbook incorporated into the MMDG suite of guidance as Volume 2, Part 4).

At the time of publishing of this document, the LUMS/VSL/TI Handbook is Part 24 of Volume 3 of the Traffic Engineering Manual. The LUMS/VSL/TI Handbook provides principles and standards for:

- lane use and incident management;
- variable speed limits; and
- traveller information tools.

The LUMS/VSL/TI Handbook is the primary reference for VicRoads LUMS Rules and roadside traveller information tools such as VMS.

MMDG Volume 1, Part 3: Motorway Capacity Guide

Volume 1, Part 3: Motorway Capacity Guide (MCG) replaces the previously published VicRoads Motorway Design Volume Guide (VicRoads, 2017) and provides guidance on the Maximum

Sustainable Flow Rates for motorways within large metropolitan cities with very high traffic demands spread over extended peak periods which usually lead to regular occurrence of congestion. These rates should be used as design volumes for future motorway projects.

The MCG includes discussion of the stochastic nature of motorway traffic flow and how this translates into probabilistic assessments of capacity for carriageways of varying lane numbers with relevant adjustment factors for other influences. This combination explains why the incorporation of ongoing dynamic management of the motorway is so valuable and that this value continues into times where roadworks and incidents are active. The combination of management through interventions (lane closures, safe speeds at incidents) and dynamic optimisation contributes much to the complexity that this report seeks to navigate but also much to the benefits achievable by Managed Motorways.

It is demonstrated that the capacity benefits exhibited within the MCG lead also to safety, journey time and reliability benefits. While the results shown include only one approach to dynamic optimisation being active coordinated ramp metering, it helps to explain how the extension to integrate dynamic variable speed limits for optimisation can deliver real benefits to Victorian motorway users and the broader community.

2.1.5 VicRoads ITS Specifications, Drawings and Guidelines

VicRoads publishes specifications, standard drawings and guidance for the provision and delivery of ITS devices in the field, many which support the Managed Motorway design and operations. The specifications, drawings and guidelines available on VicRoads website are to be read in conjunction with the Managed Motorway Design Guide and policy.

2.1.6 VicRoads Traffic Engineering Manual

The Traffic Engineering Manual has been issued by VicRoads to provide guidance for the best practice of traffic engineering in Victoria. It supplements the guidance provided by the Austroads 'Guide to Traffic Management' series of publications and various Australian Standards.

Volume 1 is the Supplement to Austroads Guide to Traffic Management, Volume 2 is the supplement to Australian Standards relating to traffic management e.g. signs, markings and delineation and Volume 3 covers additional standards and guidelines. The manuals can be found on the VicRoads website.

Practitioners throughout Victoria must ensure that the procedural and regulatory requirements are followed. VicRoads requires that traffic engineering treatments on declared freeways and arterial roads in Victoria comply with these guidelines wherever practicable.

Practitioners should only consider departures from the guidelines in special circumstances where they can be justified on the basis of good engineering principles and risk assessment.

2.1.7 Australian Standards, Austroads Guide and Supplements

VicRoads uses as key references the Austroads Guides and Australian Standards for road and traffic design and the provision of supporting infrastructure to ensure national consistency and standardisation for road work. These are used in conjunction with supplementary information developed and maintained by VicRoads.

Where supplementary information is provided by VicRoads, its application takes precedence over the information in the Austroads guides.

VicRoads' supplementary information for the Austroads Guide to Road Design is provided in standalone documents corresponding to the various Austroads guides and are available on the VicRoads website. The VicRoads Traffic Engineering Manual (Parts 1-2) provide combined supplementary information with parts corresponding to various parts of the Austroads guide to Traffic Management and relevant Australian Standards.

The VicRoads Managed Motorway Design Guide suite, as outlined above, form supplementary information to the Austroads Guide to Smart Motorways and is to be used as the primary reference for Managed Motorway design and operations in Victoria.

3 Design Principles for Managed Motorways

3.1 Context Sensitive Design

Good road and traffic design and operational management is more than just the application of engineering knowledge and principles. It must also consider the context that influences the design, construction and operation of a road. When developing design solutions, there are generally no off-the-shelf solutions that fully address all situations. Every location is unique. Well-founded design criteria must be determined for each location. The *context* of the particular project is of great significance in determining these parameters and a Context Sensitive Design (CSD) approach provides a robust method for determining the suitability of design criteria.

Any guideline must be applied only after careful analysis of what has to be designed. Its recommendations should be considered in conjunction with engineering judgement across multiple disciplines and common sense based on knowledge and experience. Those involved in making decisions during design and project scope development must exercise critical engineering judgement to ensure that context is appropriately considered in optimising design solutions for safe and efficient operations.

Many competing priorities and objectives can arise during the design of a project. Ideally, the design outcome should sufficiently address all these priorities and objectives. However, the transportation network in Victoria is complex and often requires difficult decisions to be made (usually because of limited space and/or limited budgets).

Any solution should be one that balances safety, mobility, reliability, community acceptance, stakeholder acceptance, project and maintenance costs, and aesthetic, historical, environmental and other community values. The greatest challenges and opportunities in designing a transportation solution that balances those values occur early in the design process, during project planning and the development of design alternatives (ASSHTO, September 2018).

3.2 Context Sensitive Managed Motorway Design Principles

VicRoads adopts a transparent, principles-based approach to decision-making. This approach encourages independent designs tailored to particular situations and in compliance with reasonable engineering principles.

Project officers should adopt a holistic approach in applying discretionary principles, seeking technical advice from designers across disciplines where appropriate. Safety performance must always be considered as a primary principle.

3.2.1 Road Safety Principle

The risk of death or serious injury is directly related to the likelihood of a crash and the severity of the forces vehicle occupants are subjected to during a crash. The level of this risk needs to be carefully considered when proposing a design that adopts minimum design criteria. Such consideration must take into account the speed environment, the road environment (such as the existing substantive safety, traffic composition, road facility type, geometry, roadside characteristics, etc.) and the likely success of mitigation options.

Ensuring the safety of users on the motorways is the highest principle and is complemented through the timely and effective implementation of the managed motorway tools and control as per the warrants specified in Sections 7 and 8. Evidence shows that many crashes occur at the onset and in the presence of congestion and so geometric design, consideration of driver capability/behaviours, and tools relating to reducing congestion and providing management of flows can significantly improve safety outcomes. Road Safety Audits, Safe System Assessments and Operational Efficiency

Audits should be undertaken by experts with high understanding of urban motorway contexts at all relevant stages of project planning, design and delivery.

Designing for safer operation (through planning, analysis, design and operation)

See Section 3.3 for further discussion on optimising design for efficient operations.

See Section 3.4 for further discussion regarding human behaviours and driver capability.

3.2.2 Road Network Efficiency Principle

In line with VicRoads' *Movement and Place* framework, designs should have no adverse effects on the efficiency of vehicle movement on roads designated as significant traffic or freight routes. Transport network decisions should be aligned with land-use decisions so that transport infrastructure will meet the accessibility and operational needs of all transport modes and vehicle classes in both the present and the future. Consideration should be given to vulnerable road users and also those who may not directly use the road but whose transportation needs may be influenced by the proposed works.

Motorways are to be designed with integrated physical design and operational control with an understanding of traffic conditions and the impacts of congested flow in high demand urban areas. Managed Motorways is more than the widespread deployment of ITS tools in the road side and requires physical design that targets the reduction of turbulence that can trigger flow breakdown. Integrated ITS tools and control systems need to be designed, provisioned and operated to effectively target the complex operational problems encountered within urban motorways in real-time. To achieve network efficiency, urban motorway solutions require a network operations understanding and approach which usually requires physical and ITS system implementation beyond the areas that may be immediately impacted by impacts of congestion (i.e. control and intervention tools and associated infrastructure are usually required well beyond the extents of the physical capacity upgrades).

Maximising the productivity and reliability of motorways

See Section 3.3 for further discussion on optimising design for efficient operations.

3.2.3 Community Wellbeing Principle

The goal of this principle is to ensure that transport infrastructure supports healthy liveable communities, provides high-quality roadside amenity and accommodates active travel (that is, travel that involves physical activity, such as walking and cycling). It is necessary to gain broad stakeholder and community acceptance of road designs, particularly at interfaces with the arterial road network and impacts along and across the corridor.

Ensure motorway operations are managed as a system to achieve best overall outcomes for the entire road network balancing social, safety, economic, environmental and land use integration objectives over decades. The motorway should facilitate the achievement of equity between persons irrespective of their personal attributes, financial situations, or location and should achieve equity between generations by not compromising the ability of future generations to meet their needs. Efficient and safe motorway operations enhance long-term liveability outcomes and facilitates broad and ever changing trip purposes in support of the community.

Facilitate the achievement of community equity and integrity of motorway objectives

3.2.4 Environmental Sustainability Principle

The goal of this principle is to minimise the transport system's adverse effects on the environment, and to improve the environment where appropriate. This can be achieved by protecting the natural environment – in particular the flora and fauna – and by enhancing the aesthetics of roadside amenities.

This principle extends to respecting and preserving cultural heritage values and assets, both Indigenous and non-Indigenous.

Provide a more efficient transport system that facilitates economic growth and development, reduces environmental impacts and protects biodiversity and ecosystem functions. The legacy of the decisions we make today and the transport corridors we construct tomorrow will be with us for many years to come. (van der Ree, Smith, & Grilo, 2015)

Mitigate environmental impacts and protect biodiversity

3.2.5 Utility Services Principle

This principle ensures that road reserves can accommodate other appropriate uses – such as utility services – without adversely affecting road safety. Works should not make the roadside environment any less safe than it currently is (and provide appropriate mitigation if necessary). Consideration should also be given to providing easy access and a safe workplace for utility maintenance work.

The transport system will continually evolve and so will the range of required ITS devices, tools and supporting systems to be provided in road reserves. It is important that the utility services along and across the road reserve can be used for multiple future end uses and are able to be maintained safely by personnel with minimal disruption to traffic function whilst being secure from damage and unauthorised access. Utility services must be designed and located such that when likely future motorway upgrades take place they can remain operational during construction requiring minimal relocation and disruption to transport and utility services. This requires an appreciation of highly likely future motorway upgrades within the road reserve.

Ensure appropriate utility services can be deployed in the road reserve that provide reliable and resilient services with minimal impact on road function and future upgrades

3.2.6 Investment Benefit Principle

This principle prescribes that each proposed design element, and its alternatives, be objectively reviewed to establish whether the associated capital expenditure represents the best use of community resources. Not only must the initial development costs and costs of any risk mitigation be considered, but also the whole-of-life costs (such as operation and maintenance costs).

Urban motorways contribute significantly to Victoria's overall transport task, facilitating the efficient movement of goods and services, reducing transport costs and improving timeliness and accessibility. Urban motorways facilitate more than just commuters travelling to and from employment. Within the road network, motorways provide the backbone for high-value activities such as regional and suburban freight accessing ports and distribution centres fostering competition by providing access to markets. Construction activity supporting investment, tourism and services to the community are examples of the important functions that rely on safe and efficient motorway operations.

Project planners must also ensure that current proposals align with long-term network plans (well beyond 20-30 year horizons) so as to avoid redundant works in the future. This also needs to ensure that expected future enhancements are not prohibited from being provided. When future enhancements are provided, cost implications of modification should not be prohibitive and works should limit the extent of redundant assets. While projects are typically designed to suit a future forecast design year, designers need to be cognisant that motorway assets continue to operate long after such planning horizons pass. Historically, many urban motorways have reached capacity well in advance of their predicted operational design life and serious consideration should be given to early investment in highly likely ultimate arrangements and avoid costly and disruptive upgrade transitions.

Government undertakes investments to create the environment that encourages long-term economic growth and investment that deliver ongoing outcomes and benefits for business and workers.

Ongoing reliable performance of the motorway and broader road network facilitates financial sustainability for Victorian businesses.

Effective Managed Motorway operation and control to facilitate economic prosperity and realise measurable benefits.

3.3 Principles for optimising design for safe and efficient operations

Optimising motorway designs and operation is not just adding ITS field devices. The whole motorway needs to be integrated and designed to enable it to be managed efficiently as a system. Providing the appropriate combination of design and ITS tool deployments are essential to provide the needed flexibility for operational regimes (maintenance and tuning) so that road agencies can lock-in-the-benefits of motorway projects. Figure 2-1 shows the project lifecycle. The greatest opportunities to realise these benefits in operations occurs early in the design process during planning and the development of design solution alternatives.

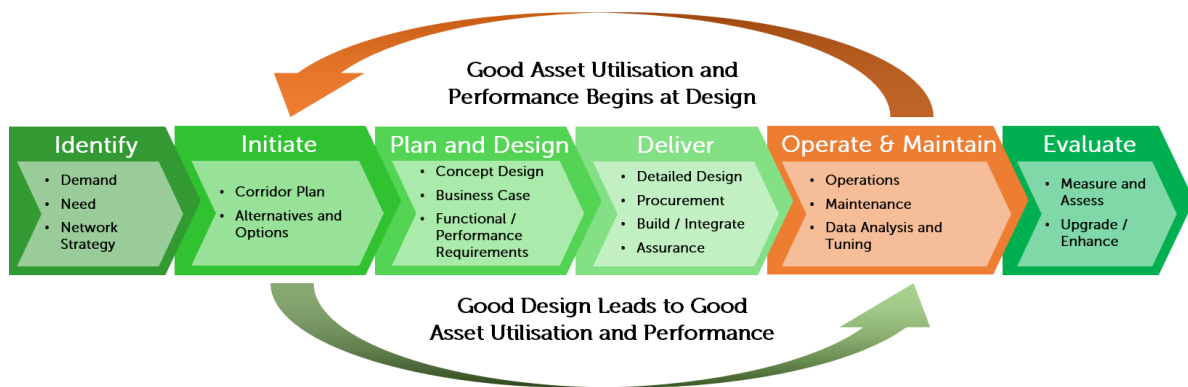


Figure 3-1 Designing for asset utilisation and performance

The interdisciplinary field of systems engineering (refer to Volume 1, Part 1: Section 2.5) focuses on how to design and manage a complex system over its life cycle and is useful for managing risk in technology-based systems. The approach is particularly useful in relation to collaboration between technical specialists in different fields and achieving performance-based outcomes through the life of the project.

A motorway can be designed and built within a few years, however it must provide safe and efficient operation every day for many years. New motorways or motorway upgrades may be a staging of ultimate longer-term designs. Consistency of design needs to ensure that they can be managed effectively, with attention given to transitioning traffic from upgraded higher capacity sections to sections with lower capacity.

Designers must consider how carriageways and lanes are arranged as well as specific potential operational bottlenecks before adding more lanes or ITS devices. Designing for flexible, resilient operations is an important component of sustainable systems. That is, those that have the ability to perform under stress and absorb a “shock”, as well as the ability to recover in the event of failure (refer Volume 1, Part 2: Section 3.4).

Motorway design may need to take system factors into account, e.g. design of the infrastructure is closely related to the traffic system, particularly in relation to vehicle detector locations, to suit control software and operations.

The monitored and optimised network provisions and approach is also the forerunner to support the next generation of connected and automated vehicles as these will need to be organised to optimise

networks if higher efficiencies from the road network are to be delivered (refer surface road access management in Volume 2, Part 3: Section 8).

3.3.1 Guiding Principles for Safer Motorway Design

Designing and operating the motorway to avoid crashes is the highest objective. Traffic safety is paramount in motorway operations as crashes not only impact people's lives but also the operational efficiency of the infrastructure. If a crash does occur this increases the risk of a secondary crash, and also impacts motorway operations until the roadway is clear again.

VicRoads research and principles for motorway design, operation and management seek to provide an understanding of the relationships between various “Traffic States” and crash risks (refer Volume 1, Part 4.). Volume 1, Part 2 of this Guide provides detailed background and examination of motorway traffic flow dynamics including mechanisms that lead to flow break down. To achieve best outcomes both in terms of traffic safety and traffic efficiency, all components need to be and can be optimised.

The safe operation of motorways has traditionally been based on the highest safety design standards and principles as well as construction practices. These generally relate to geometry (horizontal and vertical alignment), cross section (including lane widths and shoulders), merging and diverging distances, sight distance, pavement skid resistance, signage and pavement markings, clearance to and protection of roadside objects, etc.

While the above factors are essential, the following design considerations based on safety investigations will contribute to safer and more resilient motorway design for the future:

- Minimising geometric features that contribute to traffic turbulence such as poorly located lane drops/reductions, steep-upgrades, constrained geometry, visual “intrusions”, substandard/less than desirable geometric elements etc.
- Managed motorways must be designed to avoid perturbations which can create turbulence and traffic instability. (Further understanding and guidance is provided in Volume 1, Part 2 and Volume 2, Part 3 which incorporates many design considerations which are underpinned by road safety principles.)
- Optimising the number of lanes for each carriageway by considering separated carriageways in the same direction rather than increased widening of a single carriageway. This is particularly important to consider when greater than 4 lanes is required to satisfy design demand (VicRoads, 2017). Separated carriageways will also increase per-lane capacity when compared to a single carriageway (refer to Volume 1, Part 3: Section 2).
- Adopting designs that avoid areas that increase the potential for conflict due to complex merging, diverging and lane changing / weaving (refer to Volume 1, Part 2: Section 4.4 and Volume 2, Part 3: Section 4).

Lane changing is a significant dynamic traffic behaviour that can occur for various reasons. While the effects of lane changing can impact capacity, operations and sometimes safety, a motorway cannot be productive if lane changing doesn't occur. A minimum level of lane changing is required to load and unload all lanes across a motorway carriageway. (Refer Volume 1, Part 2: Section 4.4)

The principles in the design sections of this guide Volume 2, Part 3: Sections 3 and 4 account for lane changing behaviour in the context of mainline and ramp layout and geometry (to minimise turbulence and maximise capacity). This is also considered in capacity analysis using Maximum Sustainable Flow Rates (MSFR) – with appropriate adjustments for heavy lane changing, weaving areas and geometric constraints.

3.3.2 Guiding Principles for Safer Motorway Operations

The way in which motorways are managed is equally important to the guiding principles for safer motorway design and contributes to safer, more efficient and more resilient motorway operations. Principles for safe and effective motorway operations include:

- An over-riding principle is to manage traffic occupancy (density) to prevent unstable flow, to minimise flow breakdown and avoid congestion.
- “Managed Motorway” technology, and most importantly, an effective coordinated ramp metering system, has proven to contribute to less hazardous driving conditions and fewer crashes.
- Managed motorways operations require effective management policies and operational strategies as well as effective operational practice enabling management of demand at all times and at all points of entry to the motorway.

Motorways have generally been built based on the outputs of strategic network models; however, a good design must be appropriate to accommodate the various traffic patterns and demands that occur over the entire day and not just a single peak period. Forecast design volumes used for the planning of projects typically only consider two generalised traffic patterns comprising trip patterns and demands that cover only part of the full AM and PM peak periods. Peak periods may have quite different demand patterns within them (as short as 15 minutes), as travel demands change based on journey to work patterns and other coinciding trip purposes (e.g. industrial areas begin work at different times to business or retail areas and not all trips are commuting to a fixed place of employment). Designing for flexibility in operations is the key to managed motorways where the optimal system tuning (automated) may change every few minutes throughout the peak period as demands fluctuate. For example, the peak period on a Saturday may occur around midday, with similar flows to weekday peaks, but usually with quite different origin-destination patterns.

Design decisions need to be made relating to whether forecast traffic demand can be met, or if demand management will be needed to ensure optimum productivity during operations. In this latter case, clear advice needs to be communicated to the motorway operators so that appropriate network operational strategies can be considered and put into place prior to project completion.

Significant differences in operation result from unmanaged operations, managed operations (with coordinated ramp metering signals) and partially managed operations (not all ramps controlled). These applicable levels of control need to be considered during the design process with appropriate values for design capacity (refer Volume 1 Part 2: Section 2.3 and Volume 2, Part 3: Section 3). The implemented management ramp control strategies should also be considered in the holistic context. Even where all ramps are controlled, inappropriate control strategies (flushing of ramp queues) are likely to restrict realisation of full managed motorway design capacity and have a negative impact more broadly across the network and increase crash risk.

3.4 Human Behaviours and Driver Capability

In the context of motorway design, human behaviour (refer Volume 1, Part 2: Section 4.5) is active in the context of traffic theory as well as motorway safety. Perhaps one of the least understood and possibly most necessary areas of transport research, is the study of human behaviours at the micro levels within traffic flow under varied conditions and levels of complexity. Generic models describing patterns or generalised groupings of human behaviour are no longer considered an adequate way to understand or to comprehend the diverse behaviours occurring in the different traffic states observed on urban motorways.

Motorway traffic flow is complex. Different human behaviours are evident and potentially more pronounced in different traffic states. As motorways approach their operational capacity there is an increasing number of vehicle interactions that cause traffic to slow down, creating longitudinal

oscillating waves (moving forwards and backwards) in the traffic flow. Lane change numbers also rise creating a more complex domain for the motorist to process and navigate. The functional motorway design and capacity principles need to consider these impacts which are built into the principles in this Guide through adoption of consistent geometric design standards and consideration of the stochastic nature of traffic in designing for operations.

A typical motorway such as the M1 in Melbourne services a minimum of 50,000 vehicles per hour along its full length for all of the day between 5am in the morning and 8pm at night, reaching over 60,000 veh/h serviced during peak hours (measured as the sum of all entry ramp flows (refer to Figure 1-1 and Volume1, Part 1: Figure 3-1). This large vehicle fleet is heterogeneous in terms of vehicle characteristics including vehicle dimensions (size, weight) and dynamic features (e.g. acceleration and braking capacity). Along with this heterogeneous vehicle fleet (refer Volume 1, Part 2: Table 1.1) comes an even more diverse driver population expressing numerous behaviours which ultimately determines the overall traffic performance outcome of a system.

Human behaviours include unique personal (instantaneous) responses and dynamic actions such as:

- choice of speed(s),
 - determined by the numerous factors identified in Volume 2, Part 2: Section 4.3 and listed below,
- choice of lane,
 - variable and numerous on a single journey e.g. each driver makes a lane change every 2-3 kilometres on average (Knoop, Hoogendoorn, Shiomi, & Buisson, 2012),
- choice of when and where to change lanes,
 - this is sometimes opportunistic i.e. related to gaps in the traffic flow that other vehicles create as they move out of a lane. Requires preparation checking mirrors, indicating and adjusting speed to align with a gap etc.,
- constantly variable actions to maintain their position within the traffic stream,
 - gear changing (automatic or manual), mirror glancing, braking, acceleration or coasting actions,
 - mostly done subconsciously as vehicles around them also constantly adjust their speed,
- choice of when to enter and/or exit the motorway,
 - determined by numerous factors, not limited to those described below.

Decisions to change lanes and/or to enter or leave the motorway at any moment in time may be based on:

- traffic conditions reported (e.g. media including weather conditions),
- traffic conditions displayed in the roadside (e.g. VMS, VSL, lane control and travel time signage),
- traffic conditions observed (e.g. drivers looking ahead beyond the immediate vehicles in front at traffic conditions while they drive and behind and beside (both sides) through their mirrors) etc.,
- actions delayed or altered due to the presence or awareness of blind spots or lack of opportunity to manoeuvre
- the unique origin and destination of each trip and the flexibility within the road network to provide the motorist with alternative route choices.

Due to the huge number of possible human “factors” from each individual driver, when combined with the heterogeneous vehicle mix, each with unique operating characteristics (e.g. vehicle size, engine power, vehicle performance variations such as braking and manoeuvrability) in a network where each driver has a unique origin and destination, further complexities arise within the traffic stream. These cannot be fully accounted for by the physics or traffic flow theories, or adequately accounted for by traffic flow models. The outcomes depend on the instantaneous mix of individual driver behaviours and the extent there is beneficial collaboration or conflict between all the drivers traveling together within the traffic stream at each location and at each point in time (Gaffney, 2018).

4 Design Process

4.1 Overview

The design process for urban motorway provision and upgrades needs to be undertaken within the broad planning context and strategies that apply in Victoria. It also needs to account for the operational context of the project in its completed and enduring state within the broader road network.

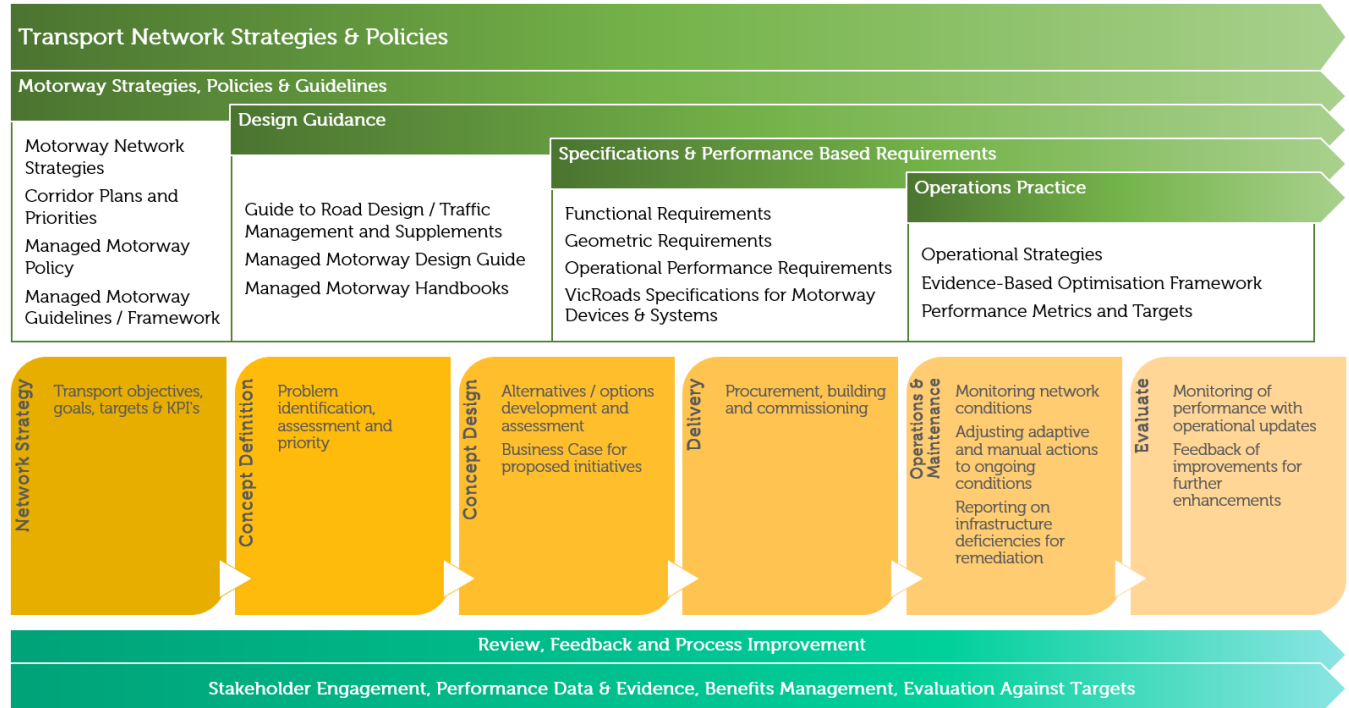


Fig 3-1: Managed Motorway Project Lifecycle

Figure 3-1 describes the overall road design process which generally follows the steps which need to be aligned with various strategies, policies, guidelines and requirements throughout the project lifecycle.

Network Strategy – A consideration of the network as a whole, with a view to adopting, where appropriate, a network-wide approach when choosing design and asset performance criteria.

Concept Definition – Identifying the purpose of and need for the project. This involves understanding the problem(s) at hand and the context in which the project is placed (for which stakeholder engagement is essential). See VicRoads' *Investment Management Approach* for guidance on problem-definition and ensuring that the right problem(s) is being addressed given the context of the site within the broader road network.

Concept Design – Planning and Developing Alternatives

- Alternatives are proposed and studied. For each alternative, the operational, safety (alignment with Safe System principles), environmental and community impacts are assessed.
- All alternatives must be designed to a stage that enables a reasonable assessment to be made of their cost and impact.
- The design of the preferred option is developed to a stage where design controls and risks can be addressed.

- During this process design development and numerous revisions are common and necessary. They are typically in response to increased information, further stakeholder input and community engagement and development of operational performance requirements.

Delivery

- Detailed Design is extended to provide all the information needed to construct the project.
- Assurance of projects objectives being met
- Commissioning of devices and warranty to ensure ongoing operation

Operations and Maintenance – expand requirements for systems

- Application of operational requirements, policy and practice
- Operational and performance monitoring to inform updated tuning parameters as traffic demands and patterns change over time
- Maintenance requirements are outlined in VicRoads Managed Motorway Framework (VicRoads, 2017)

Evaluate – The performance of the subsequent construction is monitored and the results evaluated.

- Performance measurement to ensure applied operations meet project and network objectives
- Informs enhancements to controls systems and physical assets
- Feedback into improved design practice and network operational practice

Managed motorway design requires a system approach with investigation along a significant length of motorway to gain an overall understanding of motorway performance, infrastructure characteristics and potential bottleneck locations. Considerations affect the design of the mainline, any lane changing/weaving areas, as well as the design of entry ramps to suit ramp metering signals.

The typical managed motorway analysis and design process requires an iterative process and needs to be embedded at all design stages. This is necessary as feasibility or decisions relating to one component can have implications for other components of analysis and design, as well as cost. In some cases, several iterations are required as project scope and design are formulated.

During the early stages of a project development process, the intended operational outcomes of the motorway and required level of active management should be determined from network operating objectives and any committed project objectives. The achievement of these operational outcomes may require greater provision of managed motorway tools than the recommended minimum requirements described within the policy and general warrants. An overview of many of the main components that form part of a Managed Motorway concept / functional design is provided in Volume 2, Part 3: Section 3.

Designers require a detailed understanding of what motorway control tools can and can't deliver and what further system enhancements may be required to achieve operational objectives. An operational audit can be undertaken to review the ability to achieve the set operational objectives and must be conducted when developing and delivering projects involving managed motorway tools. Along with Volume 2, Part 3, a useful reference is the Main Roads Western Australia report on Operational efficiency audit guidelines for managed freeways (Main Roads Western Australia (MRWA), 2013).

4.1.1 Importance of Robust Road Use Forecasts and Design Traffic Volumes

Traffic modelling and analysis requirements and needs should be understood as early as possible in the planning phases and when developing business cases. Depending on the size and scope of your project the traffic modelling task and resultant timeframe is very dependent on the complexity required.

It is important to establish:

- the problem that is trying to be solved, through detailed assessment and understanding of existing conditions based on traffic performance and safety records,
- the limit of works and where the civil design process and ITS tool integration applies (they are generally not the same – refer Section 5),
- key constraints including both now and within the project horizon (including broader network constraints with improvements in place),
- network operating objectives based on realistic and achievable targets,
- other committed project objectives,
- allowance for subsequent upgrades and strategic planning including placement of structures and clear spans for foreseeable widening (bridges and gantries).

Forecast design traffic volumes have a significant impact on the concept options developed and investigated. Significant time and resources can be invested in feasibility and concept designs and alignments and poor traffic forecasting outcomes can lead to either a lack of consideration of sufficient scope options and components or an over investment in scope that may not be necessary.

Forecast design traffic volumes should be rechecked at the stage when functional designs are near completion to ensure consistency of mainline lane configurations, entry ramp layouts, exit ramp layouts and that interchange operational designs are satisfactory and make sense in the context of the broader road network. It is particularly important to carry out a sensibility check of the existing and forecast traffic volumes in the broader road network with consideration of fixed constraints. This is required to make logical sense from both how existing network operates and from a logic perspective of how forecast demands on the network would be expected to grow. Network models can often have capacity constraints in certain links or areas that can significantly skew the forecast volumes. Significant changes to design traffic volumes at late stages of project development can lead to costly re-work or lost opportunities to provide sufficient or more efficient scope inclusions due to fixed constraints or decisions / commitments made earlier in the development process.

4.2 Maintaining a Consistent Focus Throughout Design

Table 4.1 below outlines some of the high level actions, considerations and outputs that generally align with the various project stages of a major Managed Motorway project (new facility or upgrade). The inclusions are not exhaustive and are provided for practitioners to appreciate some of the aspects that occur throughout the design process. Although various actions and outputs can be generally aligned with design stages, the design process is often fluid and processes can overlap, be repeated and refined as designs become more detailed and account for additional complexity and identified constraints.

When a design process commences, it is important to acknowledge that aspects of the project that are determined in the earliest stages often have a significant influence on the final project outcomes. As project development progresses, the knowledge that designers gain concerning the impacts of prior design decisions grows, generally due to the increasing levels of detail that are investigated and resolved. In parallel, the ability to make changes that significantly influence the outcomes can reduce or be constrained. The “influence” and “knowledge” triangles shown tapering and growing respectively as the project life cycle progresses can imply a smooth transition from start to end of the process. However, a “smooth” transition throughout the project development stages can only be achieved if high levels of capability, experience and forward thinking are employed to ensure appropriate decisions are made at the right stages to influence the outcomes and sufficient knowledge is gained and infused as appropriate to ensure scope inclusions / exclusions do not detract from the stated project objectives.

In general, the design team engaged in the process should have key capabilities in a range of areas. It can be unlikely that many designers will have a full range of experience across all stages and aspects of a Managed Motorway design. Accordingly, it is critical that design teams have a good mix of multi-disciplinary practitioners across all aspects of the design process as it progresses. While not all may be involved across all stages, there needs to be understanding of the critical outputs and processes that precede and follow to ensure continuity of purpose and function for the ongoing development of the project.

Note:

While all stages of a project are important to the final outcomes, the Delivery Stage of a project can present some specific challenges to meeting Managed Motorway project objectives.

Throughout recent delivery of significant urban motorways in Victoria, it has been observed that significant pressures can emerge that can influence the ability for Managed Motorway project to deliver the desired operational outcomes. Managed Motorway projects often include a large package of civil infrastructure delivery with a complementary package for ITS devices, infrastructure and systems components. Often, the ITS components can be seen by contractors and project managers as not being as critical to the project outcomes as the physical (civil) infrastructure. This can extend to “minor” components of the civil design, such as ramp designs. It is not uncommon for these components to be compromised if and when cost pressures arise (due to difficulties in delivering other aspects of a major project).

Compromises to ITS aspects and “minor” civil components can have a significant impact on the operational outcomes of a completed urban motorway project. A well designed managed motorway project will consider the contribution that ITS and ramp design components bring to final outcomes. Sound application of the Managed Motorway approach incorporating intelligent operational control regimes has been shown to deliver significantly increased throughput and reduced travel time. In some cases, these components may only represent 5-10% of overall project budget but can improve motorway performance by up to 30% on some metrics.

While pressure may emerge to remove components that may appear not to have great visual presence or impact in the physical road environment, removing critical enablers to operational performance can significantly detract from the ability to achieve desired project objectives.

Part 1: Managed Motorway – Design Principles and Warrants

Lifecycle Stage (Key Players)	Influence Outcomes	Knowledge of Impacts	Actions to Inform:		Outputs
			- Transport/Traffic Analysis - Strategic and feasibility assessment - Geometric Design Stages - Technology/Systems Integration		
Network Strategy (Identify & Initiate) (Road authorities (network owner), government decision makers and planners)			Develop transport objectives, goals, targets & KPIs Investigate corridor options (greenfield)		Problem Statement and Project Objectives Corridor and network assessment Investment plans (Pipeline) Preliminary strategic network modelling
Concept Definition (Planning) (Road authorities (network owner and manager), planners, designers, technical specialist)			Traffic surveys and data collection from network and surrounds Cross-section design options Interchange location and spacing and need for collector- distributors / SLAC Broad Right of Way / Land Requirements Strategies for foundational, intervention, optimisation tools		Problem identification, assessment and priority Clear Project Objectives and Desired Operational Outcomes
Concept Design (Development) (Road agencies (network and asset manager), development engineers, designers, technical specialists)			Alternatives/options development and assessment Quantification of significant ITS infrastructure deployment (e.g. number of ramp meters, mainline FDS, LUMS gantries, CCTV, VMS) Right of Way / Land Refinements (Temporary and Permanent) Develop network operational requirements Design Report and Operational Efficiency Audit Analysis and design to form the basis for reference design		Scope ladder including civil and tools Business case Functional Design Reference Design Client Req's Documentation & VicRoads Operational Req's Documentation
Deliver (Procurement) (Road agencies (asset manager and assurance), designers, delivery engineers, contractors and construction managers)			Procurement, building and commissioning Ensure design intentions are realised in construction Scope and Costs Controls – ensure critical aspects are not removed from deliverables		Detail Design Device and system commissioning
Operate & Maintain (Utilisation) (Road agencies (network/asset manager), contractors and maintenance managers)			Integration into network Monitoring network conditions Adjusting adaptive and manual actions to ongoing conditions Reporting on infrastructure deficiencies for remediation		Central infrastructure and systems – improvements to capacity, functionality and/or performance
Evaluate / Realise / Refine (Monitoring & Improvement) (Road authority, network / asset owner and manager)			Identification of new/refined: • Design and Planning Practice • ITS specifications and device requirements • Control systems and functions		Monitoring of performance and operations updates Feedback for improvements for future enhancements Revision to strategy, planning and practice.

Table 4.1: Managed Motorway Project Life Cycle (Development, Delivery and Operations)

5 Integrating Managed Motorway Components

The suite of parts presented in the VicRoads Managed Motorway Design Guide covers many aspects of physical motorway design and integration of intelligent transport technologies and systems.

Volume 1 of the Guide outlines a wide range of traffic science and broader justification for applying managed motorway design techniques and supporting control tools and monitoring systems. Volume 2 of the Guide outlines the application of design requirements and the complementary provision of control, information and monitoring devices in the field.

Applying the Managed Motorway approach requires an understanding of the many physical and technology aspects to ensure that scope decisions, placement and inclusion of the various elements are all integrated to meet the operational needs locally, along corridors and across the motorway network. Considered integration of all aspects, as required, are needed to address the dynamic operational challenges that can arise to ensure that optimised operations can be suitably targeted at all times.

While application of the Managed Motorways approach cannot guarantee congestion free urban motorway operations, deploying the components outlined in the Guide provides a robust and proven system that provides the ability to respond to complex, dynamic conditions and deliver good quality journeys for as many users as possible. Leaving key aspects out of urban motorway projects, even if considered small in the overall project scope, can have significant impacts on motorway performance. For example, the effectiveness of a city-wide, coordinated ramp metering system is reliant on many factors, including the placement, accuracy and reliability of vehicles detection devices, provision of sufficient ramp storage and discharge capacity on all coordinated ramps and the capability of real-time control systems incorporating state of the art control algorithms.

Note:

There can be a tendency for designers to move straight into the “how” aspects of analysis and design without understanding or focussing on the “why” aspects of the process. Volume 1 of this Design Guide is essential reading to understand the underlying concepts of motorway operation that have guided the principles of design contained in Volume 2 of the Guide.

There can also be a tendency for design teams to focus on “what” is to be designed, rather than on understanding the nature and causes of the traffic problems that the design needs to address or are inherent in many current (older) design practices. For example, designers may apply appropriate geometric design standards, but a layout may not be suitable for the traffic movements involved, e.g. variability of traffic patterns that occur within a single peak period and over the course of the week and heavy weaving movements which may include compound weaves as discussed in Volume 1, Part 2. Teams involved in managed motorway design need to incorporate a broad range of skills from many disciplines, both traditional and more contemporary in the operational sense, to ensure the solutions are appropriate to the current and future operating context of the motorway corridor and broader network.

There is a substantial amount of general advice provided regarding the placement, positioning or spacing of various components of motorway design. Simply applying the them without understanding the need to adjust provisions to suit the existing or anticipated operational challenges can result in a reduced ability to optimise operations. Copying what has been delivered in previous projects or at other locations may not address the localised problems that are evident and may emerge. In some cases, simplified application or copying can make conditions worse than expected and result in reduced ability to achieve the desired project objectives.

Ideally, a project scope and budget should not be set until there is a clear understanding and definition of the nature of the problems the project is to address, as well as robust thinking to ensure that the scope ladder of solutions (essential and optional) needed to resolve those problems are documented to direct the efforts of the designer. This approach can also provide a framework for evaluation when design decisions (or trade-offs) are being considered.

The scope of the project cannot be considered to be limited to the extent of the major civil works (e.g. lane widening and interchange improvements). Such an approach does not meet managed

motorway application principles and the concepts of performance based design for ongoing operations. Optimisation control tools need to be able to regulate system demand into and out of upgraded sections which will often require works to extend beyond the areas of the major civil works. Managing real-time conditions requires control tools for intervention and optimisation to be provided both upstream and downstream to maximise the value of the investment in physical infrastructure improvements. Relevant considerations are outlined in Volume 2, Part 2 and Volume 2, Part 3: Section 3.3.

5.1.1 On-road Design Components and Considerations Leading to Success

An actively managed motorway may incorporate a number of traffic management tools to provide a range of benefits (refer Volume 2, Part 2: Section 1 and VicRoads Managed Motorway Framework (VicRoads, 2017)).

The most effective traffic management tool for managing safety and motorway performance to achieve high levels of efficiency and travel time reliability is access control with City Wide Coordinated Ramp Metering (CWCRM). The principal aim of CWCRM on a managed urban motorway is to maintain stability of flow and prevent flow breakdown which is the cause of congestion. This results in greater travel reliability as well as improved safety, throughput and lower travel times.

While there is an emphasis on CWCRM design and operation in this Design Guide it does not necessarily mean other components are less important. All aspects of motorway design and operation have an important role to play in overall outcomes. Some physical design aspects, if not designed or incorporated appropriately, can create conditions that CWCRM cannot manage effectively without further compromises elsewhere in the broader road network.

For a sustainable and resilient system as outlined in Volume 1, Part 1: Section 2.2.2 and the managed motorway design principals above, all essential on-road ITS components are needed to provide the overall system that has the necessary flexibility to optimise operations across a range of circumstances.

A summary of the essential elements within the VicRoads holistic approach are shown in Volume 1, Part 1 and generally include:

- Organisational culture and principles (with Government support for best community outcomes as a whole), being driven from the top down.
- On-road components and supporting systems that are the focus of Volume 2, Parts 2 and 3 of the Design Guide. A focus on all of these aspects will not only facilitate optimum productivity but maximise road user acceptance, i.e., best outcomes for the road operator, for local government and for road users.
- Organisational understanding of contemporary motorway traffic theory as well as the choice of traffic management algorithms (consistent with that theory) that support the holistic principles and provide best network outcomes
- A commitment to operations AND maintenance regimes that ensure the regular tuning of control system parameters by specialised optimisation teams and maintenance practices deliver high availability of devices and systems.

Further guidance in what constitutes a managed and optimised motorway is in Volume 1, Part 1: Section 2.3.

Figure 5-1 demonstrates many components of managed motorway design and integration of control and intervention tools that are required for sustainable motorway operations. While not necessarily comprehensive, it illustrates many of the interdependencies that need to be considered in the overall managed motorway design process and implementation.

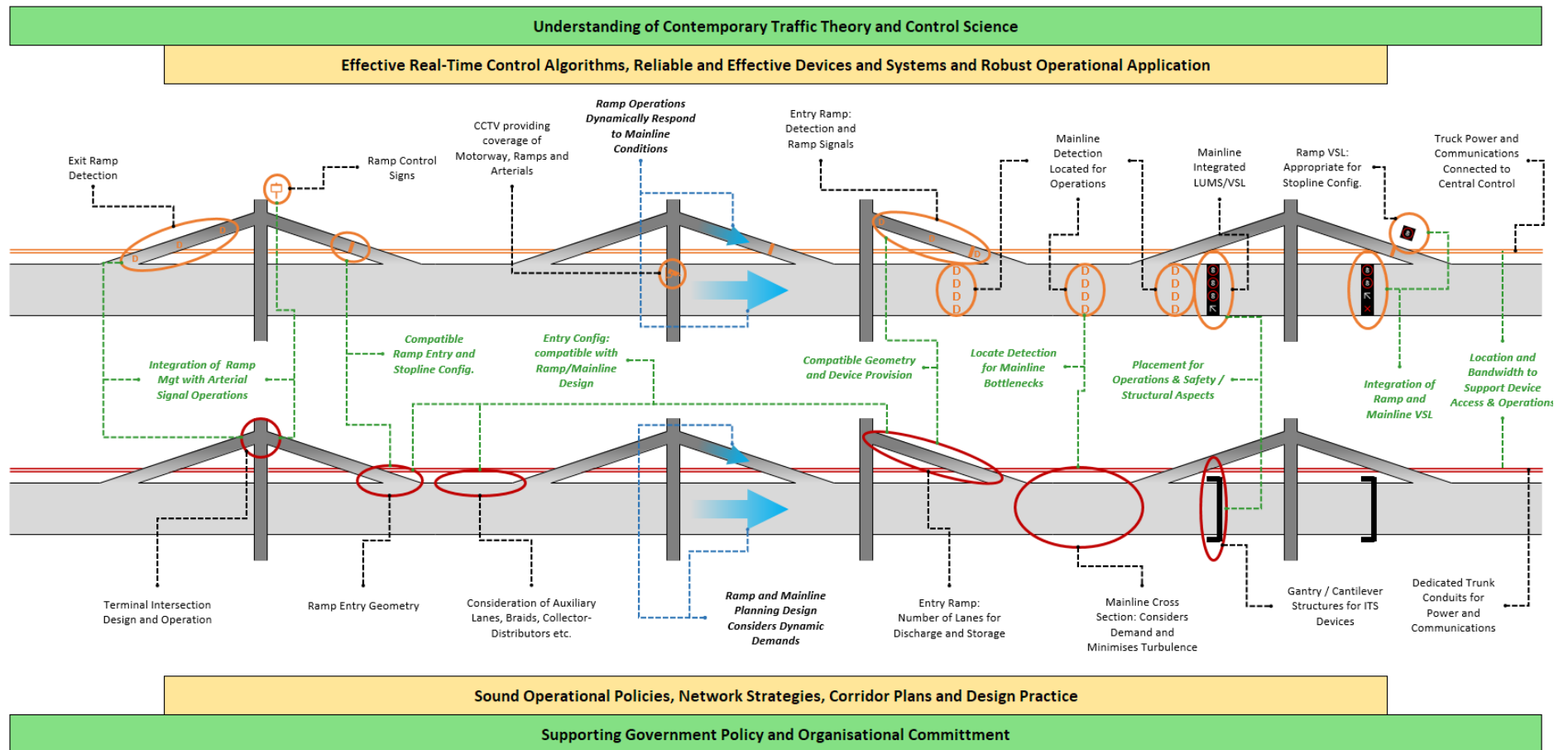


Figure 5-1: Integration of Essential Components for Sustainable Motorway Design and Operations

6 Motorway Project Scope Documentation, Endorsement and Approvals

6.1 Design Reporting and Scoping Documentation

Documentation should be an integral part of the project development and design process. The documentation should clearly outline the extents of the project, both in term of physical (civil) infrastructure and ITS devices, tools and systems (both in the field and within IT/ICT environments). The identified and reported extent of scope and inclusions needs to be in accordance the warrants and various requirements outlined in Sections 7 and 8 and across the other associated Managed Motorway documentation.

The content and depth of such documentation will vary according to the complexity of the solution, the extent of its compliance with the NDD, and whether EDD elements and design exceptions are used (each of which will need to be justified in the documentation). A design report must be prepared and kept updated from as early as Concept Design stage.

The purpose of documentation is to enable the designer to:

- To record the evolution of the project including design rationale and assumptions (and subsequent changes to each);
- Record the circumstances that require the use of EDD criteria or a design exception;
- Demonstrate that road-user / vehicle capability has been considered in the design;
- To assist in reviewing, verifying and justifying the design;
- To provide an asset maintenance record.

In addition to the above design report, a supporting Operational Efficiency Audit must also be undertaken to assess the needs for a corridor in accordance with the Operational Efficiency Audit Guidelines (Main Roads Western Australia (MRWA), 2013). The operational efficiency audit report needs to:

- Identify Locations of potential flow breakdown to identify how to prevent flow breakdown from occurring, particularly during peak times of high demand;
- Demonstrate the ability that design traffic demand and flows can be actively managed within the motorway's capacity, with acknowledgement of the overall system loading and dynamic operation;
- Consider the potential for demands to transfer / balance across multiple closely spaced surface road interchanges, especially where the adjacent surface road has good connectivity. (Strategic model demand forecasts at access locations may need appropriate rebalancing adjustments and sensitivity assessment.);
- Demonstrate ability to achieve and sustain optimal traffic flows subject to the maximum operational capacity of the motorway restore traffic flow to normal conditions as quickly as possible if flow breakdown does occur, for example following an incident;
- Demonstrate ability to minimise likelihood of occurrence of incidents that may threaten road user safety or disrupt traffic flow on the road network;
- Demonstrate ability to safely and efficiently manage unplanned incidents and events through the proposed geometric and ITS design with identification and consideration of an appropriate suite of scenarios;

- Develop a plan/strategy for operations and maintenance requirements to minimise risk to road user safety (including road workers and incident response units) as well as disruption to traffic flow on the network;
- Demonstrate provision of real-time traveller information to road users either using, or intending to use, the motorway.
- Demonstrated ability to minimise adverse impacts on traffic flows on connecting or intersecting motorways and other arterial roads, to deliver improved network-wide performance and end-to-end journeys.

The Design Report and Operational Efficiency Audit Report need to be considered together to ensure the likely design and operational outcomes are fully documented and any risks associated with potential compromises are fully assessed and accounted for. Operational assumptions (particularly around constraints) in design stages must be captured in the design and audit reports.

It is important that any deficiencies identified during development of options and concept designs and the accompanying Design / Operational Efficiency Audit Reports are assessed against the overall project objectives and the justification for investment. Where deficiencies are likely to cause ongoing operational challenges within the design life of the project, the economic and network modelling evaluation should inform the decision to further investigate the need to remove such deficiencies and form part of the overall project business case to determine the most appropriate scope ladder for the project.

6.2 Required Endorsements and Approvals

The Managed Motorway Design Guide provides extensive information to assist with developing and designing motorway schemes for deployment on Victorian Motorways. Due to the critical role that urban motorways provide in urban networks and the wide reaching impacts of poor performing motorways, various aspects of design and planning require review and endorsement by VicRoads.

VicRoads, as the coordinating road authority for all motorways, is accountable for ensuring that consistent application of managed motorway principles, tools and design aspects across the whole motorway network. VicRoads is also responsible for whole of network optimisation functions across all motorways, irrespective of private road operator responsibilities on designated sections. Accordingly, a single point of oversight is required to ensure operational aspects are considered in local, corridor and network contexts to ensure efficient and safe operations can be targeted.

In some cases, less than desirable design solutions or operational aspects may need to be considered based on site and corridor context. These aspects require approval by VicRoads for consideration in designs and application on the motorway network.

Table 6.1 provides a summary of the aspects that require endorsement / or approval from VicRoads during various design and development stages of motorway projects.

- This applies, not only to projects being developed for delivery and operation by public agencies, but also those designed, delivered and operated by private third parties for fixed or indefinite time periods.
- Points at which VicRoads should be consulted to ensure scope considerations / inclusions (exclusions) at the relevant design stage are appropriately covered, justified and documented
- Including which sections of VicRoads in particular will need to be consulted to endorse the development process and scope inclusions (exclusions) / considerations

VicRoads Approvals	Reference
Traffic Modelling and Design Volumes Use of K-factors less than 9% for urban motorway design and planning requires detailed justification	Volume 2, Part 3: Section 3.3.4.3
Uncontrolled Ramps in Managed Sections - Coordinated ramp metering designs (schemes) that include an uncontrolled ramp(s). - Submissions shall be accompanied by a detailed report outlining the design justification.	Volume 2, Part 3: Section 4.3.2.8 Volume 2, Part 3: Section 4.4.6
Entry Ramp Discharge and Storage - Average cycle times less than the desirable minimum cycle time (specified in Volume 2, Part 3: Section 6.2) or outside the limits in Volume 2, Part 3: Table 6.1 - Storage provisions less than required in relation to the adopted ramp design flow	Volume 2, Part 3: Section 6.2 (Table 6.1)
Managing High Demand Flows Ramp metering designs which use more than 1 veh/g/l, whether for temporary or permanent operations	Volume 2, Part 3: Section 6.2.1
Stop Line Layouts - Stop line layouts not covered (within standard drawings and layouts) in this Guide. Includes but is not limited to: - Non-standard layout options outline in Volume 2, Part 3: Section 6.2.1 - Single lane stop line layouts	Volume 2, Part 3: Section 6.2.1
Ramp Storage Analysis and Requirements - storage design should avoid storage on the surface road. - Design where entry ramp queue storage is provided on the upstream surface road, due to storage deficiency on the ramp. Considered to be a design exception.	Volume 2, Part 3: Section 6.3.1
Motorways with Tunnel Sections - Location of ramps (entry and/or exit), merges, diverges and the associated geometric arrangements and technology provisions. - Applicable in close proximity (500m) to or within tunnels.	Volume 2, Part 3: Section 6.4.2 Volume 2, Part 3: Section 9.3.1

VicRoads Approvals	Reference
Priority Access Lanes • Selection and configuration of treatments incorporating priority access lanes for inclusion in motorway projects	Volume 2, Part 3: Section 6.8.1
RC3 – Real Time Information Signs • Where ramp terminal intersections provide access to multiple metered ramps with different destinations, an RC3 panel for each ramp is required to enable ramp specific messages and directional travel information • Approval required for proposed provisions and locations	Volume 2, Part 3: Section 6.10.7.3
Motorway to Motorway Ramp Metering • All motorway to motorway ramp metering designs shall be subject to a design report covering design matters in this Guide. • Detailed design report required to accompany submission for consideration	Volume 2, Part 3: Section 7.1
Extended Design Domain Solutions • Staggered stopline layout • Metered Priority Lane: Option P2	Volume 2, Part 3: Appendix A

Table 6.1: Required Endorsements and Approvals

7 General Warrants for Design, Deployment and Application on Motorways

7.1 Categories of Motorways

The limits of urban motorways or routes identified as current and future urban motorways are outlined below for the purpose of monitoring and control. These limits are based on the current Metropolitan Urban Boundary (refer to Figure 7-1) which is generally aligned with the outer limits of the metropolitan municipalities and some overlap into Mitchell Shire to the north of Melbourne. It is important to note that this boundary may be subject to change over time and any changes need to be reflected in motorway designs and scope inclusion requirements and considerations outlined further in this part of the Guide.



Map 2

Melbourne 2050 Plan

Source: Map 2, Plan Melbourne 2017 – 2050, DELWP (Department of Environment, Land, Water and Planning, 2017)

Figure 7-1: Melbourne Metropolitan Area

The term freeway, as defined within the current VicRoads Managed Freeways Policy (VicRoads, 2014) (current at the release of this edition), and revised to the term 'motorway' in updated guidance, generally indicates a limited access dual carriageway facility. The policy and guidance also applies to collector-distributor arrangements, multi-carriageway facilities (operating a common direction) and roads which have similar characteristics to motorways but are not declared as such, including rural M-roads and connections and access ramps and roads considered within the motorway environment.

These guidelines are based on evidence and experience on how, when and where managed motorway tools are best deployed and the need for these tools to be fully integrated and working together to provide users with safe operations both under normal and congested conditions and in the management of incident and other special events.

Urban Motorways – Measured flows on existing Melbourne urban motorways indicate that high flows already exist across all urban and peri-urban areas that warrant the provision of optimisation control tools. Although some peri-urban locations may not in isolation meet the volume warrant in this guide, such areas would qualify for treatment to meet requirements for coordinated ramp metering system application, as outlined in Volume 2, Part 3: Section 4.4.5.

The provision of supporting civil infrastructure, such as ramp configurations catering for metering and conduits for communications and power, are long term investments and the cost of retrofitting is much higher than provision during initial construction or major upgrade. Accordingly, supporting civil infrastructure is required for all urban motorways (existing and future), including the ramp configuration allowances (for metering) and foundation infrastructure, systems and tools, even where the provision other warranted tools and systems might be deferred.

Project scope and reservation of sufficient land and space for future provisions should cater for a geometric design and roadside infrastructure. These provisions and reservations need to be suitable for ramp meters and mainline carriageways that are designed for operating under optimised traffic flow conditions using the breadth of tools required as outlined in this Guide.

Inter-Regional Motorways – There are several important inter-regional motorway routes that connect regional Victoria directly with Melbourne and pass through populated peri-urban areas and carry high volumes of daily traffic with a significant freight component. The existing and forecast high traffic demands on these routes are such that some additional geometric considerations are necessary when planning and designing these facilities to allow for expansion addressing growth in traffic and enable easier future upgrades. This should include allowances for future upgrades to entry and exit ramps and carriageway pavement and structural widths / clearances to cater for an additional running lane(s) with limited modifications / realignment. Widths and clearances need to ensure sufficient shoulders and height clearances to structures to support existing and future running lanes and carriageway configurations.

Appropriate initial investment in supporting ITS infrastructure is also necessary. This may include vehicle detection, CCTV coverage and VMS for traveller information etc. to inform identification, planning and timing of necessary upgrades and to monitor operations and changing conditions over time. These routes require considerably less extensive deployment of ITS and traffic management than required in urban areas while flows remain modest, although regular assessment should be made to identify the need for monitoring and control tools to address emerging operational and safety issues.

Other Motorways and M-Class Roads – The remaining rural motorways and designated M-class roads, carrying growing volumes of daily and seasonal traffic, require a basic level of ITS infrastructure such as limited vehicle detector stations at key locations. Where possible, dissemination of travel time advice and other traveller information via appropriately spaced / located variable message signs, which may be primarily provided to facilitate State-wide emergency management.

Motorways in Melbourne and beyond can be generally categorised according to the discussion above and have been grouped and their limits defined as below to inform design and ITS infrastructure investment requirements.

7.1.1 Urban Motorways

Generally defined as being within the limits of Melbourne Metropolitan Area boundary shown in Figure 7-1, being the outer limits of the metropolitan municipalities within the greater Melbourne urban agglomeration, or as indicated in the list below. It is noted that the list includes sections not currently operating as motorways; however, upgrades of these roads to motorway status will require appropriate consideration of the MMDG requirements.

- M1 Princes Freeway West: Western Limit – Little River Rd, Little River
- M1 Princes Freeway East: Eastern Limit – C101 (East) Nar Nar Goon Rd Connection, Nar Nar Goon
- M2 Tullamarine Freeway, including future extensions to OMRR
- M3 Eastern Freeway / EastLink / Frankston Freeway
- M8 Western Freeway: Western Limit – C801 Coburns Rd, Melton
- M11 Mordialloc Bypass / Mornington Peninsula Freeway / Peninsula Link: Southern Limit – C777 Frankston-Flinders Rd, Baxter
- M31 Hume Freeway: Northern Limit – C727 Watson Rd, Wallan
- M79 Calder Freeway: Northern Limit – C707 Gap Rd, Sunbury
- M80 Western / Metropolitan Ring Road (including North East Link)
- M420 South Gippsland Freeway
- M780 Western Port Highway
- Outer Metropolitan Ring Road (OMRR), including E6
- All other roads built or upgraded to motorway standard within the urban area

7.1.2 Inter-Regional Motorways

Rural / Semi-rural motorways linking major regional centres to Melbourne and passing through peri-urban areas, and/or feeding into urban motorways.

- M1 Princes Freeway West: Little River to Waurin Ponds (C134)
- M1 Princes Freeway East: Nar Nar Goon (C101) to Warragul (C425)
- M31 Hume Freeway: Wallan (C727) to Broadford (C382)
- M8 Western Freeway: Melton (C801) to Bacchus Marsh (C602)
- M8 Western Freeway: Ballarat Bypass – C805 to B220
- M11 Mornington Peninsula Freeway/Peninsula Link: Baxter (C777) to Rosebud (C777)
- M79 Calder Freeway: Sunbury (C707) to Macedon (C322)
- M420 South Gippsland Hwy: Southern Limit – Koo Wee Rup (C421)

7.1.3 Other Motorways

Generally refers to all rural motorways (M-class roads) whether new or being upgraded / retrofitted. Provision of ITS may also be required for environmental conditions not discussed or outlined in this Guide.

7.2 Warrants for Managed Motorway Tools and Infrastructure

Table 7.1 outlines the warrants for providing various Managed Motorways tools and infrastructure based on the category of motorway being considered and flow thresholds on the route being assessed for construction or upgrade. Description, further detailed scope requirements and considerations are associated with the tools outlined, in Section 8 and Volume 2, Parts 2 and 3. Further tools and technology provisions may also be required that are not specified in this table.

It is incumbent on the designer(s) to understand the context of the motorway facility being provided / upgraded, undertake sufficient assessment of the existing and future forecast operating conditions and ensure appropriate consideration of the requirements of the other parts of this Guide.

Part 1: Managed Motorway – Design Principles and Warrants

General Warrants	Control Tools					Foundation Tools					Supporting						
	Optimisation Tools			Intervention Tools		Information		Intelligence			Core ITS				Civil		Other
	FRS / CW-CRM	DVSL	ERM	LUMS	VSL	VMS	RTIS (RC3)	FDS	CCTV	Enviro. Mon.	Control System	Comms	Power	TMC	Ramp Provisions	Mainline Conduits	Help Phones
Motorway Classification	Freeway Ramp Signals	Dynamic Variable Speed Limits	Exit Ramp Management	Lane Use Management System	Variable Speed Limits	Variable Message Signs (Mainline)	Real Time Information Signs	Freeway Data Stations (Detection)	Closed Circuit TV Cameras	Environmental Monitoring							
Urban Motorways																	
ALL Urban Motorways Current / forecast¹ weekday traffic volumes GREATER THAN Daily: 60,000 veh/day 2-way, OR Peak Hour: 80% of unmanaged MSFR⁴ based on 15% CV at 2% grade (e.g. 1200 pcu/h/lane)	Required for Coordinated Motorway Network Control incl. M2M ² ramps Full provision of FRS and related devices in accordance with Vol 2, Part 3	Requires provision of FDS as well as VSL and / or LUMS	Required for all exit ramps, excluding metered M2M ² ramps	Required for: All Lane Running ⁶ or 4 more lanes or Multiple (Parallel) Carriageways in common direction Desirable for: 3 lanes Separate conduits for power and comms required for each direction	Mainline integration with overhead LUMS preferred Spacing to support intervention actions and dynamic systems as required	3-5km spacing, subject to spacing of major interchanges Preferably 0.9-1.2km prior to major decision location Required in advance of M2M ² interchanges and at start of LUMS environment	Required at all interface locations for entry ramps with ramp metering Separate signs required for each metered ramp at an interchange for each surface road approach	Locate in accordance with Vol 2, Part 3, Sec 5 to support control tools Required on ramps and connectors as outlined in Volume 2, Part 3 Maximum 500m spacing along all carriageway(s)	Full overlapping coverage required Ramp specific requirements outlined in Vol 2, Part 3 Required witin 200m of VMS	Local context and specific risk assessment to determine need	Enhancements may be required to integrate new / improved functionality	Trunk power and optic fibre communications required (integrate Comms in ring architecture)		Design for FRS in accordance with Vol 2, Part 3 for adequate storage, discharge capacity and priority provisions	Separate conduits for power and communications (independent of other services e.g. street lighting) and communications	Refer Sec 8.3.2.6 Required in tunnels and high risk locations. Generally not provided where CCTV, IRS ³ and cellular coverage available	
Required	Y	Y (Future)	Y	Y	Y	Y	Y	Y	Y	Site Specific							Y
Volume warrant application	Forecast ¹ meets warrants within 5 year of expected project completion					Applies to all motorways					Applies to all motorways				Forecast ¹ meets warrants within 20 years of expected project completion		Applies to all motorways
Inter-Regional Motorways																	
Selected Routes As Listed Current / forecast¹ weekday traffic volumes GREATER THAN Daily: 30,000 veh/day 2-way, OR Peak Hour: 80% of unmanaged MSFR⁴ based on 15% CV at 2% grade (e.g. 1200 pcu/h/lane)	Refer to Vol 2, Part 3 for provision requirements to suit PMTZ ⁵ or localised metering operations	Requires provision of VSL and / or LUMS and likely additional FDS Provision preferred for locations that experience recurrent congestion and queuing.	At exit ramps to signalised intersections that experience regular / semi-regular queuing that can impact mainline flow	Desirable on motorways with high flows (equiv. to urban daily flows) and 3 or more lanes Broader scope/risk considerations may also apply	Pre-requisite for provision of DVSL including back of queue management functionality	5-10km spacing, subject to interchange spacing and major decision locations Required in advance of M2M ² interchanges and at start of LUMS environment	Required at all interface locations for entry ramps with ramp metering Separate signs required for each metered ramp at an interchange for each surface road approach	To suit FRS where provided At interchanges in accordance with SD6301 Maximum 2km spacing along mainline	Required at interchanges Required witin 200m of VMS and as required for ramp metering	Local context and specific risk assessment to determine need	Enhancements may be required to integrate new / improved functionality	Device Specific Cellular possible	Device Specific Local power possible		Design for FRS if required (Vol 2, Part 3) and / or provide min ramp length 400m to nose for future FRS	Mainline conduits preferred Local power / communications may be applicable for context, scope and cost	Refer Sec 8.3.2.6 May be required 2-5km spacing depending on CCTV, IRS ³ and cellular coverage
Required	Site Specific	Site Specific	Desirable	Site Specific	Desirable	Y	Site Specific	Y	Y	Site Specific							
Volume warrant application	Forecast ¹ meets warrants within 5 years of expected project completion					Applies to all motorways					Applies to all motorways				Forecast ¹ meets warrants within 20 years of expected project completion		Applies to all motorways
Other Motorways																	
Generally Rural Motorways Current / forecast¹ weekday traffic volumes LESS THAN Daily: 30,000 veh/day 2-way, AND Peak Hour: 80% of unmanaged MSFR⁴ based on 15% CV at 2% grade (e.g. 1200 pcu/h/lane)	Local metering may be considered where localised breakdown is regularly experienced				May be required for managing locations with recurrent environmental conditions, e.g. high winds	To be strategically located to assist with emergency management		One FDS minimum for each midblock segment between interchanges / major intersections Preferred location downstream of entry taper	May be considered at high risk locations as appropriate Required witin 200m of VMS and as required for ramp metering	Local context and specific risk assessment to determine need		Device Specific Cellular possible	Device Specific Local power possible		Design for FRS if required (Vol 2, Part 3) or consider min ramp length 400m to nose for future FRS <i>[Forecast¹ meets warrants (for inter-regional mwys) within 20 years)]</i>	Local power / communications may be applicable for context, scope and cost	Refer Sec 8.3.2.6 May be required 5km spacing depending on CCTV, IRS ³ and cellular coverage
Required	Site specific	N	N	N	Site specific	Site specific	N	Y	Site specific	Site specific	Y	Y	Y	Y	Site specific	Site specific	Site specific

Notes: 1. "Forecast" period for weekday traffic volumes determined relative to planned project completion

2. M2M = Motorway to Motorway

3. IRS = Incident Response Service

4. MSFR = Maximum Sustainable Flow Rate (refer Volume 1, Part 3)

5. PMTZ = Partially Managed Transition Zone (refer Volume 2, Part 3: Section 4.4.5)

6. All Lane Running generally applies to 3 or more lanes with no shoulders.

Table 7.1: General Warrants for Managed Motorway Deployment based on Motorway Classification

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8 Managed Motorways Tools and General Requirements

8.1 Managed Motorway System

An integrated motorway management system may interface a number of real time on-road traffic management tools. Table 8.1 provides a summary of Managed Motorway tools and their contributions to integration within the broader motorway management system.

Managed Motorways Tool		Level of Active Management				
		Network monitoring & intelligence	Traveller information	Traffic management & control interventions	Route optimisation	Multi-modal network optimisation with journey management
Optimisation Control	CRS			S	P	Su
	DVSL			S	P	Su
	Exit ramp mgt.			S	P	Su
	End-of-motorway mgt			S	P	Su
	Arterial road interface mgt			S	P	Su
	Arterial road mgt system (ARMS)			S	S	P
Intervention Control	LUMS (including VSL)			P	Su	Su
	Entry ramp mgt			P	Su	Su
	WAND			P	Su	Su
	Mwy dynamic re-configuration (incl entry/exit ramp mgt)			P	Su	Su
Foundation	VMS		P	Su	Su	Su
	Publish to third parties		P	Su	Su	Su
	AID	P	Su	Su	Su	Su
	Traffic detectors	P	Su	Su	Su	Su
	CCTV	P	Su	Su	Su	Su
	Congestion alarms	P	Su	Su	Su	Su
	Weather and environmental monitoring	P	Su	Su	Su	Su
	Real-time GUI	P	Su	Su	Su	Su

'P' if it is the primary function of the tool to deliver that level of active management

'S' if it is the secondary function of the tool to deliver that level of active management

'Su' if a tool supports other tools in delivering the required functionality for that level of active management

' ' if the tool does not contribute to a particular level of active management

Source: VicRoads Managed Motorway Framework, Table 4.2

Table 8.1: Summary of Managed Motorway Tools and Management Roles

VicRoads has a systematic approach to ITS tool deployment where the benefits are measured at the road system level. VicRoads Managed Motorway Framework (VicRoads, 2017) provides more detailed information regarding tools and system requirements. It is important to note that there are important interfaces and dependencies that affect the functionality of each tool as well as design considerations such as layout of devices and system performance requirements.

The sections that follow summarise the tool categories and provide a general description of the tool functions and general requirements for provision. These sections should be read in conjunction with other parts of this guide which provide more detailed information about the deployment of managed motorway tools and when they are best applied. It is noted that technical details and requirements are

also included in VicRoads ITS specifications with further performance requirements specified in the VicRoads Managed Motorway Framework (VicRoads, 2017).

8.2 Overview of Managed Motorway Tools

The Managed Motorways toolkit discussed in Volume 2, Part 1: includes various technologies and control strategies for delivering different levels of active management. Further details on these tools are provided in (VicRoads, 2017) which provides an overview of the toolkit in its entirety, providing high-level functional and technical requirements for each tool, in line with the Systems Engineering methodology.

The individual tools available for use in the active management of motorways are listed in Table 8.2, including tools that are currently in operation, as well as tools that are in development or planned for development. Each Managed Motorway tool is part of a total control system (e.g. integrated tool chain) and for function can be divided into two primary categories being “Control Tools” and “Foundation Tools”.

Control Tools		Foundation Tools	
Network Optimisation Control	Intervention Control	Information	Intelligence
City Wide Coordinated Ramp Metering (CWVRM) system Dynamic variable speed limits (DVSL) ¹ Arterial road interface system Arterial road management system ² Exit ramp management system End-of-motorway management system ²	Lane use management system (LUMS) including variable speed limits (VSL) Entry ramp management system Wide area network dispersion (WAND) ² Motorway dynamic re-configuration (including entry and exit ramp mgt systems) ²	Variable message signs (VMS) External information publication for third party use	Traffic detectors (primarily speed, volume and occupancy – SVO – data) CCTV Automatic incident detection (AID) ¹ Congestion alarms ² Real-time graphical user interface (GUI) Weather and environmental monitoring system

¹ Tools currently in development to be integrated with CWCRM - ² Tools planned for development

Table 8.2: The Managed Motorways Toolkit

Control Tools use the information from the intelligence tools to optimise motorway performance, maximising safety, reliability and capacity. As illustrated in Table 8.2, “**Control Tools**” can be separated into two categories depending on their primary function in relation to the levels of active management (i.e. Network Optimisation or Intervention) as follows:

- **Network Optimisation** – These control tools for route and network optimisation and these include City Wide Coordinated Ramp Metering (CWCRM), dynamic variable speed limits (DVSL), Arterial Road Interface and Exit Ramp Management systems.
- **Intervention** – These control tools responsible for intervening to control traffic speed and lane/carriageway use following an incident, congestion or other event. For example, integrated speed and lane use management systems (LUMS) and entry ramp management systems that support motorway closures.

Likewise, “**Foundation Tools**” are split into two categories as follows:

- **Information** – These tools provide real-time information to road users via on-road variable message signs (VMS) as well as through publication of data to third parties for wider dissemination via mobile phone and in-vehicle systems. Provision of information on travel

times and motorway conditions on both the arterial and motorway network can assist in managing demand across the network, particularly during incidents and congestion. Provision of information is particularly important during unusual conditions such as incidents and during road maintenance activities.

- **Intelligence** – The intelligence function is the foundation of managed motorways, informing the control and information functions. These tools provide the real-time data that is critical to identifying and monitoring network performance outcomes and issues (including outcome monitoring) and providing the inputs to dynamic algorithms that fine-tune towards a defined objective target.

“Control Tools” generally require various functions of “Foundation Tools” for their effective operation and use many of the same field devices and detector data. In this context, tools are described as being “tool chains”. For example, the City Wide – Coordinated Ramp Metering (CWCRM) system and the entry ramp closure management system both utilise traffic signals and ramp signs to control traffic leading on to and within the entry ramp using combinations of common and specialist algorithms. These are driven by the same detector data to control the traffic and provide advice to motorists. Hence the Managed Motorway toolkit consists of a variety of “tool-chains” that assist managing traffic entering the motorway, traffic on the motorway and traffic exiting the motorway. Therefore, when designing a Managed Motorway, it is important that there is understanding that the higher order optimisation tools naturally assume that the foundation tools and intervention tools have been provided according to the warrants contained in Volume 2, Part 1 and design guidance contained in Volume 2, Parts 3 and 4.

8.2.1 Integration of Control Systems and Tools

The generalised approach to controlling Victorian Managed Motorways in Figure 8-1 demonstrates the integration of the following functions within VicRoads control paradigm:

- Traffic management and control interventions
- Route optimisation
- Multi-modal network optimisation with journey management

The two optimisation approaches (route and network) are captured in the automated algorithm operations category and the intervention approach in the response plan category. The traveller information approach is covered in the traveller information pathway in each of these categories and the whole operation is fed by the network intelligence function. This representation is for a single operator or system.

Much of the operation of Victorian Motorways is automated through the use of configured algorithms and rules-based response generation processes. In Figure 8-1 these activities are shown in black. Human operators play a complementary role in managing the motorway, supported and informed by the system. Operator actions are shown in blue.

The need for automation and integration of these functions has been determined to be a mandatory requirement for operating complex urban motorway networks. The variability of geometric conditions (changing numbers of lanes and proximity to ramps), the dynamic nature of traffic demands and patterns and the randomness of disruptive events is beyond the ability of most, if not all, human operators to appreciate, assess and respond effectively to simultaneous demands in necessary timeframes. Real-time optimisation functions using advanced feedback control across expansive motorway networks cannot rely on humans in the loop. The interactions between automated and human controlled tools are too complex and require real-time responses that only a rules-based arbitration system can manage which brings only the necessary decisions to the operator’s attention.

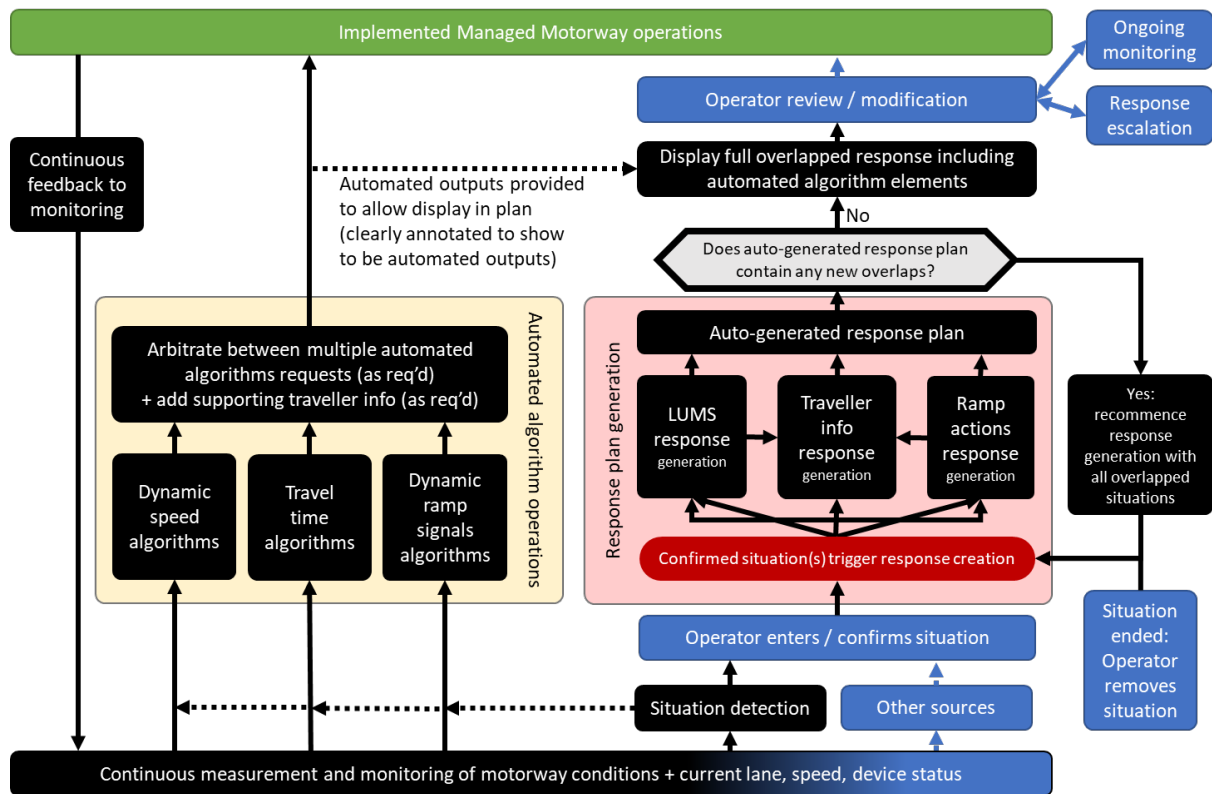


Figure 8-1: Generalised integrated control approach for Victorian Motorways (Single Operator)

8.3 Foundation Tools

8.3.1 Foundation Systems and Infrastructure

Foundation systems and infrastructure refers in part to the central equipment and control systems located off-motorway, particularly in and around the Traffic Management Centre. It also encompasses the systems that power and enable communications with field devices. This infrastructure and these systems are shared across all managed motorways and other ITS within VicRoads.

Where changes to the control system or additions to communications or power systems are required, these should be made keeping in mind the longer term requirements for the system or the corridor.

The foundation systems and infrastructure are necessary to permit the successful implementation of the managed motorway operations. The move towards fully managed motorways throughout the urban area provides the imperative for the provision of this enabling infrastructure.

8.3.1.1 Control System

The functionality of the managed motorway relies on the integrated ITS control system (i.e. software and computing hardware). An integrated software platform becomes particularly important as the number of tools increases along with their interdependencies. VicRoads has committed to an ITS platform broadly based on the principles of Service Oriented Architecture. Many of the systems functions referred to in this Guide are already provided for within the software procured by VicRoads; however, some services will likely require further software enhancement to incorporate functions or features for a specific network need. Supporting ICT systems will require expansion (increased capacity or performance) and new services to keep the control system software current (maintenance and additional operational utilities i.e. monitoring and reporting).

Where managed motorway projects create a requirement for improved capacity, functionality and/or performance of central infrastructure and control systems, allowance for funding these improvements

must be included within the project TEC(s). Lead times may be significant and must be programmed accordingly.

8.3.1.2 Telecommunications System

Tele-communications underpins ITS as it does much other information technology. With increasing deployment of ITS assets in motorway corridors and expansion of fully managed motorway operations, it becomes increasingly beneficial and necessary to have high quality communications such as fibre optic cable within the motorway corridor. High-capacity communications infrastructure is also a key enabler for future Vehicle Infrastructure Integration initiatives (e.g. C-ITS applications utilising V2I / I2V).

8.3.1.3 Power System

A reliable power supply is necessary for the successful operation of ITS. Similar to communications, the increasing number of ITS assets in motorway corridors means that power supply should be considered along the motorway corridors in addition to the option of localised, individual connections.

8.3.1.4 Traffic Management Centre

The Traffic Management Centre (TMC) plays a key role in active management of the motorway network and interacts with all the management tools. Expansions of managed motorways need to consider impacts on the TMC, including the capabilities and resources needed for ongoing management and optimisation of these facilities. Improved situational awareness and human-machine interface considerations must be addressed as network coverage and management demand increases.

The provision of field infrastructure for managed motorways needs to prioritise management tools to locations where most needed. For existing motorways, it is recognised that the addition of management tools is constrained by available funding. Prioritisation of rollout of the field infrastructure should be based on maximising the return on available funding.

8.3.2 Intelligence Tools

8.3.2.1 Freeway Data Stations (FDS) – Vehicle Detectors

Freeway Data Stations (FDS) provide vehicle volumes, speed and occupancy (proxy for density) on a lane by lane basis supplemented with classification/length data. The information is the basis for monitoring and controlling motorway operations. Vehicle detectors and the data they provide are critical for many of the downstream monitoring, information, intervention and control functions, which highlights the need for device accuracy, reliability and maintenance requirements. Details related to detector accuracy and performance requirements are outlined in VicRoads Specification for The Supply of Freeway Data Stations (VicRoads, 2018).

New installations of FDS should be based on technologies which minimise whole of life costs, including traffic management costs of installation and maintenance.

Vehicle detectors should also be installed on entry ramps and mainline carriageways for Coordinated Ramp Metering and other mainline monitoring and optimisation functions (including collector-distributor roads and other forms of separate carriageways) as required, and also on exit ramps to monitor and manage traffic queues.

8.3.2.1.1 General Requirements for FDS on Main Carriageways

The following locations provide a summary of general locations for FDS provision on urban motorway carriageways. More detailed requirements for locating FDS on ramps and motorway carriageways is outlined in Volume 2, Part 3: Sections 5, 6 and 7.

- Downstream of Entry Ramps: at the end of the ramp merge taper, generally 320m downstream of the nose for standard merge arrangements. Location may vary depending on entry ramp and merge type.
- Upstream of Entry Ramps
- Downstream of Exit Ramps
- Other Mainline Locations – at or immediately downstream of potential bottleneck locations
- In addition to the above locations, generally provide at 400m to 500m spacing (i.e. 500m max.) along the full length of the motorway

Provision of FDS and associated vehicles detectors on inter-regional and other motorways is outlined in Table 7.1. On these motorways, the primary purpose for intelligence is for monitoring and planning purposes, although in locations where Control Tools are also warranted, appropriate provisions for locations and technology selection should be adopted. On these motorways, consideration should also include co-location / co-utilisation of other road asset management facilities, such as Weight-in-Motion (WIM) and heavy vehicle monitoring and compliance sites, which also use vehicle detection.

8.3.2.2 Closed Circuit TV Cameras (CCTV)

CCTV provides vision of the motorway, enabling more detailed assessment of conditions than provided by vehicle detection equipment. This is particularly useful for managing unusual conditions such as incidents and planned events. This is also a useful tool in congestion management, such as for the assessment of queue lengths and conditions on arterial roads on the approach to the motorway as well as the ongoing optimisation of tools such as coordinated freeway ramp signals. CCTV images are also shared with key incident and emergency management partners.

8.3.2.2.1 General Requirements for CCTV

- On Urban Motorways, cameras should provide full overlapping coverage of both carriageways and also aim to incorporate video coverage at any key freeway interchange and of ramps with Freeway Ramp Signals, including arterial road approaches to the ramps.
- A camera spacing of approximately 1.5km to 2.0km will generally fulfil the requirements for CCTV cameras on straight freeways, however cameras should be located to ensure that coverage is complete and unobstructed. A closer spacing will be required on freeways with curved alignments or where enhanced monitoring is required. Note that this camera spacing is based on the use of cameras that are capable of full pan, tilt and zoom (PTZ) operation.
- Additional requirements for CCTV cameras, particularly around managed ramps and interchanges is provided in Volume 2, Part 3, Sections 6 and 7.
- For inter-regional and motorways, CCTV cameras are recommended to be provided at interchanges or high risk locations as appropriate.
- CCTV cameras should be placed within 200m of each Variable Message Sign for reviewing and confirmation of displayed messages.

8.3.2.3 Travel Time Tracking

This equipment tracks anonymised vehicle movements for travel time calculations. It may also be useful for determining origin-destination patterns depending on the source, resolution and coverage of the data source.

As an example, data may be sourced from Bluetooth sensors deployed at fixed locations across the road network or from third party data providers that source, process and supply various forms of probe vehicle data.

Data derived from the intelligence function has maximum benefit when used in conjunction with data from other sources, such as weigh-in-motion (WIM) and vehicle detection data. Storage, access and integration of data ideally requires a coordinated approach and are to be considered as part of the Central Control System(s) and foundation infrastructure (refer to Section 8.3.1).

8.3.2.4 Automated Incident Detection

Automated incident detection is recommended for all motorways which have Freeway Data Stations. Automated incident detection using FDS generally does not require additional in-field devices but does require appropriate control system capabilities and potential enhancements for expanding system capability to address emerging complexity in traffic networks. Certain detection technologies may be able to provide richer data measures that can enrich incident detection algorithms, making them faster and more effective in identifying incident conditions. For some higher risk lengths of motorway, varying dedicated technology deployments of incident detection, such as video image processing, may also be appropriate.

8.3.2.5 Environmental Monitoring

This equipment monitors environmental conditions such as temperature and wind speed and other atmospheric conditions, water levels and road surface conditions (e.g. presence of ice). In certain circumstances, environmental monitoring and control systems may be appropriate because of the prevailing weather conditions at the location and can directly activate equipment such as pumps, warning signs or variable speed limits.

On certain motorways in Victoria, ice detection and warning systems and weather stations have been implemented to advise drivers of possible traffic hazards (such as fog, ice, high winds and/ or flooding) and to improve road safety. The West Gate Bridge has an environmental monitoring system which includes monitoring of wind speeds and is an example where environmental conditions are an input to a control function being variable speed limits.

On Managed Motorway sections where the conversion of shoulders into running lanes can result in undesirable flow depths (surface water on pavement) in open traffic lanes for short periods during intense rainfall events. In such cases, suitable environmental detection (potentially based on localised measured rainfall intensity) may be necessary. Measured conditions beyond desired thresholds may prompt a change in speed or lane closure supported by suitable VMS messages.

Given the breadth of applications, limited general guidance is available for environmental monitoring systems, and provision is to be based on the context, risks, potential benefits and costs of individual proposals. Proposals related to ice must consider the Black Ice Management Policy.

8.3.2.6 Help Phones

Help Phones enable motorists to advise or seek assistance from the Traffic Management Centre in relation to incidents or broken down vehicles. VicRoads Help Phones Policy (reference) outlines principles for the consideration and provision of help phones. As many drivers have access to mobile phones, the standards now require fewer help phones than previously provided.

Help phones may be installed to provide motorists with an alternative mean to contact the VicRoads Traffic Management Centre or road operator for assistance where ready access to public phone is not available.

Communications solutions for new help phones should be designed to minimise whole-of-life costs and reflect the low frequency of calls from most of these phones.

8.3.2.6.1 General provision and spacing considerations

Urban Motorways (not including tunnels):

- No provision required where full CCTV coverage, FDS, cellular coverage and Incident Response Services (IRS) are available. Consider decommissioning existing help phones as part of upgrade projects where CCTV, FDS, cellular and IRS coverage will be available. (Removal to be undertaken in accordance with VicRoads Help Phones Policy (Reference)).
- 2km on urban freeways lacking full CCTV, FDS, cellular or IRS coverage.

Inter-regional Motorways:

- 2-5km on rural freeways, depending on CCTV, cellular and IRS coverage

Rural Motorways:

- 5 km spacing should be considered

Tunnels:

- Up to 120m in tunnels.

Provide inside tunnels at spacing of 60-120 metres to provide a higher level of service. Both left and right side and installations are required to avoid the need for pedestrians to cross running lanes

Provide phones for all permanent Emergency Stopping Bays or at emergency cabinets.

Help phones should be installed in pairs, directly opposite each other in the following configuration:

- install phones on the left hand side of the carriageway only where there are up to two full-time running lanes per carriageway,
- install phones on the left and right (median) sides of the carriageway where there are three or more full-time running lanes per carriageway,
- locate phones such that a pedestrian may access a telephone without the need to cross a freeway ramp,
- locate phones so that a road user would not be standing closer than 3.0m to the traffic lane to use the phone (e.g. no emergency stopping lane) and consider widening the area to provide for greater safety and access for mobility impaired persons (refer Standard Drawing SD2091).

The average spacing along a length of motorway should achieve the nominal spacings outlined above as applicable within a tolerance of 10% but within the upper limit for tunnels. Apart from tunnels, individual spacing may be up to 1 km more or less than the nominal in order to avoid the need for pedestrians to cross ramps to get to a phone, or to avoid other practical restrictions on placement of the phones.

8.3.3 Information Tools

8.3.3.1 Variable Message Signs

Variable Message Signs (VMS) provide a range of information to motorists including advice on emergencies, delays, detours, travel times and traffic conditions. VMS on arterial roads can also be used to provide details of motorway conditions to motorists before they enter the motorway.

Variable message signs assist with the control of motorway traffic during incidents or emergencies. They provide motorists with the necessary information to allow them to make informed decisions on route choice based on real-time conditions and future significant planned events. The signs also facilitate safer conditions for personnel undertaking road works and maintenance activities.

Variable message signs should be located to advise the maximum number of motorists about general traffic conditions on the motorway and about alternative routes and provide diversion advice for incidents or significant congestion if appropriate. The highest priority messages on VMS are those requiring immediate action by the motorist, for example, a carriageway or lane closure due to an incident downstream resulting in mandatory merging and / or diversion.

On managed motorways, deployed VMS are able to display incident warnings as well as real time traffic information and travel time information (refer Figure 8-2). These will supersede on-route Trip Condition Signs (TCS) and Trip Information Signs (TIS) for new or upgraded managed motorways and replace TCS and TIS in the long-term. Where VMS are used as a substitute for dedicated travel time signs, the display of travel time must incorporate both the number of minutes to that destination and the appropriate colour and wording (or symbology) indicating Light, Medium and Heavy traffic conditions. The need for both types of information has been demonstrated through public comprehension testing. Where a VMS is to be utilised to provide Trip Information, the design and location principles should be in accordance with the requirements in this section and Managed Freeways Handbook for Lane Use Management, Variable Speed Limits and Traveller Information (VicRoads, 2013).



Figure 8-2: Composite VMS signs showing trip condition and travel time information.

Signs must be sited far enough in advance of decision points (e.g. exits to other major routes) to allow drivers to read and interpret the message, make a decision, and make any necessary manoeuvres based on the message when applicable. However, siting should attempt to avoid the likelihood that drivers forget regular and relevant messages or fail to associate the information with the location or condition on the road to which the messages will apply. For messages that require drivers to make a conscious change in their planned travel, experience suggests that 30 seconds is sufficient time to perform all the necessary tasks in comfort in most circumstances, and that 45 seconds is too long.

8.3.3.1.1 General requirements for locating VMS on motorway carriageways:

- VMS are recommended to cover all decision points associated with motorway to motorway interchanges
- VMS should be placed 900-1200m before a major decision point (absolute minimum 300 m)
- Successive VMS should be no closer than 1000m
- The minimum distance between a VMS and lane control signs/signals should not be less than 200m
- Positioning of VMS needs to consider the proximity of freeway direction signs and other overhead mounted infrastructure used to communicate with drivers spacing. In complex motorway environments positioning needs to consider the proximity, legibility, consistency and comprehension of information that will be presented to drivers from the perspective they will have as they proceed through the network.

8.3.3.2 Real Time Information Signs (RTIS)

Real Time Information Signs (RTIS) provide travel time and condition information for the motorway at the start of the entry ramp. This enables road users to make informed route choice decisions about whether to use the motorway, particularly during incidents or congestion. In relation to Managed Motorways applications, this sign is also referred to as “RC3” on standard drawings for Freeway Ramp Signals associated with surface / arterial roads.

Advance RTIS may also be used in additional locations to those required in this Guide and where it is desired to provide information about motorway traffic conditions. (Note: Advance refers typically to an upstream location for early advice to motorists, not differing technology.) Advance RTIS signs are not required in locations where there is no alternative route prior to the motorway and there are RTIS signs at the motorway entry ramps.

RTIS (RC3) are to be provided at all entry ramps with ramp signals, refer to Volume 2, Part 3: Section 6 of this Guide and Section 4.8.3 of Managed Freeways Handbook for Lane Use Management, Variable Speed Limits and Traveller Information for more details. Travel information signs for Motorway to Motorway metered ramps have separate functions, sign types and positioning requirements (refer Volume 2, Part 3: Section 7).



Figure 8-3: RTIS Sign

8.3.3.2.1 General requirements for locating RTIS:

- Dedicated RTIS signs are provided for all movements into metered ramps at a desirable distance in the order of 80m to 150m prior to the left and right turn lanes at the interchange, subject to consideration of the speed limit.
- RTIS (including Advance RTIS) are mounted at the side of the road and are not generally suitable for advising motorists of conditions that may apply only to the traffic lanes on the far side of the carriageway.
- Advance RTIS should be installed approximately 50 to 100 metres in advance of associated destination signs, thereby separating the more detailed freeway / arterial condition information from the destination sign information. (Refer Figure 8-3)
- In some locations, it may be suitable to provide advance RTIS on both sides of the carriageway, for instance, on divided arterials approaching a full diamond freeway interchange.
- RTIS devices (or variants) are also useful on the broader surface road network where real-time or variable information is communicated to road users but where a full-size VMS may not be warranted or feasible.

The use of RTIS and Advance RTIS signs has replaced the use of Freeway Condition Information panels and signs, previously integrated into static direction signs. RTIS signs provide more information to drivers regarding travel time to select destinations in addition to condition information on the motorway as well as the ability to communicate more detailed messages when applicable.

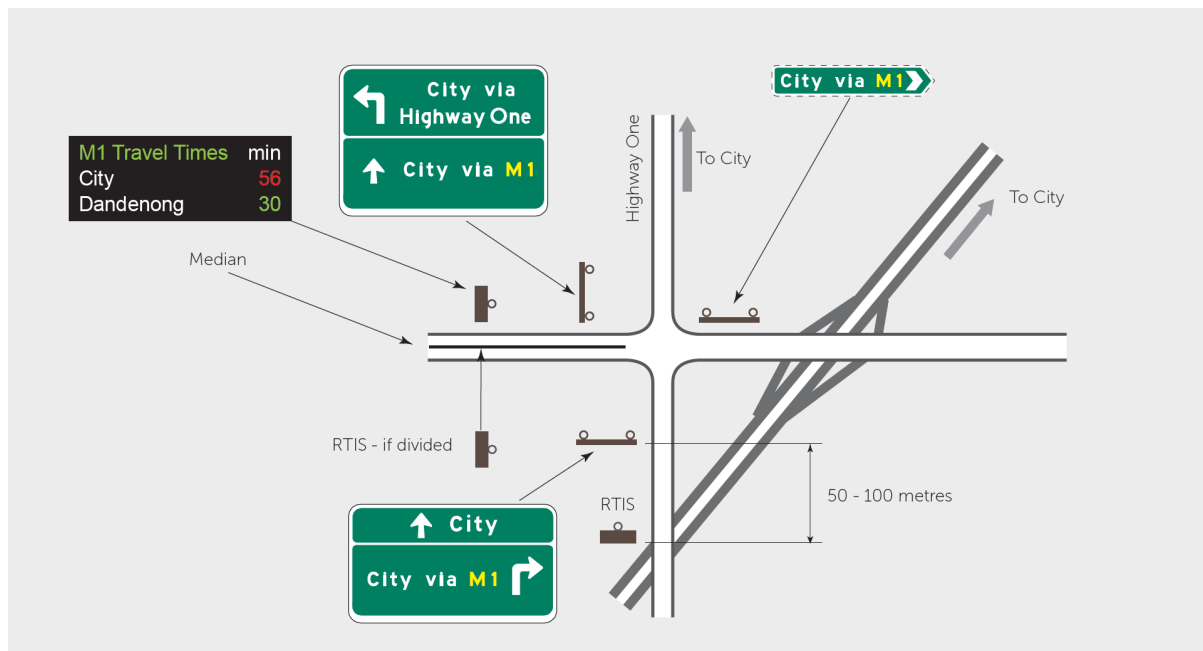


Figure 8-4: Advance Real Time Information Sign – Example Layout

8.3.3.3 Travel Time Information

Real-time travel information is generated by VicRoads motorway control system for utilisation on field devices and for re-broadcast over various physical and digital media. Travel time information is displayed on VicRoads managed signs and also provided to other road operators for display on their devices as appropriate. In relation to motorways, this is provided on VMSs, RTISs and other legacy forms of devices providing traveller information (e.g. legacy Trip Information Signs and Trip Condition Signs).

Travel Time Information can be derived based on aggregated measures from sources that track or re-identify vehicles in an anonymised manner (e.g. Bluetooth or probe vehicle data) or estimated through algorithms using vehicle detector data from freeway data stations (FDS).

Travel time and selected road network condition information is also available to road users through a variety of other channels including:

Website and Mobile Applications

- Travel information provided through digital media, including real-time travel time information and additional content regarding incidents and events, is generally provided for pre-trip planning and should form part of a broader network-wide travel information strategy.

Radio

- Radio messages can reach road users both before and during the trip. This makes them a powerful communication tool, but VicRoads has limited control over the content and timing of messages. Tunnel environments in Melbourne already have radio re-broadcast facilities, enabling the control room to take over the broadcast when necessary.

In-Car Systems

- The use of in-car navigation systems with dynamic routing information is now an increasingly common feature in vehicles on the road network. These systems may use a variety of real-time travel information sources, including travel time information from road operators.

CCTV Images on Digital Media

- Static images are made available on VicRoads website and through mobile applications to enable drivers to see the traffic conditions at key location on the road network and assist with trip planning. These are sourced from a network of dedicated fixed CCTV cameras provide a visual indication of motorway conditions at selected locations.

8.4 Control Tools

8.4.1 Intervention Control

The primary purpose for intervention control tools is to enable road operators to rapidly and effectively manage traffic in the vicinity and on the approach to unplanned incidents or planned events. There are a number of purposes for intervening or managing road traffic conditions which are primarily to provide:

- safer operating conditions and warning for motorists approaching and traversing an affected area, and
- a controlled and safer environment for first responders and other response services required to attend an incident or undertake works within the motorway and associated roadside area.

There are three main intervention actions available to road operators which are:

- Managing speed through changing speed limits to appropriate levels over affected lengths and an appropriate approach buffer,
- Managing access to lanes through lane control at a point and approaching upstream lengths, and
- Restricting access to a motorway carriageway through various ramp control actions, in combination with lane control actions and traveller information to support diversions.

Other controls not discussed in this Guide could include controlled gates allowing transfer of traffic between adjacent motorway carriageways or broader network diversion strategies to reduce demand on motorways during incidents or events.

8.4.2 Variable Speed Limit and Lane Use Management Systems (VSL and LUMS)

8.4.2.1 Variable Speed Limits (VSL)

Variable Speed Limit (VSL) systems can improve road safety and traffic flow by displaying suitable safe regulatory speed limits under different conditions. These conditions can relate to environmental conditions such as wind or rain, incident/event or roadworks conditions, or the density of traffic flow.

VSL systems can also be used to manage speeds to achieve improved traffic flow outcomes under certain operating conditions. A discussion of the impacts of speed on traffic flow and how it could be integrated into control systems alongside complementary optimisation tools is provided in volume 1 Part 2 of this Guide. Changing speeds under some conditions can also have detrimental impacts on traffic flow requiring appropriate understanding and integration in real-time optimisation control tools.

VSL are communicated to motorists by a series of roadside or overhead electronic variable speed limit signs. VSL can also be provided as part of an integrated Speed and Lane Use Management System (LUMS) using overhead signs. Where a VSL system is deployed on a motorway carriageway, VSL signs are also required on the associated entry ramps to advise entering motorists of the applicable speed limit on the main carriageway and particularly in the merge area.

On sections of urban motorway with both VSL and ramp signals, it is expected that ramp signals will play a greater role in optimising productivity, with VSL assisting. VSL would play a primary role in the provision of safe conditions, supported by ramp signals, particularly during management of incidents.

8.4.2.2 Lane Use Management

Application of a Lane Use Management System (LUMS) on urban motorways refers to the allocation and management of available road space to achieve desired performance outcomes. The most common application for urban motorways is expected to be Integrated Speed and Lane Use Management System; other applications can include dynamic use of the shoulder for exit queue storage and priority applications for specified road user classes as described below. The primary devices used for application of integrated VSL and LUMS are overhead mounted Lane Use Signs (LUS) which incorporate speed limit and lane control symbols. Refer Managed Freeways Handbook for Lane Use Management, Variable Speed Limits and Traveller Information (VicRoads, 2013) for more detail.

8.4.2.3 Integrated Speed and Lane Use Management System

Integrated Variable Speed and Lane Use Management provides both speed and lane use control over a motorway carriageway through Lane Use Signs (LUS) providing VSL and lane control functionality.

- Speed limit symbols (speed value with a red annulus, solid or flashing) above lanes indicates the lane is open to traffic and displays an appropriate speed value for the carriageway in relation to the traffic conditions being managed. A flashing annulus indicates that the speed limit has been reduced from the section default speed due to an intervention action being applied (manual or dynamic).
- A red cross over a lane indicates the lane is closed over the full distance to the next overhead sign location.
- Merge symbols (angled arrows pointing down to the left or right) indicate traffic must merge in the direction of the arrow. The signal indicates the applicable lane is closed at the next downstream overhead sign location.
- Exit symbols (angled arrow pointing up to the left or right) indicates that drivers in the lane must exit at the next exit ramp associated with the direction of the arrow.

The Managed Freeways Handbook for Lane Use Management, Variable Speed Limits and Traveller Information (VicRoads, 2013) sets out placement requirements for LUMS gantries. Integrated Speed and Lane Use Management signs and systems are not utilised for arterial roads or reversible lane facilities that do not have rigid barriers separating opposing traffic.

Real-time management of lane use (for incidents or unusual conditions) is most effective when a reduced speed limit applied to lanes remaining open. This provides a higher level of safety for people on the road in a closed lane – such as road workers, incident responders and others involved in incidents.

The use of integrated lane control and/or VSL near roadworks and incident conditions can support the provision of a safe working environment; however, these control tools should not be used in place of appropriate traffic management measures required for managing worksite safety and access.

8.4.2.4 General Requirements for the Provision of VSL and LUMS

General requirements for VSL and LUMS as system control tools are provided below. Further information regarding siting and spacing of VSL and LUS/LUMS gantries along motorway corridors is provided in the Managed Freeways Handbook for Lane Use Management, Variable Speed Limits and Traveller Information (VicRoads, 2013).

Enhancement projects to deploy VSL and/or LUMS on existing motorways can be the subject of a business case identifying:

- enhanced safety,
- enhanced incident response,
- enhanced support for planned events,
- improved capacity from all lane running, and
- utilisation for optimisation and advanced safety functions (i.e. Dynamic VSL and back of queue protection).

Overhead mounting of VSL and integration with LUMS should be provided when the carriageway has:

- All lane running operation, either through repurposing of existing shoulder(s) or widening of a carriageway without the provision of full width shoulders (e.g. shoulders < 3m)
- Four or more lanes (with or without shoulders),
- Locations where shoulders are opened and closed manually or dynamically for utilisation as a running lane, or
- Three lanes combined with high truck volumes (say, more than 900 trucks/h) or there is a desire to dynamically manage vehicle speeds.

The provision of overhead integrated VSL and LUMS is strongly recommended as part of an urban motorway capacity upgrade project, or provision of new urban motorway links. Undertaking the civil works and structural provisions for power and communications and overhead lane control signs is more cost effective during major construction than deploying dedicated LUM signs and supporting infrastructure at a later stage when considering whole of life costs and disruptions savings.

Extensive utilisation over many years on the Melbourne urban motorway network and the ability to more safely manage traffic has demonstrated the effectiveness of integrated VSL and LUMS. Consistency of treatments and operation across the motorway network are highly desirable and creates common conditions across all motorways with clear expectations conveyed to drivers. Accordingly, provision of LUMS on three-lane urban motorway carriageways is highly desirable. Interregional and two-lane urban motorways with shoulders may be more amenable for management using side mounted VSL, although LUMS may also be considered with appropriate justification and benefit realisation.

Where VSL signs are provided overhead, including as part of a lane use management, the same speed limit shall apply to all lanes that are part of the common carriageway. (i.e. Differential speeds are not permitted across lanes on a common carriageway, being a carriageway where lanes are separated only by line marking or penetrable separator.)

Where multiple carriageways are provided for traffic in the same direction (e.g. collector-distributor or separated limited access carriageways) and VSL functionality is provided, signs should be mounted overhead for all carriageways to avoid confusion that may be associated with side mounted signs. In some cases, adjacent carriageways may have less than three lanes, however, overhead mounting is still desirable and utilisation of a common structure over multiple carriageways may be appropriate.

8.4.3 Restricting Access to a Section of Motorway

The ability to close entry ramps to restrict traffic access to a motorway is integrated into the functionality of freeway ramp signals and is achieved through the utilisation of ramp control signs (RC1) located at the ramp terminal intersection at the start of entry ramps. Where the terminal intersection is controlled by traffic signals, dedicated phases are utilised to restrict movements onto the entry ramp (such as right and left turn movements) complement regulatory restrictions on RC1

signs. This may require signalised control of left turn slip lanes. Traveller information on RTIS (RC3) and other information systems also supports entry ramp closures.

A full motorway carriageway closure can be implemented through the application of lane closures on all running lanes. Full carriageway closures require stepped closure of lanes over an appropriate distance, supported by merge symbols, reduced speeds and traveller information upstream of the managed/restricted area.

On multi-carriageway motorway facilities or where a motorway has a major fork / carriageway separation, access to a restricted motorway section can be achieved through lane closures using LUMS in advance of carriageway connectors or the fork location. Display of lane closure symbols over all running lanes at the start of a separate carriageway or ramp indicates a full closure.

8.5 Network Optimisation Control

8.5.1 City Wide Coordinated Ramp Metering

Freeway Ramp Signals (FRS) are traffic signals that manage access to the motorway, to prevent capacity being exceeded (and subsequent flow breakdown), by breaking-up platoons of entering vehicles to avoid overload of the merge area. FRS are most effective when implemented as a city and corridor-wide adaptive system (City Wide Coordinated Ramp Metering (CWCRM)), providing full demand control of motorway corridors and networks to achieve high levels of efficiency while providing an effective means to manage queues at entry ramp signals.

CWCRM provides an effective means of managing and optimising motorway traffic flows to minimise the likelihood of mainline traffic flow breakdown and achieve more stable traffic flows that improve safety and throughput and reduce and travel times and travel time variability.

CWCRM uses a suit of dynamic algorithms that makes a combined decision based on data from the motorway and a number of entry ramps. This operation is able to regulate the entry of traffic from a number of ramps to address the overall motorway objectives and to regulate demand and balance flows between ramps. **Freeway Ramp signals necessitate freeway data stations to feed the adaptive algorithms and CCTV along the motorway to monitor conditions on motorway carriageways and ramps.**

Further detail information outlining the ramp metering principles, operational modes, strategies and benefits are provided in Volume 2, Part 2 of this Guide. Layout, design and infrastructure requirements associated with FRS / CWCRM are provided in Volume 2, Part 3 of this Guide.

The efficiency benefits achieved through the avoidance of flow breakdown mean that total journey times should be lower than in an unmetered situation. At locations where ramp queues formed prior to the installation of metering, ramp waiting times may also reduce although public perceptions may not reflect this. There are two types of ramp signals installation:

- isolated metering of a single entry ramp
- coordinated route-based treatment, providing effective control of the motorway by metering all entry ramps and allowing effective management of space available for queue storage.

Isolated metering has only limited applicability in the Melbourne urban environment, and a route based treatment will be required:

- where the congestion and flow breakdown is occurring over a length of motorway; or
- where flow breakdown occurring at a particular location cannot be addressed by an isolated ramp meter, i.e. the motorway flow causing the flow breakdown results from a combination of a number of upstream entry ramps.



Figure 8-5: Freeway Ramp Signals – Including Ramp VSL Integration with Mainline LUMS and Co-location of ITS Assets

It is important to note that in a route based treatment, even those individual entry ramps that do not meet the criteria for isolated ramp signals still require metering. If this complete treatment is not provided, access equity cannot be achieved and rat-running behaviour will be encouraged. Access equity is provided through balancing queues across multiple ramps, efficiently utilising available system storage space and managing wait times. To achieve this, metering of all ramps are required including minor entries from Service Centres, other facilities or developments with direct ramp access and connections from local roads (roads and accesses that are not Declared Arterial roads). Leaving even one entry unmanaged can severely compromise the control of a motorway and result in flow breakdown and significantly reduced operational capacity of the motorway corridor and broader network for many kilometres upstream and downstream of the impacted motorway section.

8.5.1.1 General Requirements for Provision of Freeway Ramp Signals:

- Provided on ramps where main carriageway volume warrants outlined in Table 7.1 are met downstream of the ramp entry for the applicable motorway category,
- To complete route-based treatments where upstream or downstream ramps along the motorway are currently metered,
- Where flow breakdown already occurs on the motorway regularly (once per week) and traffic volumes are below the volume warrants in Table 7.1,
- Provided on ramps upstream of recurrent operational bottlenecks (identified through analysis) to support ramp metering operations in a coordinated manner. Refer to Volume 2 Part 3: Section 4.4.5 regarding the provision of ramp signal sites as part of a Partially Managed Transition Zone (PMTZ),
 - Up to 10 controlled ramps may be required to provide “fully managed” conditions with respect to a 5 lane cross section.

- Priority lanes may be considered on entry ramps and must be metered.
 - Designation for priority access is via vehicle class in accordance with regulatory provisions, such as public buses, trucks and high occupancy vehicles and may be considered for preferred or designated routes, to reduce queuing delays to these vehicles (refer to Volume 2, Part 3: Section 6.8).

8.5.1.2 General Requirements for Motorway-to-Motorway Ramp Signals

The general principle for optimising route performance is to control and regulate all traffic entering a managed motorway, including traffic from motorway-to-motorway (system) ramps which are generally high flow ramps which have the potential for delivering large uncontrolled flows to bottleneck areas. The coordinated ramp signals system is then able to best manage flow to an optimum level along the whole route and coordinate the operation at all ramps to balance priority, equity of access, queues and waiting times.

Provision of a motorway-to-motorway ramp meter shall always be provided in conjunction with upstream and / or downstream ramp meters from surface roads (entering the same carriageway as the metered motorway ramp) to provide a system response and support the motorway-to-motorway ramp operation. Managed motorway design and operations shall not rely on an isolated motorway-to-motorway ramp meter to control bottlenecks.

In some cases, traffic demands on motorway-to-motorway connections may be too high to safely and efficiently meter – typically where motorway branch connections come together. In such cases, metering of demands is achieved through the provision of ramp meters on entry ramps from surface road upstream of the motorway-to-motorway connection.

Further requirements, details and considerations for metering motorway-to-motorway connections are provided in Volume 2, Part 3: Section 7. A summary of key factors for inclusion when designing metered motorway-to-motorway connections is provided below.

- The need to provide an adequate number of stand up lanes at the metering stop line to ensure discharge flows can meet demand,
- The need to provide no less than desirable storage, and a preferably more where achievable for modest investment'
- Locating and designing storage areas to minimise the likelihood of queues impacting other free-flow movements within interchanges or on upstream motorway carriageways,
- Provision of variable speed limits, lane control and advisory signs approaching motorway-to-motorway ramp signals to control speeds and to prepare drivers to navigate queue storage areas.

8.6 Other Facilities and Actions Supported by Foundation and Control Tools

8.6.1 Priority Access Lanes

A managed motorway environment includes the objective of stable, efficient traffic flow on the motorway. Consideration may be given to providing dedicated, class restricted metered priority lanes on entry ramps for public buses, trucks, or in some cases high occupancy vehicles on preferred or designated routes, to reduce queuing delays to these vehicles. Priority access lanes on entry ramps (discussed in Volume 2, Part 3: Section 6.8) can provide significant real (as well as perceived) priority for these road user classes without adversely affecting the overall productivity of the motorway. Where motorways terminate at arterial roads which have a capacity deficit (e.g. the Eastern Freeway at Hoddle Street), priority lanes may be considered on the motorway as a form of extended queue jump facility. The impacts of mainline special use lanes and preferred alternative treatments are

discussed in Volume 2, Part 3: Section 4.3.2.11 and are generally discouraged due to significant impacts on safety and efficiency.

8.6.2 Motorways without Emergency Stopping Lanes

Principles for the deployment of traffic and safety facilities on sections of motorway with no Emergency Stopping Lanes (ESL) available (either full-time or part-time) are outlined below.

- Minimise the chance of crashes and vehicle breakdowns occurring.

The lack of an ESL can increase the risk of crashes involving vehicles stopped or stopping due to a breakdown and can increase the consequences of any crashes or breakdowns.

- Clear any incidents as quickly as possible and minimise localised impacts throughout incident duration.

If an incident occurs in a traffic lane, there will be considerable traffic congestion and a greater chance of secondary crashes.

Incident management strategies may require implementation of staged plans that can assist emergency services accessing incident locations and relocating impacted road users to safer positions within the carriageway.

Managing Traffic Around an incident

Where an ESL is not available, a broken-down vehicle will adversely impact traffic flows, due to the blockage of a traffic lane and the turbulence caused by drivers changing lanes to get around the obstruction. To avoid the greater chance of secondary crashes, approaching drivers need to be alerted and diverted away from the affected location as early as practicable.

Providing a Transition Process

Where an ESL operates on a part-time basis, a process must be implemented to ensure that there are no safety hazards or risks present, such as stopped vehicles or significant objects, when the lane changes from an ESL to a traffic lane.

Combined Treatments

For sections of motorway without Emergency Stopping Lanes, the following measures should be considered:

- Provision of Integrated Speed and Lane Use Management System (LUMS),
- Emergency Stopping Bays (ESB) typically at 500m spacing or practicable,
- Vehicle detection for all emergency stopping bays (ensuring technology is provided and located to ensure stationary vehicles do not impact the ability to accurately detect other movements on the associated carriageway),
- CCTV coverage including all emergency stopping bays and any areas under bridges or other structures that may obscure stationary objects,
- Automated Incident Detection with appropriate abilities and high sensitivity,
- Liaison with Emergency Services to ensure that appropriate response strategies are developed and understood,
- Dedicated and funded motorway Incident Response Services (IRS) with Traffic Management Centre (TMC) support and monitoring

8.6.3 Part-Time Facilities

Part-time facilities may include changed use of a lane (e.g. switching between running lane and ESL) through signs specifying utilisation during particular times of the week / day or preferably through Lane Use Signs (LUS) managed through the motorway control system.

Extended lengths of part-time lane use by general traffic should desirably be managed using LUMS. Specialised applications such as use of ESL for exit queue storage (over short lengths), or by priority vehicles (buses using ESL during peak periods), may be signed rather than managed with LUS, provided the conditions are invariant. Any part-time facilities that continue across entry and exit points require careful design to ensure safe operation that is easily understood by drivers.

Part-time use of the ESL for exit queue storage can improve safety and traffic flow by relocating stationary vehicles out of the path of moving traffic. In some cases, this will formalise arrangements that are ongoing practice approaching the exit, improving safety by better managing such ongoing practice.

Part-time facilities are to be provided only on a needs basis. Exit queue storage treatments should be considered where queues from the exit frequently overflow the exit ramp and suitable arrangements can be implemented.

Where part-time facilities are provided, detection shall also be provided to ensure traffic flow conditions are able to be monitored and measured (i.e. provide vehicles detection across all lanes including the ESL used for part-time operations).

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