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Smart Freeways

Policy Framework Overview

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Smart Freeways Policy Framework Overview

This document is authorised by the Executive Director Network Operations. Please submit all comments and requests to the Network Operations Planning Manager.

Authorisation

As Executive Director Network Operations I authorise the issue and use of this document Smart Freeways Policy Framework Overview.

MEHDI LANGROUDI

Approved by **Executive Director Network Operations**

Date: 7 AUG 2025

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Preface

Smart Freeways policy and guidelines

The Main Roads Western Australia's (Main Roads) Smart Freeways policy and various guidelines influence overall planning, project development, delivery and ongoing operation of Smart Freeways in Western Australia.

The Smart Freeways documents were originally developed as part of the Managed Freeways Policy Framework in 2012. At that time Main Roads used the term 'Managed Freeways', which was changed to 'Smart Freeways' during the first Smart Freeways project on Kwinana Freeway northbound. Major revisions to these documents were undertaken in 2020, and new versions of the Smart Freeways Guidelines were issued in March 2021. After subsequent years of Smart Freeways projects and operations in Western Australia, further revisions to these guidelines were undertaken in 2024. These new versions of the guidelines were then issued in 2025.

Historically, intelligent transport systems (ITS) on freeways were typically considered case by case. Our current approach is outlined in the Smart Freeways policy, which states that all freeways are considered for ITS provision at either Freeway Type F (Foundation) or Smart Freeway Type C, B or A standard according to these guidelines.

Main Roads Smart Freeways policy and guidelines comprise the documents listed in the table below. This document is shown highlighted.

Document	Description
Smart Freeways Policy	One-page high-level policy statement setting out Smart Freeways objectives and principles.
Smart Freeways Policy Framework Overview	Smart Freeways context, principles, corporate governance, processes and intended outcomes to achieve policy objectives.
Smart Freeways Provision Guidelines	Guidelines and warrants for application of Smart Freeways traffic management treatments and ITS devices.
Smart Freeways Operational Efficiency Audit Guidelines	Guidelines for formal examination of traffic analysis and design of all freeway projects.
Guidelines for Variable Message Signs	Guidelines for the design and use of variable message signs for traveller information for safe and efficient travel for road users.
Supplement to Victoria's Managed Motorway Design Guide, Volume 2: Design Practice, Parts 2 and 3	Main Roads supplement relating to: • network optimisation tools (benefits and operation of coordinated ramp signals) • planning and design for mainline, entry ramps (including ramp signals), exit ramps and interchanges.
Supplement to Victoria's Managed Freeways Handbook for Lane Use Management and Variable Speed Limits	Main Roads supplement relating to: • Lane use management system (LUMS). • Variable speed limits (VSL).

Smart Freeways concept

Smart Freeways make the best use of the existing freeway network, particularly during times of high demand and traffic incidents. We use ITS and operational strategies that enable dynamic network management and operation in real-time. Smart Freeways traffic management initiatives, complemented by appropriate mainline and ramp geometric improvements, work together as an integrated system to achieve and maintain optimal freeway traffic conditions with minimal delays and congestion.

Over recent years, Victoria's approach to managed motorways in Melbourne has achieved unparalleled, sustainable benefits to freeway operations for safety, productivity, efficiency and reliability. We have applied the same holistic principles and learnings, while also working towards national consistency.

Smart Freeways design and operations should consider both the perspective of the road user and the road operator:

- **Road user** – Smart Freeways provide a better driving experience and meet the road user's expectations for safe and reliable travel on a preferred traffic route.
- **Road operator** – Smart Freeways meet the road operator's need for the most efficient and productive use of existing and proposed freeways through real-time monitoring and effective control of traffic.

Background and concept

Freeways are essential infrastructure for Western Australia's economy, providing for the safe and efficient movement of people and goods. Freeways and high standard arterial roads comprise 27 per cent (or 201 km) of the metropolitan state road network (746 km), yet include 54 per cent of the total vehicle kilometres travelled (VKT) in the AM peak and 57 per cent of total VKT in the PM peak.

The Department of Planning, Lands and Heritage forecast a population of 3.5 million people in the Perth and Peel areas in 2050 (*Perth and Peel@3.5million* report, 2018). It is expected that significant levels of traffic growth will occur, and this could cause increasing congestion which would adversely impact social and economic activity in Western Australia. The Infrastructure Australia *Urban Transport Crowding and Congestion* report (*Australian Infrastructure Audit 2019* - Supplementary report), predicts that the cost of congestion in Perth will increase from $1.53 billion in 2016 (2019 Audit) to $3.62 billion in 2031 (2019 Audit). Main Roads is exploring opportunities to maximise the use of new and existing infrastructure assets using Smart Freeway technology to improve operational efficiency and accommodate future traffic demand, whilst minimising the need for costly network expansion.

Smart Freeways is a concept proven worldwide to deliver best outcomes for both the road user and the road operator. This is through sustained and safe use of the full productive capacity of the asset.

Smart Freeways concept – Making the best use of the existing freeway network, particularly during times of high demand and traffic incidents. This is realised through the application of intelligent transport systems and operation strategies that enable dynamic network management and operation in real-time. Smart Freeways treatments, complemented with appropriate mainline and ramp geometric improvements, work together as an integrated system to achieve and maintain optimal freeway traffic conditions with minimal delays and congestion.

Main Roads will implement Smart Freeways technologies on their freeway network based on coordinated ramp signals (CRS) as the primary control mechanisms to prevent or delay flow breakdown. CRS are considered to be the most effective management technology to achieve high levels of travel efficiency, productivity and reliability. They have proven to be effective in sustaining capacity during peak periods and reduce inefficiencies caused by flow breakdown.

Additional technologies that have a key role in achieving a safe and high-performance freeway environment with informed road users are all lane running, variable speed limits and lane use management, supplemented by real-time traveller information and incident management systems.

Smart Freeways support traffic operators and road asset managers in carrying out their responsibilities for effective road network operations. The improvements in transport efficiency result in social, economic and environmental benefits to road users and the wider public.

The Smart Freeways policy is fully aligned with Main Roads' strategic direction, Keeping WA Moving, with areas of focus on customers, movement, sustainability and safety. It is further driven by state and federal government strategies and initiatives including the National Road Network Optimisation Program, listed as a high priority initiative in the Infrastructure Australia 2019 Infrastructure Priority List.

Smart Freeways policy

Main Roads is progressively introducing Smart Freeway solutions into our existing and future road assets, aiming to provide the safest and most reliable, productive and resilient state roads for our customers.

Policy objectives

Our objectives are to create a world-class Smart Freeways system for:

- reliable travel times
- efficient movement of people and freight
- improved network productivity contributing to the state's economic prosperity
- improved safety of all road users including road workers
- reduced congestion, emissions and cost of travel
- additional capacity from the existing network through targeted improvements and using appropriate technology
- improved network resilience and flexibility to meet abrupt change in demand or available capacity due to incidents
- enhanced real-time information to improve the customer travel experience
- connected and automated vehicles aligned with national guidance.

Policy principles

This policy is underpinned by the following principles:

- Solutions will be guided by this policy and Smart Freeways guidelines, which are aligned with best practice guidelines as appropriate.
- Smart Freeways are to be part of an integrated transport system and aligned with long-term network planning.
- Smart Freeway solutions will be designed to address specific performance issues identified by network analysis and based on robust data.
- All ITS solutions will take into consideration national ITS architecture, systems engineering, whole-of-life costs and proven technologies.
- Planning and design decisions will consider the potential impacts of connected and automated vehicles as they emerge.
- All Smart Freeway designs will be subject to operational efficiency audits.
- All freeways will, as a minimum, have real-time network monitoring capability and intelligence, and provision for Smart Freeway Type C, B or A treatments when needed. Refer to section 5 of the *Smart Freeways Provision Guidelines* for the definition of these Smart Freeway types.
- Customer perspective and education are essential to the solution.
- We will confirm objectives and benefits through on-going performance monitoring, evaluation and operational fine tuning.
- We will encourage innovation and development of skills and expertise through research and development trials, as well as strategic partnerships with other road agencies, industry, research institutions and universities.

Governance

There is shared responsibility across Main Roads for the Smart Freeways documents, as well as for Smart Freeways planning, design and implementation as outlined in Section 5.

Network application

All existing and future freeway-standard roads in Western Australia will be progressively upgraded to Smart Freeways as appropriate, following detailed network analysis and on a prioritised basis as funding allows. In the short-term, the focus will be on current and programmed freeway projects and congested sections of the network.

Abbreviations

ALR	All lane running
AID	Automatic incident detection
BDC	Basis for design and construction
CCTV	Closed circuit television
CRS	Coordinated ramp signals
DE	Design exceptions
EDD	Extended design domain
ICT	Information and communications technology
IRS	Incident response service
ITS	Intelligent transport systems
LUMS	Lane use management system
NDD	Normal design domain
NOPF	Network operations planning framework
PTA	Public Transport Authority
RNOC	Road Network Operations Centre
RTTO	Real-time traffic operations
SF	Smart Freeways
SWTC	Scope of works and technical criteria
TDE	Technology design exceptions
TPF	Transforming Perth freeways
UPS	Uninterrupted power supply
VDS	Vehicle detection station
veh/h	Vehicles per hour
VMS	Variable message sign
VSL	Variable speed limits
WA	Western Australia

1 Introduction

1.1 Smart Freeways policy framework overview

The Main Roads Western Australia (Main Roads) Smart Freeways policy and various guidelines, collectively referred to as Smart Freeways Policy Framework, influence overall planning, project development, delivery and ongoing operation of Smart Freeways in Western Australia.

The Smart Freeways policy and associated guidelines were originally developed as part of the Managed Freeways Policy Framework in 2012. At that time Main Roads used the term 'Managed Freeways', which was changed to 'Smart Freeways' at the time of the first Smart Freeways project on Kwinana Freeway northbound. The 2020 updated documents supersede the previous Managed Freeways documents.

Historically, ITS on freeways were typically considered case by case. Our current approach is outlined in the *Smart Freeways Policy*. It states that all freeways are considered for ITS provision at either Freeway Type F (Foundation) or Smart Freeway Type C, B or A standard according to these guidelines.

Main Roads' Smart Freeways policy and guidelines comprise the documents listed in Table 1.1 below. This document is shown highlighted.

Table 1.1: Smart Freeways policy framework documentation

Document	Description
Smart Freeways Policy	One-page high-level policy statement setting out Smart Freeways objectives and principles.
Smart Freeways Policy Framework Overview	Smart Freeways context, principles, corporate governance, processes and intended outcomes to achieve policy objectives.
Smart Freeways Provision Guidelines	Guidelines and warrants for application of Smart Freeways traffic management treatments and ITS devices.
Smart Freeways Operational Efficiency Audit Guidelines	Guidelines for formal examination of traffic analysis and design of all freeway projects.
Smart Freeways Variable Message Signs Guidelines	Guidelines for the design and use of variable message signs for traveller information for safe and efficient travel for road users.
Supplement to Victoria's Managed Motorway Design Guide, Volume 2: Design Practice, Parts 2 and 3	Main Roads supplement relating to: • Network optimisation tools (benefits and operation of coordinated ramp signals). • Planning and design for mainline, entry ramps (including ramp signals), exit ramps and interchanges.
Supplement to Victoria's Managed Freeways Handbook for Lane Use Management and Variable Speed Limits	Main Roads supplement relating to: • Lane use management system (LUMS). • Variable speed limits (VSL).

1.2 Purpose of this document

This document expands on Main Roads' corporate Smart Freeways policy. It is designed to provide a high-level statement of intent and principles to govern decision-making for active management of the freeway network and considers all phases from planning to ongoing operation and maintenance. It seeks to ensure all Smart Freeways projects are complementary and aligned to achieve a common vision and outcomes, and should be referred to at an early stage for all projects on existing and future freeway routes in Western Australia.

The document covers the following key topics:

- background and policy context
- intended outcome and objectives
- policy principles
- governance and network application for design, implementation, operations and maintenance.

A description of the definitions used in the document is included in Appendix A.

1.3 Consultation

This policy framework overview has been developed in consultation with key stakeholders across Main Roads and will be reviewed and updated on a regular basis by the designated custodian (Section 5.1.1).

The development of this document has considered the relevant guidance provided by Austroads and Infrastructure Australia, as well as the policy approaches taken by a number of other Australian and overseas jurisdictions, that are developing Smart Freeways or already have Smart Freeways in operation. This includes Victoria, New South Wales and Queensland in Australia, as well as the UK and the Netherlands.

2 Background

2.1 Need for smart freeways

Freeways[1] are essential infrastructure for Western Australia's economy, providing for the safe and efficient movement of people and goods. As of September 2024, freeways and high standard arterial roads comprise 27 per cent (or 233 km) of the metropolitan state road network (866 km), yet include 51 per cent of the total vehicle kilometres travelled (VKT) in the AM peak and 50 per cent of total VKT in the PM peak.

Freeways need to be designed to provide free-flowing high-speed environments, as they are the most productive and highest capacity road asset. They are important assets for Western Australia's economy, providing for the movement of people and goods throughout the urban areas.

Western Australia is expected to experience significant increased economic activity and population growth over the next decade and beyond. The Department of Planning, Lands and Heritage forecast a population of 3.5 million people in the Perth and Peel areas in 2050 (*Perth and Peel@3.5million* report, 2018). It is expected that significant levels of traffic growth will occur, and this could cause increasing congestion that would adversely impact social and economic activity in Western Australia.

The Infrastructure Australia *Urban Transport Crowding and Congestion* report (*Australian Infrastructure Audit 2019* - Supplementary report) on congestion (2016) estimates the 'avoidable' cost of congestion, that is without continued action, for the Australian capitals to be approximately $19 billion for the 2016 financial year and predicted this cost to rise to $39.6 billion by 2031. For Perth, this corresponds to a rise from $1.53 billion (2016) to $3.62 billion (2031). The Western Australian Government has committed to supporting the economic prosperity of the region by improving traffic flows and managing congestion on the freeway network.

Expansion of the freeway network to provide additional capacity is not always a feasible or the most effective solution to address congestion and accommodate current and projected traffic demands. The availability of land and funding may be insufficient for implementing the required infrastructure improvements, and projects may not be aligned with community expectations of liveability and sustainability. Additionally, traffic flow characteristics cause unmanaged freeways to perform worse when demand is highest (that is during peak periods), making them more vulnerable to flow breakdown, congestion and incidents. Management and operation technologies are required for Western Australia's freeway network to operate at an optimal capacity and safety level.

Main Roads is committed to identifying management and operation solutions that reduce congestion and improve the productivity and efficiency of existing freeway infrastructure. This will enable the extraction of additional operating capacity from the freeway network to cater for increasing demand and to sustain performance during periods when demand is highest.

[1] Freeways are defined as highways with no access for traffic between interchanges and with grade separation at all intersections. All roads that are to be upgraded to planned freeway standard will also be considered for Smart Freeway design and ITS technologies.

2.2 Smart Freeways concept

ITS provide opportunities to improve network efficiency through technologies incorporating equipment deployed on the roadside and operating systems. The integrated application of ITS technologies and operational strategies to the freeway network, referred to as Smart Freeways[2] has been adopted as a proven and cost-effective solution to improve freeway performance in Australia and worldwide.

Smart Freeways concept – Making the best use of the existing freeway network, particularly during times of high demand and traffic incidents. This is realised through the application of ITS and operation strategies that enable dynamic network management and operation in real-time. Smart Freeways treatments, complemented with appropriate mainline and ramp geometric improvements, work together as an integrated system to achieve and maintain optimal freeway traffic conditions, with minimal delays and congestion.

Smart Freeways help traffic operators to improve road safety and 'keep traffic moving' by actively managing mainline traffic flow, traffic demand, congestion and incidents. They also ensure that the full productive capacity of freeways is used, particularly during times of high demand incidents.

The Australian approach to an actively managed (smart) freeway network incorporates technological and operational technologies to provide a safer and more reliable level of service for the network. Access control to the freeway with coordinated ramp signals is identified as the most effective management tool to achieve high levels of travel efficiency, productivity and reliability. Coordinated ramp signals have proven to be effective in sustaining capacity during peak periods by preventing, or delaying, the onset of flow breakdown and congestion. They also assist in recovery following flow breakdown.

Additional technologies that have a key role in achieving a safe and high-performance freeway environment are all lane running, variable speed limits and lane use management, supplemented by real-time traveller information and incident management systems. To achieve the best outcomes of these systems and provide road users with timely and relevant information on freeway conditions, network intelligence through real-time data collection and surveillance is also essential. This requires technologies such as closed-circuit television (CCTV) cameras, vehicle detection systems and automated incident detection (AID) for faster incident management. A description of key Smart Freeways technologies considered for deployment on Western Australia's freeway network is included in the *Smart Freeways Provision Guidelines.*

Smart Freeways technologies have been implemented in Australia through Victoria's M1 Project and are delivering demonstrable benefits and improvements in freeway safety, throughputs and travel speeds (see summary in *VicRoads Managed Motorway Design Guide, Volume 2:* Design Practice, Part 2 Managed Motorway – Network Optimisation Tools – Section 6, 2019).

At the federal level, Smart Freeways initiatives are being encouraged by Infrastructure Australia (IA) which lists the National Road Network Optimisation Program as a high priority initiative in the Infrastructure Australia 2019 Infrastructure Priority List. The federal government is investing $4 billion

[2] Smart Freeways is the term that has been adopted in Western Australia. The Australian Federal Government, Victoria, NSW and Queensland use the term Managed Motorways.

over the next 10 years in the Urban Congestion Fund, which is funding projects such as the Transforming Perth's Freeways Program, which includes widening as well as Smart Freeways technology. IA recognises that continued investment is needed across the transport network to ensure high quality, well integrated and reliable services are delivered. Infrastructure Australia (2019) believes that to address the problem of urban congestion across road corridors in Australia's capital cities, investment is required in initiatives that are focused on productivity enhancing network optimisation, as well as continued investment in new capacity.

Main Roads has developed the Smart Freeways concept in Western Australia to identify opportunities for addressing existing and forecasted problems on the freeway network and delivering benefits to road users. Smart Freeways are seen as an important initiative within the broader transport planning objectives of Main Roads and the state government, and will be a major driver in the future development of Main Roads network operation services. The policy context for Smart Freeways in Western Australia is detailed further in the following section.

2.3 Policy context

There are many drivers for the implementation of Smart Freeways in Western Australia, from both state and federal government levels. The *Smart Freeways Policy* (see Appendix B) reflects the priorities for the development of Western Australia's freeway network within the context of the wider Western Australia and national transport network.

The Smart Freeways Policy is intrinsically linked to broader transport planning and Main Roads corporate strategies,. This ensures it is built from strong fundamental principles that are at the core of Main Roads corporate vision, while also supporting network management and operations service delivery objectives for the entire strategic road network.

To ensure consistent application of standards, principles and governance in Western Australia, the requirements in this *Policy Framework Overview, Provision Guidelines* and other design guidelines applies to planning, detailed design and construction across all freeways. The Smart Freeways Policy Framework documents are applicable to all projects within Main Roads, as well as to work carried out by consultants, contractors and potential future road operators. This is irrespective of how the project is being delivered or operated and, for example, includes projects that are related to design and construct, alliance and public-private partnerships, as applicable.

The strategic context for Smart Freeways implementation in Western Australia is illustrated in Figure 2-1.

Common theme: Making the best use of existing infrastructure

National Transport Network	WA Transport Network	WA Freeway Network
Priority: Investment in a national transport network that supports productivity, livability and sustainability outcomes	**Priority:** Development of an integrated transport system for WA, providing for efficient, safe movement of people and goods	**Priority:** Real-time management and operation of freeways to optimise performance of the state transport network
Key Australian Government strategic documents: *Our Cities, Our Future* (Department of Infrastructure and Transport 2011) *Communicating the Imperative for Action* (Infrastructure Australia 2011a) *National Managed Motorways: The Foundations for Smart Transport Infrastructure* (Infrastructure Australia 2011b) *National Land Freight Strategy Discussion Paper* (Infrastructure Australia 2011c)	**Key WA Government strategic documents:** *Directions 2031 and Beyond* (Western Australian Planning Commission 2010) *Perth & Peel @ 3.5 million* (DoPLH , 2018) *Perth & Peel @ 3.5 million: Transport Network* (DoT, Main Roads, PTA, 2018) *Zero WA Roads Death* *Driving Change, Road Safety Strategy for Western Australia 2020-2030*	**Key Main Roads strategic documents:** *Keeping WA Moving* (Main Roads, 2018) *Road Safety Management Policy ROSMA* (Main Roads, 2016) *ITS Masterplan 2022-2030* , (Main Roads, 2024) *Information Management and Technology Strategic Plan 2014* – 2020 (Main Roads, 2014) *Crisis and Incident Management Policy* (Main Roads 2019) *Strategic Asset Management Plan 2018-2022* (Main Roads, 2019)

Driven by
Contributes to

Figure 2-1: Strategic context for Smart Freeways in Western Australia

3 Intended outcomes and objectives

3.1 Smart freeways policy

Main Roads is progressively introducing Smart Freeway solutions into our existing and future road assets, aiming to provide the safest, and most reliable, productive and resilient state roads for our customers. The policy is attached in Appendix B.

This will be achieved through considered application of Smart Freeways technologies that integrates innovative technology and operational strategies, supported by appropriate mainline and ramp geometric improvements, to deliver enhanced customer-focused services through stakeholder consultation. The active management of freeways will enable Main Roads to extract maximum value from this important asset.

Main Roads can only achieve its strategic direction of Keeping WA moving, and its aspiration to provide world class outcomes for the customer through a safe, reliable and sustainable road-based transport system, if it ensures a coordinated and cross-organisational approach to Smart Freeways delivery.

3.2 Applicable types of planning and implementation projects

The principles in this policy framework overview and the other Smart Freeway guides can be applied to the following generalised work types:

Table 3.1: Types of work to which the Smart Freeways Policy Framework Outline *is applicable*

Work type	Description
Existing freeway improvement	Retrofitting a new coordinated ramp signalling system to improve safety and productivity from existing infrastructure. Other localised works would generally be needed, including vehicle detection stations and improvements at entry ramps to provide required discharge capacity and storage.
Existing freeway upgrading	Where additional mainline capacity and/or improved interchanges are provided for additional capacity and improved travel time reliability
New freeway design	Providing a new major link in the freeway network.

The construction of successful Smart Freeways projects will only be achieved by focussing on all relevant matters through the Main Roads RO&DS process and lifecycle as shown in Figure 3-1.

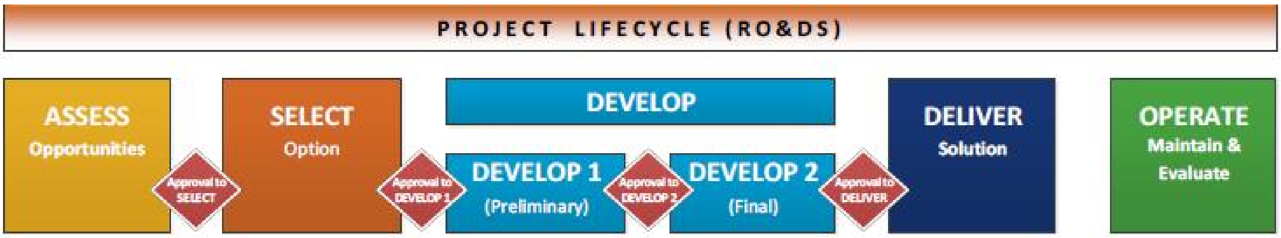


Figure 3-1: The Main Roads RO&DS process and lifecycle

3.3 Smart Freeway outcomes

A successful Smart Freeway is defined as one that delivers improvements for users of the freeway network and the wider community in the following areas:

- **Safety** – for all road users, including minimisation of freeway flow breakdown and congestion during operations, as well as the safety of road workers and maintainers during incidents.

  Desired outcome – reduced incident rates and severity.

- **Productivity** – of the existing freeway infrastructure.

  Desired outcome – optimal vehicle throughput (vehicles per hour).

- **Efficiency** – of vehicle movements in terms of travel speeds, particularly during peak periods.

  Desired outcome – improved average travel speeds.

- **Reliability** – of travel conditions from day-to-day.

  Desired outcome – less variable and more reliable travel times.

- **Driver experience** – of travelling on the network, including provision of real-time traveller information.

  Desired outcome – informed and satisfied road users.

- **Sustainability** – for the community.

  Desired outcome – positive economic, social and environmental outcomes[3].

- **Resilience** – of the transport network.

  Desired outcome – flexibility in responding to abrupt changes in demand or capacity and rapid recovery if flow breakdown occurs.

- **Transforming freeways to 'smart roads'** - in preparation for future co-operative ITS (e.g. vehicle-to-infrastructure communications).

[3] For example, this could include: minimising vehicle operating costs, enhanced road-user experience and contributing to improvement in quality of life through savings in travel time, reduction in emissions (per unit of travel), maximising the return on capital investment in the road network by optimising its efficiency and productivity, and deferring or avoiding the need for expansion of the existing network.

Desired outcome - freeway infrastructure and vehicle technologies are part of an integrated system that delivers maximum travel and safety benefits to road users.

As appropriate, individual Smart Freeway projects should develop SMART (specific, measurable, attainable, relevant and timely) performance objectives as well as performance targets and evaluation measures against each of these areas, depending on the specific circumstances of the freeway.

Achieving improvements in these areas will deliver a range of social, economic and environmental benefits to road users and the community, whilst supporting traffic operators and asset managers in carrying out their responsibilities for effective road network management and operations (see Figure 3-2).

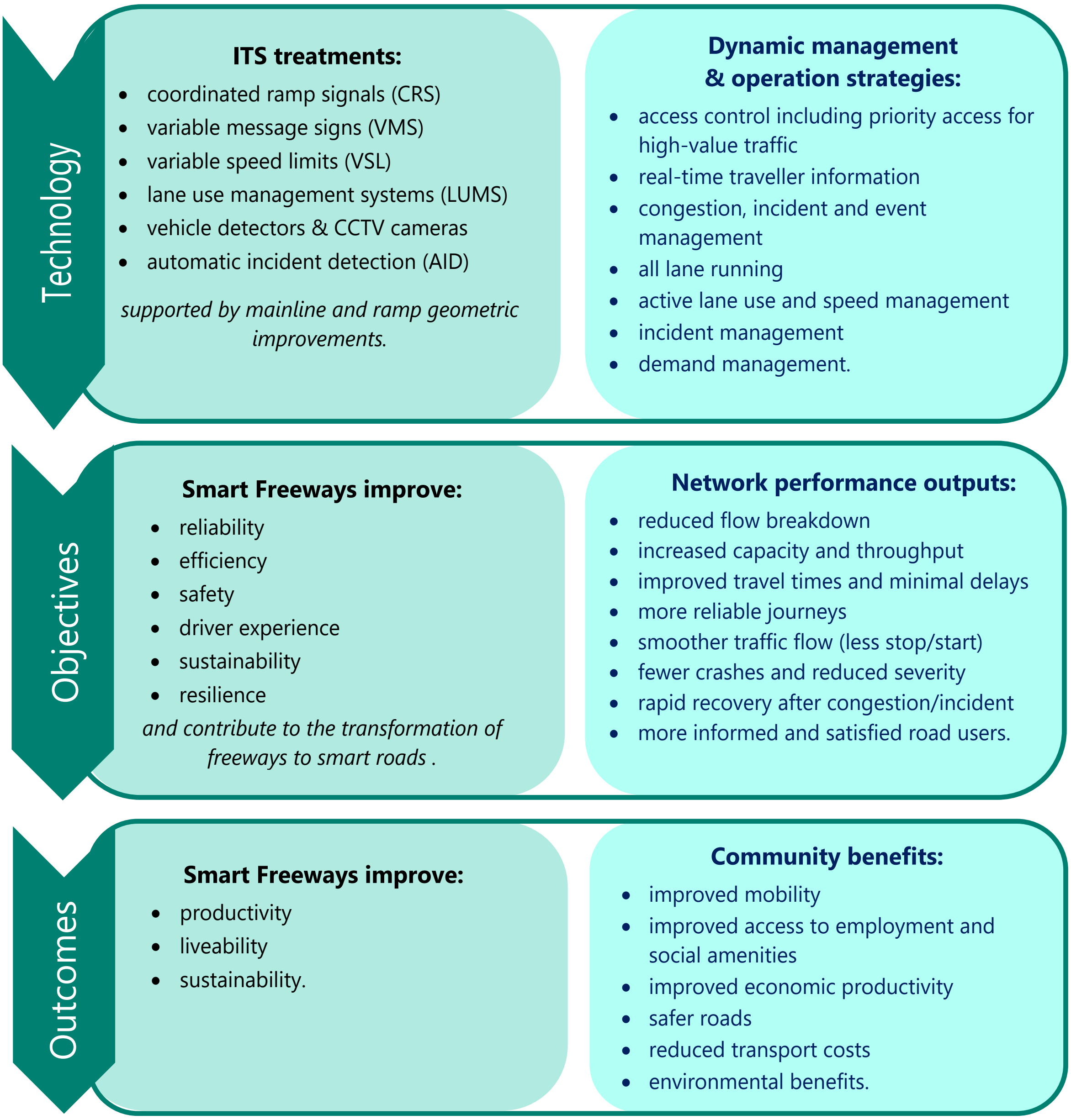


Figure 3-2: Smart Freeways technologies, objectives and outcomes

3.4 Key enablers

To accomplish the desired outcomes of Smart Freeways, organisational development, with a strong focus on the operational backbone, is essential. This will require action in the following areas:

- **Effective and integrated planning** – integrating Smart Freeways with Main Roads' longer-term planning for freeways and the wider road network.
  - *Desired outcome* – Smart Freeways solutions are considered alongside other solutions for future development of Main Roads network at an early stage in the planning process, recognising that Smart Freeways technology planning horizons are around 10 years.
- **Enhanced awareness of Smart Freeways philosophy** – achieving awareness and understanding of the Smart Freeways concept and benefits.
  - *Desired outcomes* – all directorates have embedded Smart Freeways considerations and requirements in their decision-making processes and strategies.
    - » all directorates accept their leadership roles and responsibilities for successful implementation and operation of Smart Freeways.
- **Organisational capability development** – building and sustaining the required resources with suitable skills for all phases of implementation, from planning to operation and maintenance.
  - *Desired outcome* – Main Roads has sufficient staff with the skills, knowledge and experience to implement and operate Smart Freeways, engaging external consultants or contractors as required.
- **Managing innovation** – encouraging its adoption in a controlled and risk-conscious environment.
  - *Desired outcome* – Smart Freeways exploit innovative technology and operational strategies, which have demonstrable and clearly understood benefits with minimal or well-considered risks.
- **Commitment to pursue opportunities for funding** – for all phases of project development, delivery, operations and maintenance.
  - *Desired outcome* – Main Roads has scoped and secured sufficient budget for successful planning and construction of Smart Freeways, including the technology and operational strategies, as well as budgets and resource commitments for the ongoing operational and asset management tasks.

4 Policy foundations

The complexity of Smart Freeways requires a strong understanding of the critical elements underpinning their success. Main Roads has learned from, and builds on, the experience of other jurisdictions, and applies this to the Western Australian context, improving on what has been delivered previously.

The following key foundations underpin the Smart Freeways policy and provide guidance for planning, project development, delivery and ongoing operation and maintenance of Smart Freeways projects to achieve the desired outcomes.

4.1 Integrated transport planning

Smart Freeways is one available solution to improve the efficiency and productivity of Western Australia's freeway network. It may not be the only solution for addressing all current and future congestion and network performance issues. Other solutions may include a combination of alternative management options, for example demand management strategies, as well as road infrastructure (capacity) upgrades and public transport improvements.

The key principles are:

- Prior to the implementation of Smart Freeways, the strategic objectives of the project need to be determined, and the most appropriate solution needs to be defined. In some situations, other or additional solutions may be more effective to achieve the desired outcomes.
- Smart Freeways solutions can help to reinstate the supressed or wasted operational capacity on freeways and operate them at optimum efficiency during times of high demand. This will delay, or in some cases, avoid the need for large capital expansion by using the existing road assets more efficiently. However, coordinated ramp signals benefits alone may not be sufficient when freeways reach their ultimate capacity, and require integration with longer-term network planning and capacity upgrading needs. These projects may also consider other solutions to manage future traffic demand and associated issues. The planning horizon for Smart Freeways ITS is generally ten years.
- Smart Freeways should be applied in a coordinated manner with other transport solutions to form an integrated transport system for Western Australia.
- Smart Freeways are led by an operational approach. Therefore, it is important to identify and understand the transport issues across the network before the specific and detailed problem assessment, options analysis and solution prioritisation.
- The full benefit of Smart Freeways can only be realised if a whole-of-network approach is taken to enable controlled access and prevent situations where unmanaged freeway sections adversely impact Smart Freeways performance or vice versa.
- Upgrade of a freeway section may have adverse effects on an adjacent section of freeway, for example by increasing traffic volumes, which may result in the adjacent section also requiring Smart Freeways solutions. Through the whole-of-network approach, the design of individual Smart Freeway or capacity upgrade projects should consider and address the impacts on the interfacing freeway network.

- Smart Freeways aim to improve the overall efficiency of the road network, including the surrounding arterial and local road network, so that the traffic flows are more efficiently distributed across the entire road network subject to the functionality of the road.
- Congested freeways can have significant adverse effects on traffic flows on the strategic and local road network. Smart Freeways can help to address this by improving throughput on the arterial network during peak periods, however, this may have some localised adverse impacts on connecting roads. The *VicRoads Managed Motorway Design Guide Volume 2:* Design Practice, Part 2: Managed Motorway – Network Optimisation Tools (June 2019) indicates:

  "the overall economic imperative is that, when necessary, freeways should be given priority over arterial roads and, where this would result in a negative impact on the arterial network, this should be managed accordingly to provide a net overall gain to the system's users".

- Appropriate design strategies can be implemented to minimise impacts of Smart Freeways operations on the adjacent road network, for example maximising ramp storage at freeway interchanges, where ramp signals are installed, to prevent queues extending onto arterial roads.
- The operational strategies developed specifically for Smart Freeways should be fully integrated within the operational strategies applied to the wider road network.
- Smart Freeways technologies should be applied to sections of freeway where they provide a higher benefit-cost ratio and a more sustainable solution, compared to alternatives including traditional network improvement projects (for example capital expansion). This comparison should be detailed in the business case for Smart Freeways projects.
- Smart Freeways must be considered for incorporation in the scope of all new build and upgrade projects for the freeway network and be delivered as an integral part of the project at the time or in the future as appropriate. The freeway must be designed to facilitate progressive implementation of Smart Freeways when the technologies are required, for example at opening or after an acceptable future time (five to ten years), depending on the predicted increase in demand.

4.2 Smart Freeways technologies

Smart Freeways can incorporate a range of ITS technologies (such as field equipment, communications and central control system) as well as operational strategies. This enables delivery of user-driven services, for example minimisation of mainline flow breakdown, congestion, incident management and provision of traveller information.

A description of key Smart Freeways technologies considered for implementation on Western Australia's freeway network is included in the provision guidelines.

The Smart Freeways 'toolkit' should be applied to a section of freeway according to the following principles:

- Depending on the circumstances of the problem and the traffic situation, a combination of complementary technologies is likely to deliver the best outcomes, as opposed to deploying individual technologies in isolation. However, it may not be necessary to use all available technologies and operational strategies for each project.

- The most appropriate technologies to be applied will be subject to various factors and characteristics of the freeway. Analysis of the current and predicted future traffic conditions should be undertaken to determine the problems to be addressed and to help identify the best solution. Selection of Smart Freeways technologies and their combination, therefore, depends on the circumstances of the problem to be resolved or the targeted road user services to be provided. The technologies should work together as part of an integrated system.
- Interventions may also include localised mainline or ramp geometric improvements to achieve optimal configurations of the carriageway for maximum operational efficiency, for example, to remove bottlenecks caused by lane drops. These should be considered at the start of the planning process.
- Geometric changes may also be required for implementation of specific technologies. For example, coordinated ramp signalling may need lengthening and/or ramp widening for required design ramp discharge capacity and queue storage.
- Other types of technology include fixed signing and road marking strategies to support effective network operations, for example, merge warnings at appropriate distances.
- A standardised approach is to be applied for determining design volumes for capacity analysis and design. This will ensure that consistent assumptions are applied and that outputs from analyses are comparable.
- It is important to understand the intended individual and aggregate impact of the technologies on road user and traffic behaviour, which ultimately drive Smart Freeways performance.
- All future freeways will, as a minimum, have real-time network monitoring capability and intelligence, and provision for higher order Smart Freeway treatments when needed (Section 5.2).

Note: Further information on Smart Freeways technologies to be used in Western Australia, including guidelines and warrants for deployment, are provided within the *Smart Freeways Provision Guidelines,* which are part of the Smart Freeways policy framework documents.

4.3 Real-time data collection

Traffic control and provision of travel information are the core functions of a dynamic and responsive traffic management system. However, it cannot be managed if it is not measured, therefore, network intelligence is required. The backbone of Smart Freeways operations is the real-time collection, analysis and management of accurate data on traffic flow characteristics and network conditions. The information generated from this data enables road operators, as well as road users, to make informed, safer and more coordinated decisions and ‘smarter’ use of the network.

Smart Freeways requirements for real-time data collection are of a much higher level of accuracy and availability than those that were needed in the past for traffic operators and historical performance reporting. Hence, technical specifications are required, and traffic data collection devices and systems are deployed and maintained to specified Smart Freeways maintenance intervention levels.

Smart Freeways should facilitate:

- automatic collection of detailed real-time traffic flow characteristics and system performance data
- communication of the data to a central control system, where the data will be processed, validated and archived
- real-time dissemination of information to road users and other internal and external stakeholders
- ongoing network and system performance monitoring and reporting.

Further information relating to the traffic control system and network is provided in the *Provision Guidelines* Section 9.

4.4 Ongoing operations and asset management

4.4.1 General principles

Smart Freeways use sophisticated and dynamic technologies governed by operational strategies to monitor and evaluate network performance and respond to changing traffic conditions. These technologies form part of the whole-of-network-operation approach of Main Roads that incorporates:

- one common operational management system and user interface for all ITS technology, referred to as the central control system, including Smart Freeways, traffic signals, and metropolitan and rural remote ITS

  (Note: Main Roads' tunnel control system works independently but this may be integrated with the central control system in future.)
- real-time active management of traffic flow on the freeway network, governed by operating strategies
- collection and storage of real-time data, and provision to third parties
- ongoing proactive and reactive maintenance (see Section 4.4.2).

The technologies that partially operate automatically, as well as the traffic operators who have critical input to guide system response and interact with stakeholders, are both essential elements for the effective operation of Smart Freeways.

As a result, a commitment to ongoing operational and asset management efforts is essential for achieving Smart Freeways benefits. This can be facilitated by adhering to the following principles:

- Smart Freeways may provide cost-effective solutions for improving the productivity of an existing freeway asset, however, they should not be necessarily considered as 'low-cost', as for most freeways there will be works associated with upgrading the entry ramps, ramp signals and VDS. The business case for funding of Smart Freeways should consider the whole-of-life costs of ITS technologies and make provision for recurrent costs for ongoing operations and maintenance.
- Strategies for Smart Freeways operations and asset management should be developed and implemented. The strategies should be tested and regularly reviewed.
- Smart Freeways should be operated from Main Roads' ITS central control system. Operational efficiency will be achieved if all ITS operations across the network are integrated with this system.

- Traffic operators should be given comprehensive training on the desired outcomes of Smart Freeways and how to achieve this through appropriate application of operational strategies.
- Smart Freeway design should consider maintenance requirements to facilitate improved efficiency and safety of maintenance practices.
- Maintenance service contracts should incorporate restoration targets and intervention levels that are aligned with the criticality of the technology components for delivering an end-user service.
- Maintenance considerations should take into account the relatively short life span of ITS assets, compared to the roadway infrastructure, and the funding needs for asset renewal or replacement.

4.4.2 Performance-based maintenance management

A commitment to ongoing operational and asset management is essential for achieving Smart Freeways benefits, for example fast and timely maintenance of vehicle sensors will contribute to achieving the safety and operational benefits of Smart Freeway operations.

Smart Freeway technologies generally require firmer maintenance response times, which may differ from those Key Performance Indicators (KPIs) included in the existing maintenance contracts. Therefore, the design and technology selection must include details addressing monitoring, service and maintenance arrangements, including targets and intervention levels that are aligned with the importance of the technology components for delivering the end-user operation and benefits.

The development of a Smart Freeways project must consider the whole-of-life costs of ITS technologies as well as make provision for recurrent costs of ongoing operations and maintenance, including spare parts requirements and the relatively short life span of ITS assets and needs for asset renewal or replacement.

To ensure continuous performance of a Smart Freeway, a Concept of Maintenance (CoM) should be developed during the project development and design phases or included in the development of a Concept of Operations (CoO). For planning purposes, the CoM should document and describe the maintenance and device management requirements of all ITS assets and infrastructure to be implemented on the Smart Freeway, the life cycle and frequency of maintenance required for each ITS asset, details relating to replacement parts, any on-site access constraints, time needed to conduct maintenance, and any traffic management requirements during maintenance.

4.5 Freeway performance management

Ongoing performance management is required to understand whether a Smart Freeways project is continuing to meet its objectives and to ensure the technologies are working appropriately and have the desired benefits for road users. This involves:

- monitoring of traffic characteristics
- freeway performance analysis and evaluation
- reporting against freeway performance indicators / measures
- optimisation and adjustment / fine-tuning of settings and algorithms
- real-time system performance management.

As a result, performance management should be embedded in the organisational framework for Smart Freeways. Current performance monitoring and reporting regimes may need to be reviewed and adapted for Smart Freeways performance reporting.

Key principles for performance management are:

- Freeway performance monitoring and analysis is undertaken centrally by Network Operations and reported periodically.
- The freeway performance (real-time and historical analysis) is monitored and optimised by the freeway performance team.
- RNOC manages, records and reports on incidents and the type of incidents occurring.
- Monitoring and evaluation of Smart Freeways projects must be undertaken for performance reporting to funding bodies and to confirm that benefits are realised, as well as to inform the design and delivery of future Smart Freeways projects. This will require 'before' and 'after' traffic and safety data.

  Note that safety benefits can only be fully determined after at least 3 years of operation, although trends may be apparent within that period.
- Freeway performance evaluation measures should be well-defined and quantifiable where appropriate. It is useful to define these measures early in the planning process so that the required data is collected.
- Monitoring and evaluation should also measure road user and community satisfaction and perceptions of Smart Freeways.

4.6 Stakeholder engagement

Smart Freeways is a relatively new concept in Western Australia. Therefore, the potential benefits of Smart Freeways and particularly the various technologies need to be communicated clearly to road users. An environment of trust is important for successful implementation of Smart Freeways projects.

Early and ongoing stakeholder engagement and education is imperative for realising the benefits of Smart Freeways, through achieving:

- **Main Roads shared ownership** – supporting the development of collaborative relationships (including workshops and training) with key internal stakeholders to ensure they are involved in the development of the projects, recognising the longer-term roles they play in planning, design, delivery, operation and maintenance of Smart Freeways.
- **Political acceptance** – clearly communicating the business case and performance outcomes in the context of high-level transport strategies to secure ongoing funding commitments.
- **Public awareness and acceptance** – consultation and education programs (for example driver education campaigns) to facilitate road user understanding of how Smart Freeways work and the benefits their effective use will bring.
- **Community acceptance** – reassuring the community that the impact of Smart Freeways on the local environment will be minimised, and that Smart Freeways can help to reduce traffic impacts (such as air quality and noise).

- **Emergency services partnership** – working collaboratively with emergency services to determine effective incident response arrangements and protocols.
- **Police partnership** – working collaboratively with the police to optimise incident response and also to identify and implement appropriate enforcement mechanisms to encourage compliance with the Smart Freeways technologies.
- **Local government involvement** - working with local government to sustain safety and travel efficiency on the local road network and maximise benefits for the entire transport network.
- **Priority user needs** – understanding priority user needs (for example freight, public transport and emergency vehicles) to inform the design of priority access technologies.
- **Industry support** – facilitating mutually beneficial knowledge transfer, to ensure the practicalities of implementing ITS are understood and considered in the design process and to facilitate capability development within both Main Roads and industry.
- **National collaboration** – sharing best practice and knowledge with the other state road authorities (for example directly or via Austroads Network Taskforce).
- **Knowledge transfer** – learning from the experience of Smart Freeway implementation in other jurisdictions and from researchers.

A set of mechanisms will assist Main Roads in the stakeholder engagement process, including:

- **Stakeholder engagement strategy and plan** – that incorporate communication strategies and plans of individual projects which target all stakeholder groups and are updated regularly while the project progresses.
- **Smart Freeways internet site** – for dissemination of Smart Freeways-related information.
- **Knowledge transfer program** – to achieve internal and external familiarity with the Smart Freeways concept and related ITS technology and operational topics.

4.7 Driver behaviour and compliance

Road users are an integral part of Smart Freeways, interacting dynamically with vehicles and the road infrastructure, and responding to information presented to them. Smart Freeways aim to influence driver behaviour, and a high level of compliance is essential to achieve maximum effectiveness. The following principles should be considered to ensure Smart Freeways influence driver behaviour in the right way and minimise driver frustration:

- Understand the desired driver behaviour to achieve the project objectives.
- Create a self-compliant driving environment, where road users comply with instructions in an intuitive manner because they understand the benefits delivered by Smart Freeways to themselves and other drivers, as well as the risks associated with non-compliance.
- Use appropriate algorithms to control traffic in a reasonable way from the start of operations, so that drivers trust and comply with the instructions.
- Ensure that the instructions and information given to road users are timely, accurate and appropriate for the situation.

- Identify appropriate mechanisms for encouraging compliance including education programs and enforcement. It needs to be noted that Smart Freeways will be a new driving experience for many Western Australia motorists. A focus on enforcement communicates a negative message and may undermine the community's willingness to take up the technology. Therefore, Smart Freeways needs to ensure traffic control measures, such as variable speed limits, are appropriate for the circumstances. A period of grace may be needed while motorists learn to understand the new traffic requirements, before extensive enforcement is implemented. In some jurisdictions it is noted that enforcement at ramp signals is generally not required (see *Provision Guidelines* Section 6.6). A focus on education is important, particularly during an initial period of implementation.
- Enforcement approaches should be considered in relation to specific technologies. For example, in the case of coordinated ramp signalling, occasional non-compliance does not usually result in any inherent safety issues. Hence enforcement should only be considered when the observed non-compliance levels are significant.

4.8 Road user and safety perspective

The design of Smart Freeways is targeted to achieve optimal safety, network efficiency and productivity. During the design process it is important that the designer understands the road user and safety perspectives and the implications of design decisions.

In the road user and community perspective, Smart Freeways should:

- Provide an intuitive and consistent driving experience across the entire regional and national freeway network.
- Consider options for achieving further benefits for priority users including freight, public transport and high occupancy vehicles (HOV), ensuring that this does not compromise the overall effectiveness of the Smart Freeway.
- Take into consideration construction and maintenance requirements to minimise inconvenience to road users during road works and maintenance activities.

In the perspective of road safety, Smart Freeways should:

- Take a risk-based approach so that road user safety is at the core of the design process, by ensuring design decisions reflect Smart Freeway design principles to prevent or minimise the potential for flow breakdown.
- Be designed not only to improve road safety for road users but also for people working on the network, including incident response teams, maintenance contractors and road workers. For example, the design should incorporate sufficient provisions for contractors to perform maintenance activities safely without major disruptions for traffic flow.

The Road Safety Commission (RSC) is dedicated to tackling road trauma and helping other state and local government agencies across WA meet the state and Commonwealth targets for reducing fatal and serious injuries, with an end target of no fatal or serious injuries by 2050.

4.9 Network operations planning process

Due to the complex nature of Smart Freeways, a coordinated and integrated approach is required for the governance and delivery of Smart Freeways projects. Main Roads has developed a *Network Operations Planning Framework* (NOPF) (ARRB / Main Roads WA 2014) which recognises the competing demands for road space and functionality from various road user groups. It focuses on providing an evidence-based and participatory approach to the planning of traffic management and operation of the road network, to better optimise the use of road assets to meet customers' requirements through technology and collaboration with stakeholders.

The NOPF shows the importance of the inter-relationship between infrastructure plans for the construction of new road projects and the role of network operations in the planning and implementation process. The planning framework is an iterative process combining infrastructure and non-infrastructure solutions to achieve the best performance of the network operation.

The planning process provides road network managers, planners and operators with sufficient guidance, without being too prescriptive, to facilitate best practice and a consistent approach to planning for road network operations to achieve desired outcomes. The planning process consists of eight steps, from the scoping of the project to the implementation and use of the network operations plan, and includes feedback loops and required deliverables as summarised in Figure 4-1.

Another approach that has been used internationally is the systems engineering approach that focusses on the management of systems projects and ensures outcomes of the project are in line with both the clients' and the end users' needs (see Section 4.10).

Encouraging use of the network operations planning process for all Smart Freeways projects ensures that the intricacies of network operations planning – such as road user priorities, integrated transport system objectives, effective problem assessment, development of project plans, delivery and operation, maintenance and evaluation – are made inherent parts of Smart Freeways requirements.

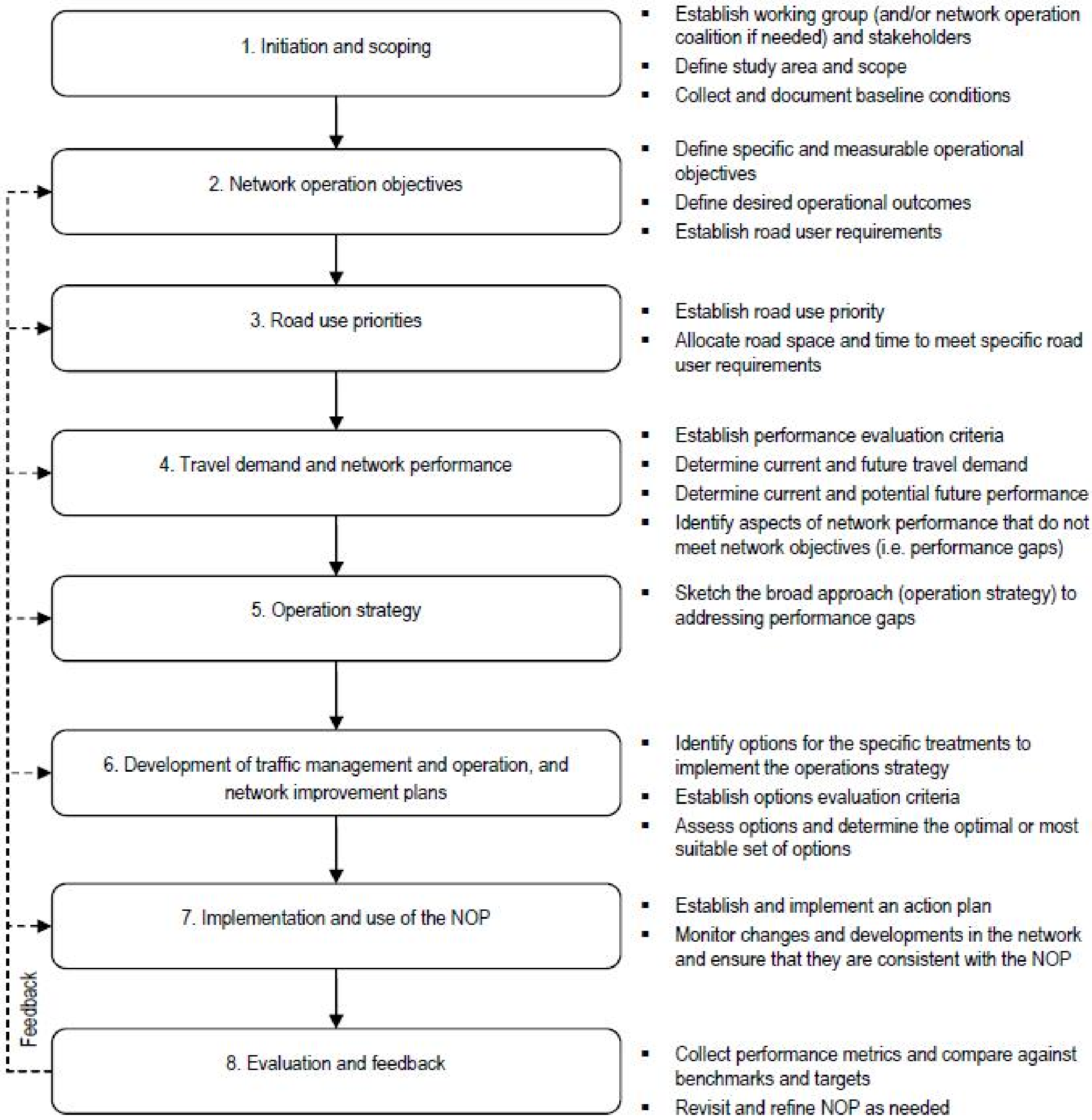


Figure 4-1: Summary of Main Roads network operations planning process

4.10 Project development

Development of Smart Freeways designs needs to consider Smart Freeway performance objectives, which are generally based on route needs, and traffic investigation and analysis. These should inform the design, rather than trying to validate a layout which may be inadequate or conceived without clear identification of needs or adequate traffic engineering input.

The appointment of route managers within network operations provides a route-based focus for the management and operation of the road network. Each route manager is responsible for performance of individual routes aligning with Route Operation Plans (ROPs), developed using the same methodology as for Network Operations Plans (NOPs). The NOPs define operational objectives, establish key performance indicators (KPIs), identify performance gaps, and outline a strategy and a plan for addressing any identified performance gaps. ROPs fulfil a similar purpose to NOPs but at route level rather than being applicable to a subnetwork or network level.

At project level (which may not necessarily cover the entire route), there needs to be a focus on the ROPs for the route. NOPs also have a role, as they cover the subnetwork over which the project has an operational influence. For example, improvements from a project may change traffic patterns and volumes within a project's 'area of influence'. The development of a NOP as part of a project will undertake a performance gap analysis for the subnetwork within the project's area of influence and also identify performance issues. The project may not necessarily be able to resolve all the potential performance issues, particularly when they are outside the project scope, but may draw the attention of the network planners to such issues for future action, or in some cases, to recommend a change in a project's scope.

For a Smart Freeway project, the project-based NOP will consider the sub-network within the project's area of influence. This needs to be compatible with the ROP for the freeway in terms of operational objectives and performance indicators for the freeway as a whole, or for applicable segments within the freeway. Ideally, the improvements proposed in the NOP within the project area will reflect and be consistent with the operations strategy and plan identified in the ROP for the freeway.

During project development and design there will also be a number background documents and reports that need to be developed for the project delivery, such as:

- traffic analysis report
- design report and drawings
- concept of operations
- concept of maintenance (refer Section 4.4.2).

4.11 Systems engineering approach

In addition to the Network Operations Planning Framework, the systems engineering approach to ITS projects is a useful tool to manage the Smart Freeways projects and to ensure outcomes of the project are in line with both Main Roads' and the road users' needs. Systems engineering provides an integrated and structured set of methodologies for successful implementation and management of ITS projects. The approach promotes up-front planning and system definition before technology identification and implementation. Documenting stakeholder needs, expectations, the way the system is to operate (concept of operations), maintenance requirements, and the system requirements (what the system is to do) before implementation leads to improved system quality.

Both the United States (Federal Highway Administration 2009) and the Netherlands (Rijkswaterstaat 2008a) have developed a systems engineering approach to:

- Improve the quality of the outcomes by promoting up-front planning and system definition before technology identification and implementation.
- Reduce the risk of costs and schedule overruns by promoting stakeholder engagement throughout the project development and improving project control with clearly defined decision points.
- Gain wide stakeholder participation through a common and standard development process that enables stakeholders to understand and actively participate in the development.

- Maintain, operate and evolve the technologies used through clear documentation of the requirements, design, verification, development and support phases.
- Maintain consistency with the state and national ITS / Smart Freeways architectures.
- Provide flexibility in procurement options and ensure proprietary developments are minimised, proprietary sub-systems are identified, and the use of industry standards is promoted.
- Keep up to date with the rapid evolution of the technology through the promotion of system modularity and the use of standard interfaces where possible (plug and play).

In line with the systems engineering approach developed in both countries, a model of six phases is defined throughout the life cycle of a project (Figure 4-2). The model illustrates the key principles of the relationship between the early phases of planning a project and the end results – the life cycle approach. A characteristic of ITS projects is that the systems and processes can be renewed during the user phase and can be executed several times during the project's lifecycle. The specification, design and production phases during the project lifecycle are depicted in Figure 4-2.

Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
Concept	Development	Production	Operation	Updates	Renewal
Planning, exploration of benefits & management	System requirements & design	Construction, implementation, integration & verification	Including validation and asset management	Improvements	

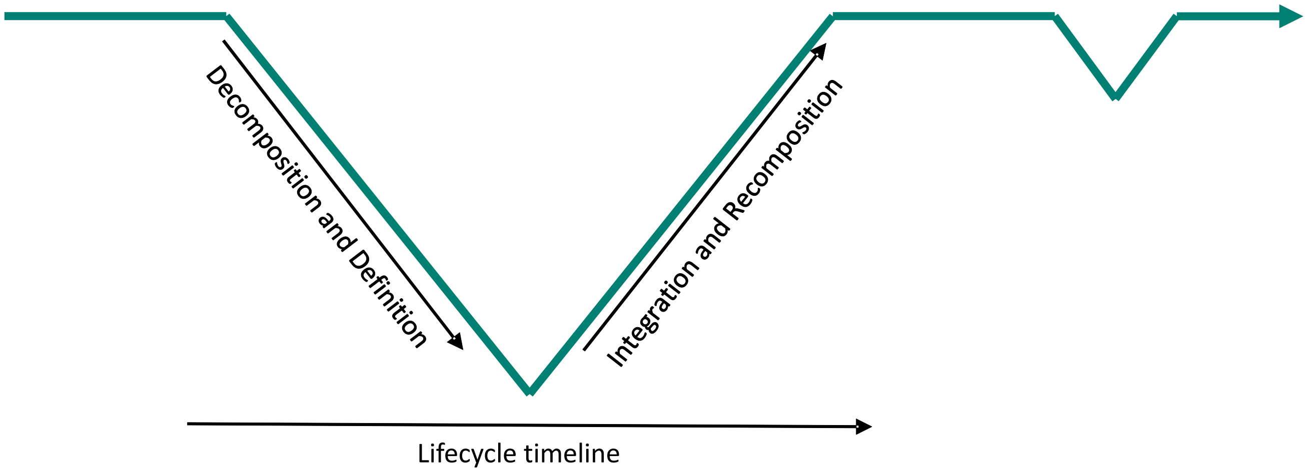


Figure 4-2: Simplified systems engineering project lifecycle

4.11.1 Key principles

In relation to both the Network Operations Planning Framework and the systems engineering approach, the following key principles for planning Smart Freeways projects apply:

- The planning process and development of key deliverables for each Smart Freeways project should be in line with the Network Operations Planning Framework.
- To ensure the deliverables of the Smart Freeways projects meet Main Roads' and the road users' needs, a systems engineering approach should be adopted to manage the Smart Freeways project. This means encouraging a focus on the system definition prior to technology identification and implementation, this includes identifying intended traffic outcomes as well as the designs and devices needed to achieve those outcomes.
- Documenting stakeholder needs, expectations, the way the system is to operate and the system requirements.
- Separate operational efficiency and road safety audits should be carried out by suitably qualified and independent experts at the concept design stage and detailed design stages.
- Main Roads should identify and manage all risks associated with all phases throughout the project, using a defined risk management process. Risks should be transferred to those most able to handle the risk, for example contractors.
- All Smart Freeways technologies should be verified and validated by testing the functionality of the technologies and operational strategies before the system goes live.
- Project needs and requirements should be considered at the early stages of the planning and design process to support the identification and deployment of the ITS equipment on the network, for example if general upgrades of the IT and communications infrastructure are required to facilitate a specific freeway project. The critical path for delivery of concurrent projects in relation to delivery of Smart Freeways and other ITS projects should be considered and appropriate actions initiated.
- It may be necessary to review existing legislation and regulations at an early stage to identify any potential barriers or requirements for Smart Freeways implementation.

4.12 Procurement of ITS technology

As procurement of the right technology is critical to the successful operation and perceived effectiveness of Smart Freeways, the following principles apply:

- The technology used must have demonstrated performance specifications from the manufacturer (particularly systems and vehicle sensors) as well as desirably be proven in other road authorities and shown to be delivering measurable results.
- Smart Freeways systems must integrate and be compatible with Main Roads' existing ITS and operating environment or have the ability to replace existing systems, so duplication of applications and information will be minimised.

- Procured technology must be compatible with the Smart Freeways central control system and communication systems operated by Main Roads. Where new functionalities are required to the control system or an expansion of the communication system is required, this must be costed within the procurement. The Main Roads control system contractor needs to confirm during the tender process that he can deliver any proposed software changes required by the Smart Freeways delivery contractor (drivers for new devices and any system changes and so on) to meet the delivery timelines of the project. The control system contractor needs to also confirm that the cost and risk profile of these works are appropriately included in the tender evaluation assessment.
- The product purchased should preferably be an off-the-shelf product but with compatible drivers to interface with the Main Roads central control system, with minimal configuration and customisation required for use on the Western Australia road network. However, opportunities for innovations should be sought, taking into account appropriate risk management measures.
- The products procured must be capable of continuous improvement. Performance and improvements can be monitored and are measurable.
- The technology used must be sustainable and readily scalable for network expansion and additional functionality.
- Procurement of new and upgraded technologies must align with best practice and adequate up-to-date standards and guidelines.
- Existing design standards and specifications may need continual review and be amended where appropriate to accommodate Smart Freeways requirements.
- Procurement documentation must generally define the purpose (why) and functionality (what) of the technology rather than the technical specification (how), to give industry the opportunity to introduce innovative solutions.
- Procurement must consider evolution of advanced ITS technologies, such as cooperative ITS systems (that is vehicle-to-infrastructure communications) which may be incorporated in Smart Freeways in the future.
- The costs of the technology procured will be assessed based on the whole-of-life costs and will reflect positive value for money.
- ‘Design for maintenance’ principles must be incorporated in the design of the technology.
- Product upgrades, support, service level agreements and training must be readily available and accounted for in the procurement process.
- Procurement of the technology must be through contractors that are best able to provide or source the equipment or work required and have experience with the requirements, with consideration to the ‘buy local’ policy of Main Roads.
- A service level agreement (SLA) must be arranged with the contractor on critical pieces of the technologies supplied, to ensure the reputation of the Smart Freeways concept. The SLA might specify the levels of availability, serviceability, performance, operation and other attributes related to the guaranties and warranties of the system delivered.
- A requirement for the testing and commission of equipment must be included in the contract specification.

4.13 Organisation development and people readiness

Smart Freeways has involved the application of skills and knowledge to new areas, as well as the development of new skills and knowledge. This has required forward-thinking leadership to mobilise staff and the wider industry, whilst managing the risks associated with application of innovative technologies and network operations. There has also been the need to expand current staff resources due to more intensive ongoing operational and asset management functions.

To ensure that Main Roads has the continuing organisational capability to deliver and operate Smart Freeways into the future, a systematic approach is required to identify resource requirements and maintain appropriate capabilities. This approach involves:

- Continuing awareness and understanding of the Smart Freeways principles and benefits throughout Main Roads, ensuring that all directorates involved have embedded Smart Freeways considerations and requirements in their decision-making processes and strategies.
- Consideration of Smart Freeways related resources as well as appropriate training and capability development strategies.
- Continuing the identification of new and changing Smart Freeways capabilities, functions and skills required for each phase of the project lifecycle, from concept and development to operation and asset management. This includes specific skills required for the design of communications infrastructure, systems engineering, testing and commissioning of ITS technologies, as well as the traditional civil, traffic engineering and ICT skills.
- Encouragement of innovation through carefully considered research and development trials and a controlled and risk-conscious environment, where innovative technology and operational strategies are procured that have demonstrable and clearly understood benefits with minimal or well-considered risks.
- Development of skills and expertise to be encouraged by fostering mutually beneficial partnerships with other road agencies, industry, universities and research institutions.
- Securing of sufficient budget for continuing development and construction of Smart Freeways as well as budget for the ongoing operational and asset management tasks and resource commitments.

5 Governance and implementation

5.1 Governance

The effective planning, design and implementation of Smart Freeways and related projects is essential to ensure sound outcomes. This needs to be informed by different perspectives of specialist project stakeholders and the community for this high profile and complex infrastructure program.

5.1.1 Smart Freeways policy framework

The *Smart Freeways Policy, Policy Framework Overview* and other guideline documents are the basis for Main Roads planning and design guidance for Smart Freeways projects in Western Australia. These documents provide direction for incorporating Smart Freeways requirements in all projects on the freeway network.

The Smart Freeways policy is a Main Roads corporate policy approved by the Managing Director of Main Roads. Executive Director Network Operations is the custodian of this policy document.

The Director Congestion and Movement is the owner of the following Smart Freeway documents:

- *Policy Framework Overview*
- *Provision Guidelines*
- *Variable Message Signs Guidelines*
- *Operational Efficiency Audit Guidelines.*

The Executive Director Planning and Technical Services has responsibility for the geometric design standards of all Smart Freeways and is also the owner of the following Smart Freeway documents:

- *Supplement to Victoria's Managed Motorway Design Guide Volume 2*: Design Practice - Parts 2 and 3.
- *Supplement to Victoria's Managed Freeways Handbook for Lane Use Management and Variable Speed Limits.*

The above Smart Freeways documents will be reviewed and updated from time to time, as required, to keep abreast of changes in technology, standards and practices.

There is shared responsibility for considering any design or operational departures from the Smart Freeways documents and their approval as outlined in Section 6. Any departures from the Smart Freeways requirements or other design guidelines are to be formally documented and signed off as part of an auditable process.

The Executive Director Infrastructure Delivery is responsible for delivery of Smart Freeways projects, while the Executive Director Network Operations is responsible for the operation of Smart Freeways. The General Manager Network Management and Delivery is the owner of the Smart Freeway assets.

5.1.2 Steering committees

Smart Freeways steering committees may be set up from time to time to review policy and guideline documents, or specific design, traffic management or other management areas needing a specific focus.

5.2 Indicative Smart Freeways future network implementation

The long-term vision is that Smart Freeways are to be considered for all existing and future freeway standard roads in Western Australia. The freeway network applicable to the 2031 and 2046 planning horizons are shown in Table 5.1 and on the maps in Figure 5-1 and Figure 5-2.

The network planning information should be considered indicative for project development, as circumstances relating to development and network assumptions, as well as available funding for improving the network, will change over time. For any specific project, there will also be a need to consider the scope relative to Smart Freeway warrants (see *Smart Freeway Provision Guidelines*) and detailed analysis from both a local and freeway corridor perspective. The corridor perspective must also consider areas outside the 'formal' limits of the project.

Table 5.1: Smart Freeways future network extents

Freeway	2036 Smart Freeway Extent - both directions	2051 Smart Freeway Extent – inbound only
Mitchell Freeway	Narrows Bridge to Hester Avenue	Narrows Bridge to Toreopango Avenue
Kwinana Freeway	Narrows Bridge to Safety Bay Road	Narrows Bridge to Mandjoogoordap Drive
Graham Farmer Freeway	Mitchell Freeway to Great Eastern Highway	NA
Reid Highway	NA	Mitchell Freeway to Roe Highway
Roe Highway	NA	Reid Highway to Kwinana Freeway
Tonkin Highway	NA	Gnangara Road to Anketell Road

In the shorter term the focus is on high-demand and congested sections, and on programmed road projects on the freeway network. Main Roads has completed the initial application of Smart Freeways on the Kwinana Freeway in the northbound direction, north of Roe Highway. The project demonstrates the benefits and constraints of Smart Freeways design and operations, leading to a wider network assessment of the Smart Freeways concept. Main Roads' Smart Freeways policy is to progressively introduce Smart Freeway solutions to our existing and future freeways.

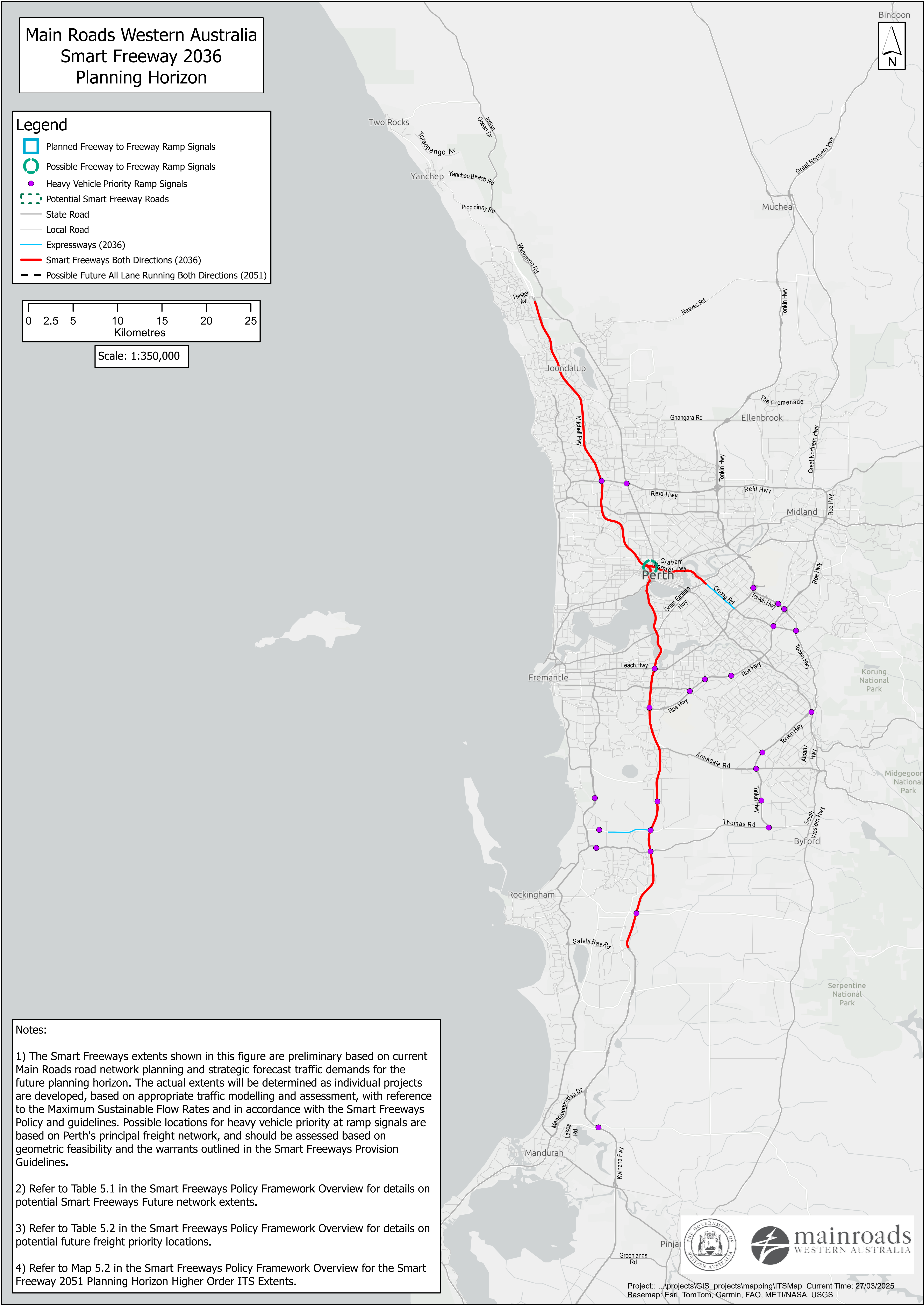
A broader implementation program, which provides for delivery of Smart Freeways projects metropolitan-wide in a progressive and systematic manner, is underway as part of the Transforming Perth's Freeways Program. This program defines the required staged approach and prioritisations (road sections and type of technologies) and is being informed by network analysis and modelling to identify current and future performance issues.

Smart Freeways treatments are applicable to the three work types as outlined in Section 3.2. The following projects will receive specific focus in improvement programs:

- **Current projects on the freeway network**, where detailed design has commenced. For these projects incorporation of design standards for implementation of Smart Freeways in the future will be considered. This might involve contract variations or additional funding and therefore should be assessed carefully.
- **Programmed projects on the freeway network**, where detailed design has not yet commenced. Smart Freeways technologies will be integrated in the scope of these projects according to needs defined in the provision guidelines. As a minimum this includes the provision of design standards for future implementation of Smart Freeways. Additionally, inclusion of Smart Freeways technologies to improve the (future) network performance should be considered.
- **Congested sections of the freeway network**, where a current or future problem has been identified with regard to demand and congestion management, but that are not yet on the list to be upgraded. An assessment of the network performance will be carried out to identify the benefits of Smart Freeways technologies, without the need for civil upgrades. If the benefits acknowledged reflect a positive impact of Smart Freeways on the network performance of the road section, a separate Smart Freeways project can be initiated.

All current and programmed civil road projects on the freeway network will be designed to facilitate the implementation of Smart Freeways when required, for example at opening or at an acceptable future time (for example ten years). Even though Smart Freeways technologies may not be applied initially, all future freeways will, as a minimum, have real-time network monitoring capability and intelligence, and provision for higher order Smart Freeway treatments when needed. This should ensure a cost-effective retrofit at a later time. The minimum Smart Freeways design requirements to be considered for current, programmed and new freeway projects are described in Main Roads' *Smart Freeways Provision Guidelines* document.

Main Roads Western Australia Smart Freeway 2036 Planning Horizon



Notes:

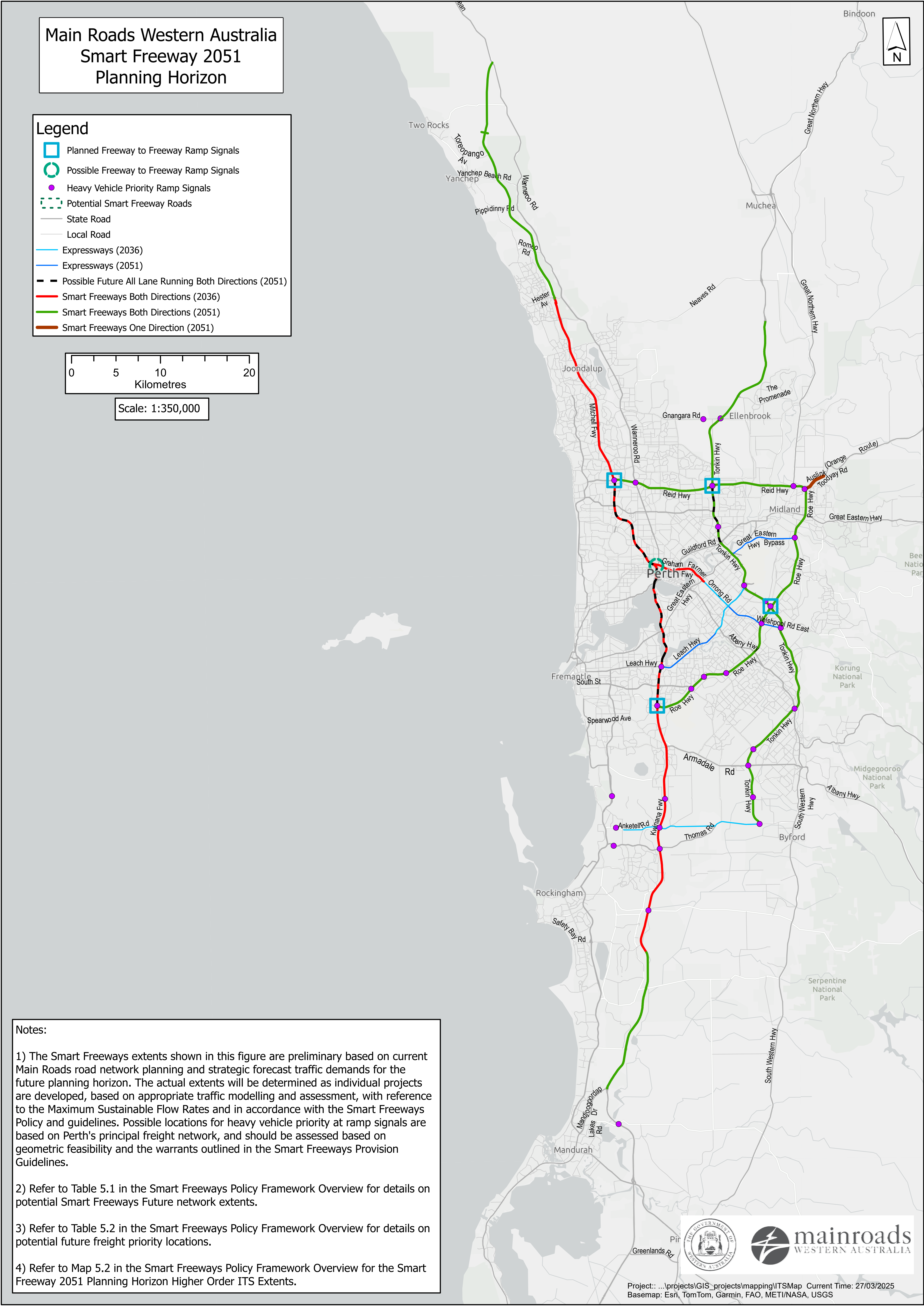
1) The Smart Freeways extents shown in this figure are preliminary based on current Main Roads road network planning and strategic forecast traffic demands for the future planning horizon. The actual extents will be determined as individual projects are developed, based on appropriate traffic modelling and assessment, with reference to the Maximum Sustainable Flow Rates and in accordance with the Smart Freeways Policy and guidelines. Possible locations for heavy vehicle priority at ramp signals are based on Perth's principal freight network, and should be assessed based on geometric feasibility and the warrants outlined in the Smart Freeways Provision Guidelines.

2) Refer to Table 5.1 in the Smart Freeways Policy Framework Overview for details on potential Smart Freeways Future network extents.

3) Refer to Table 5.2 in the Smart Freeways Policy Framework Overview for details on potential future freight priority locations.

4) Refer to Map 5.2 in the Smart Freeways Policy Framework Overview for the Smart Freeway 2051 Planning Horizon Higher Order ITS Extents.

Main Roads Western Australia Smart Freeway 2051 Planning Horizon



Notes:

1) The Smart Freeways extents shown in this figure are preliminary based on current Main Roads road network planning and strategic forecast traffic demands for the future planning horizon. The actual extents will be determined as individual projects are developed, based on appropriate traffic modelling and assessment, with reference to the Maximum Sustainable Flow Rates and in accordance with the Smart Freeways Policy and guidelines. Possible locations for heavy vehicle priority at ramp signals are based on Perth's principal freight network, and should be assessed based on geometric feasibility and the warrants outlined in the Smart Freeways Provision Guidelines.

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mainroads WESTERN AUSTRALIA

Project:: ...\projects\GIS_projects\mapping\ITSMap Current Time: 27/03/2025
Basemap: Esri, TomTom, Garmin, FAO, METI/NASA, USGS

5.3 Performance-based design

A performance-based design process creates challenges and the need to develop a range of technical capability across disciplines to ensure sound decision making. This requires a specific design intent that will optimise the completed project's performance outcomes.

The range of stakeholder views applied to freeway projects has created a need for design concepts to be part of inter-disciplinary design practice. These concepts include:

- A focus on creating roadways and related infrastructure that provide safe travel for all users.
- Context sensitive design and solutions that place priority on assuring that highway projects fit the context of the area through which they pass. This means balancing project needs as well as the values of the highway authority and community in decision making.
- A design process that considers explicit consideration of performance measures, typically operational and safety performance measures.
- Practical design that focuses on needed improvements and removing of improvements that are not essential, thereby managing the overall cost of a project.
- Safe system design that takes a holistic approach, with the responsibility for road safety being shared between all aspects of the transportation system, that is roadway infrastructure, road users, travel speeds and vehicle safety.
- Designing a roadway to focus on and maximise the travel time reliability of the operations.
- Value engineering as a systematic process of project review by a multi-disciplinary team to provide recommendations for improving a project's value, quality and performance.
- Consideration of all road users as applicable.
- Consideration for future / ultimate design.

These differing concepts recognise the need to consider competing priorities and viewpoints in the design of a project and hence consider and balance all competing stakeholder goals and interests.

The Main Roads Smart Freeways policy and guideline documents aim to highlight road safety and operational principles which both require a high priority during design. Therefore, the design intent must be to produce a Smart Freeway and ITS design that will maximise the completed project's performance outcomes, as Smart Freeway design is not just about ITS devices but about a freeway that works to optimise safety and efficient traffic operations.

Therefore, as part of development of freeway projects, the Scope of Works and Technical Criteria (SWTC) and the Basis for Design and Construction (BDC) documentation shall specify design performance criteria as outlined in the Smart Freeway guides for the freeway mainline, entry and exit ramps, and at interchange intersections. Further guidance is provided in the S*upplement to Victoria's MMDG Vol 2, Part 3:* Sections 1.3 to 1.7. A list of other documents relating to project development is provided Section 4.10.

The design principles that contribute to achieving safety and operational outcomes are provided in Victoria's *Managed Motorway Design Guide* (MMDG). Main Roads *Supplement to the MMDG Volume 2,* Parts 2 and 3, includes guidance relating to design intent and Smart Freeway project design performance targets (see Part 3 Section 1.5).

The safety outcomes and other benefits that can be achieved from a well-designed and managed freeway are documented in Victoria's MMDG Volume 2: Part 2 Section 6.

5.4 Consideration of freight movement and efficiency

The efficient movement of freight will contribute to the state's productivity. Therefore, trucks may be given specific consideration and priority using a dedicated priority lane at ramp signals.

Where this can be accommodated in design, the freight access advantage is provided with a shorter queue relative to other traffic. Table 5.2 provides a guide to locations where a priority advantage for freight vehicles should be considered. Other ramps may also be considered where there is a high volume of trucks and a separate lane can be accommodated in the design.

Further detailed guidance relating to priority access lanes is provided in the *Supplement to the MMDG Part 3*, Section 6.8: Priority Access Lanes.

Table 5.2: Potential future freight priority locations

Smart freeway network	Freight route connection	Potential heavy vehicle priority for entry ramps
Kwinana Freeway	Leach Highway	Southbound ramp only
	Roe Highway	Southbound ramp only
	Rowley Road	Both directions
	Anketell Road	Both directions
	Thomas Road	Both directions
	Mundijong Road / FRCAH	Both directions
	Lakes Road	Northbound ramp only
Mitchell Freeway	Reid Highway	Both directions (from Reid Highway westbound only)
Reid Highway	Mitchell Freeway	Eastbound ramp only
	Wanneroo Road	Both directions
	Tonkin Highway	Both directions
	Great Northern Highway	Both directions
Roe Highway	Toodyay Road (future Perth-Adelaide National Highway)	Both directions
	Great Eastern Highway Bypass	Both directions
	Tonkin Highway	Both directions
	Welshpool Road East / Orrong Road	Both directions
	Nicholson Road	Both directions
	Willeri Drive	Both directions
	South Street	Both directions
	Kwinana Freeway	Eastbound ramp only

Smart freeway network	Freight route connection	Potential heavy vehicle priority for entry ramps
Tonkin Highway	Gnangara Rd	Both directions
	Reid Highway	Both directions
	Collier Road	Both directions
	Leach Highway	Both directions (from Leach Highway eastbound only)
	Abernethy Road	Southbound ramp only
	Roe Highway	Both directions
	Welshpool Road East	Both directions
	Albany Highway	Both directions
	Ranford Road	Both directions
	Armadale Road	Both directions
	Rowley Road	Both directions
	Thomas Road	Northbound ramp only

5.5 Consideration of freeway-to-freeway ramps

As part of a coordinated system to manage and control mainline traffic, the provision of ramp signals on freeway-to-freeway ramps is generally required to minimise downstream potential for flow breakdown (see *Smart Freeways Provision Guidelines*).

Depending on the nature of the interchange, different design approaches may be appropriate as outlined in Victoria's *Managed Motorway Design Guide: Volume 2* Part 3, Chapter 7 (2019). Where freeway-to-freeway ramp signals are provided they would only operate when needed, and uninterrupted free-flow entry would be available at other times.

Table 5.3 provides a guide to locations where freeway-to-freeway ramp signals should be considered. This must also be considered as part of mainline volume and capacity route analysis, based on design flows and maximum sustainable flow rates (MSFR) along the route being managed, in accordance with Victoria's MMDG Volume 2 Part 3, Sections 4.3 and 4.4.

Table 5.3: Potential freeway-to-freeway ramp signal locations

Freeway-to-freeway interchange	Entry ramps to be controlled
Roe Highway / Kwinana Freeway	All
Roe Highway / Tonkin Highway	All
Roe Highway / Perth Adelaide National Highway	All
Tonkin Highway / Reid Highway	All
Reid Highway / Mitchell Freeway	North, south and east approaches
Whiteman Yanchep Highway / Tonkin Highway	Southbound direction only

6 Design departure governance

6.1 Overview

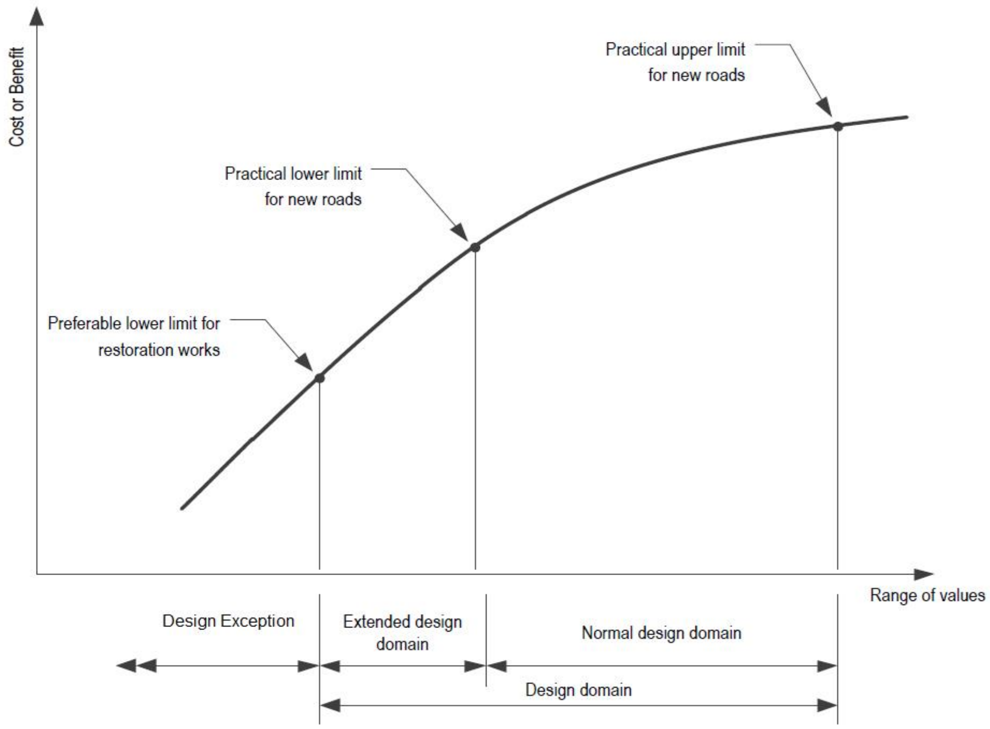
Effective governance of Smart Freeways design is essential to ensure sound project outcomes. Design decisions need to be informed by current standards and different perspectives of specialist project stakeholders for this high value and complex infrastructure program.

Where departures from design standards are deemed necessary for any aspect of Smart Freeways design, the justifications for the design departures should be documented in the SWTC and BDC to inform detailed design and delivery.

6.2 Departures from design standards

6.2.1 Context

Design domain can be thought of as a range of values that a design parameter might take. It is a range of design parameters that can be justified in an engineering sense (based on test data, sound reasoning etc.) and therefore can have a reasonable level of defence if questioned. The design domain approach places emphasis on developing appropriate and cost-effective designs rather than providing a design that simply meets standards. Figure 6-1 illustrates the concept that requires a designer to select a value for each design element from a range of values, considering the benefits and costs of each selection.



Notes:

- The value limits for a particular criterion define the absolute range of values that it may be assigned.
- The design domain for a particular criterion is the range of values, within these limits, that may practically be assigned to that criterion.

Figure 6-1: The design domain concept

Source: Based on Austroads (2015)

Figure 6-1 shows that the design domain comprises a Normal Design Domain (NDD) and an Extended Design Domain (EDD). Within the context of geometric road design, the lower regions of the design domain represent values that would generally be considered less safe or less efficient, but usually less expensive than those in the upper regions of the domain. The decision on the values to adopt must be made using objective data on the changes in cost, safety and levels of service caused by changes in the design, together with consideration of performance outcomes (safety and operational efficiency) and in some cases, when comparing scope options, a benefit-cost analysis.

Relative benefits and performance data is not always available, particularly data that relates to changes in the values associated with specific design elements and parameters to safety performance. Designers need therefore refer to relevant documents, including Victoria's *Managed Motorway Design Guide*, the Austroads *Guide to Road Design* series of documents, and research reports to assess the potential effects of changes in values for the various design elements involved. The data chosen should also consider the importance of incorporating Safe System principles in the design.

Using this concept provides the following benefits to the designer:

- It is more directly related to the road design process, placing a greater emphasis on developing appropriate and cost-effective designs rather than merely following prescriptive standards.
- It reflects the continuous nature of the relationship between changes in the design dimensions and service, cost and safety, as the designer must consider the impacts of trade-offs throughout the domain and not just where a standard threshold is crossed.
- It provides an implied link to the 'factor of safety', a concept commonly used in civil engineering design processes where risk and safety are important.

A ***Design Exception*** (DE) is part of a design that adopts values outside the design domain (that is, outside both the NDD and the EDD) and includes innovative technology or treatments through "Pilot Projects" or "Trials", because the performance of the technology or treatment in WA may be unknown or untested. They are unlikely to provide reasonable road-user capability, unless the treatment or technology has been satisfactorily demonstrated elsewhere. (Reasonable road-user capability is the capability a court of law decides a road user should reasonably expect to have, when they are taking reasonable care for their own safety.)

The ***Extended Design Domain*** (EDD) offers some latitude in road design, and, in many cases, road-user capability will still be adequate with a design that incorporates EDD criteria. However, when a design incorporates a DE, road-user capability is largely unknown, so a high level of technical judgement and understanding of road user behaviour are needed to inform and review the design.

6.2.2 Smart Freeways types of departures from standards

The design standards and guidelines applicable to Smart Freeways contribute to ensuring operational safety for road users as well as an ability to achieve optimum traffic performance. Therefore, departures from the Smart Freeways standards, guidelines, or principles forming the basis of operations, must be formally approved by Main Roads after due consideration of all constraints, criteria and risks.

Within the context of Smart Freeways, design departures can be considered under three categories:

- **Normal Design Domain** (NDD) – design parameters that are considered practical lower limits, or 'absolute minimums,' and are typically discussed in the body of the Main Roads guideline documents. This includes 'special cases,' that is design layouts or parameters that are not Main Roads' preferred position but may respond to specific constraints such as retrofit situations. These designs and parameters are identified in the guidelines documents as requiring approval in accordance with this document.
- **Extended Design Domain** (EDD) – as defined in the *Guidelines for the Extended Design Domain & Design Exception Process*, these are design parameters that are either outside the requirements of the NDD or have not been considered in the Main Roads guidelines, but where other national or international guidance and research reports are available that provide data and justification that can have a reasonable level of defence if questioned. These parameters represent values that would generally aim to balance designs within various constraints, including safety, efficiency or other parameters, but also result in more economical designs. The decision on the values to adopt must be made using objective data on the changes in cost, safety and operational outcomes, caused by changes in the design, and should be supported by a risk analysis as well as the provision of mitigating measures. Use of EDD should also preferably be supported with a benefit-cost analysis.
- **Design Exceptions** (DE) – as defined in the *Guidelines for the Extended Design Domain and Design Exception Process*, these are design parameters that are not contemplated in the Main Roads guidelines, and for which there is limited national or international data or research available to justify their use. A high level of technical judgement is needed to inform and review the design, and any use of such values must be formally approved by the relevant Executive Director in Main Roads after due consideration of all constraints, criteria and risks.

  Design exceptions also include the trial of a new technology or a pilot project to test a new system. From this point of view, a DE does not meet the description of a design parameter falling outside of the NDD and EDD values as indicated in Figure 6-1. It makes sense therefore to differentiate between a DE using a value outside of EDD and NDD values and a DE using a technology new to WA. This type of DE is termed a Technology Design Exception.
- **Technology Design Exception** (TDE) – a design that adopts a specific technology, device or concept of operations that has not been considered in the Main Roads guidelines, but where other national or international guidance and research reports are available that provide data and justification that can have a reasonable level of defence if questioned. The use of this technology or concept of operations would generally aim to achieve a more economical solution while still meeting the objectives of the project and the minimum performance, safety and operational requirements of Main Roads.

6.3 Approval documentation

6.3.1 General principles

The approval process applies to all design departures from the Smart Freeways *Policy Framework Overview, Provision Guidelines* and design guideline documents. Design departure approvals are managed under Main Roads Delegation of Authority (DoA) with respect to "designs varying from Main Roads standards", and the requirements below.

Any changes to design parameters can have a fundamental impact on the performance of two facets of freeway operations, namely *safety* or *operational efficiency*. Arguably, any changes will have an impact on both, but in many cases, the prime impact will be on either safety or operational efficiency.

Smart Freeway operations and design departures need to focus on:

- route management requirements which need to be considered as a whole, that is on the sum of the parts, relative to operational objectives
- individual site-specific design departures which are considered relative to specific design targets focussed on safety and/or operations
- targeted use of ITS technologies consistent with warrants based on safe and efficient operation.

6.3.2 Reports

Departures from the guidance in the Smart Freeway documents must be documented in a report, or reports, and signed off as part of an auditable process. When reporting on departures and available options, an increase in project scope or cost to improve the project design and outcomes may be a valid recommendation.

Appendix C provides an example of a design departure request memo. More detailed technical reports also need to be submitted to include the following matters, as applicable:

- demonstration that the adoption of a standard design or operational concept (in accordance with the Smart Freeways documents) **is not feasible because of physical, environmental, heritage, social or economic constraints**
- demonstration of the use of mitigation measures to offset potential safety or operational risks – for localised site and system operational outcomes
- a revised benefit-cost analysis, if a change of project scope or budget is recommended.
- implications for asset management or maintenance
- risk evaluation with a focus on qualitative (rather than quantitative) assessment relating to desired project outcomes of the adopted design or operational concept
- demonstration that the adoption of the design departure is in the overall community interest with respect to investment strategies, road safety strategies, and other strategies that relate to freeway networks.

6.4 Approval process

6.4.1 Timing and record-keeping

The approval process must be initiated as early as practicable within the project development process, and ideally at or before the 15% design stage (draft design report). Approved design departures can then be incorporated into the final design report at that stage of design.

Approved designs resulting from the design departure process must be carried forward to later stages of project design, or implementation. If during more detailed stages of design an approved design departure needs adjustment, that is further compromising of NDD standards, they need to be resubmitted for further review and approval as delegated below. This includes projects with implementation that use design and construct, alliance, public-private partnerships, or other delivery mechanisms.

In the context of operational efficiency audit of a project design (see separate Smart Freeway Operational Efficiency Audit Guidelines), the Project Manager will ensure that matters identified in an audit, which are outside of the NDD and not previously considered under the design departures requirements, are submitted for appropriate approval according to the defined delegation for the matters identified.

Design documentation, reports and records of decisions should be recorded in the Main Roads filing system, as well as forming part of handover documentation to design teams dealing with later phases of the project design or construction, that is as part of Scope of Works Technical Criteria (SWTC). Reports and records of approval must be retrievable documents and not part of contract documents which may have limited access.

The decisions on why design departures have been allowed must be defendable but should not set a precedent for similar design departures being automatically allowed in future cases. The approval processes are intended to ensure that the responsibility for the use of EDD, ED or TDE is taken corporately by Main Roads, and is not placed on an individual designer or other organisation.

6.4.2 Delegation of decision-making

The design departure approval process is outlined in Figure 6-2 and described in further detail below.

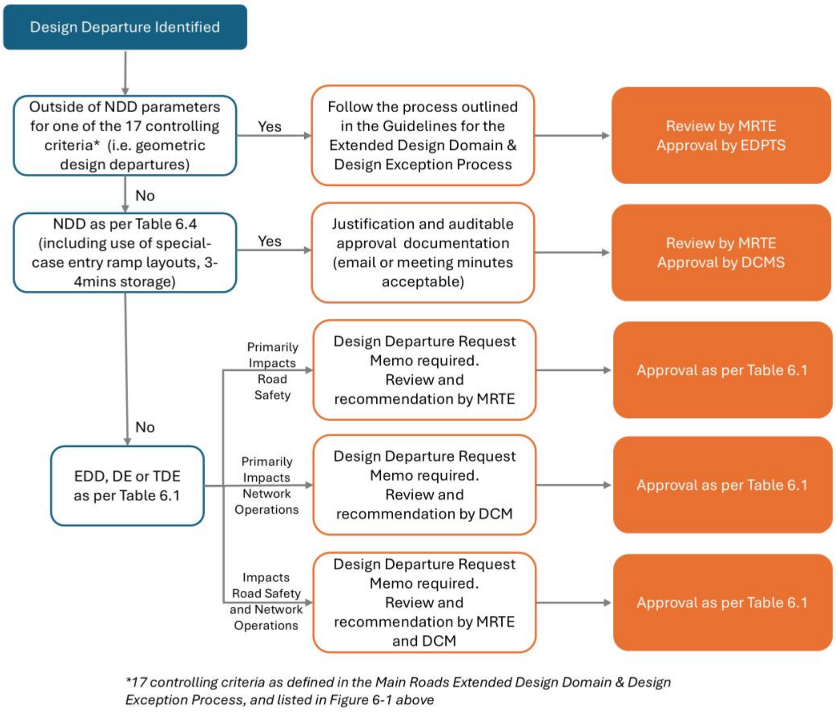


Figure 6-2: Design departure approval process

NDD, EDD and DE parameters for any of the 17 controlling criteria identified in the EDD & DE Guidelines

Documentation must be as per the document *Guidelines for the Extended Design Domain & Design Exception Process* (the EDD & DE Guidelines). The 17 listed criteria in those guidelines that are of substantial importance to the operational and safety performance are:

1. Design speed
2. Lane width
3. Shoulder width
4. Bridge width
5. Horizontal alignment
6. Superelevation
7. Vertical alignment
8. Grade
9. Stopping sight distance (including Approach Sight Distance at intersections)
10. Cross slope
11. Vertical clearance
12. Lateral offset to obstruction
13. Structural capacity / design vehicles
14. Acceleration lane length
15. Deceleration lane length
16. Waterways capacity / serviceability requirements
17. Pavement design

Figure 6-3: The 17 controlling criteria of substantial importance to operational and safety performance

Approvals for design departures that impact primarily on geometry and road safety need to be given by the Executive Director Planning and Technical Services (EDPTS), using the current process detailed in the *Guidelines for the Extended Design Domain & Design Extension Process* (Main Roads, 2020). Most of the seventeen controlling criteria, identified in Section 5.2 of these guidelines as critical for design purposes in WA, are applicable to the geometric design of Smart Freeways. Any proposed departures from Main Roads standards, with respect to these controlling criteria, require a review by the Manager Road and Traffic Engineering (MRTE) and approval by the EDPTS.

The Director Congestion and Movement (DCM) or the Executive Director Network Operations (EDNO), as applicable, must give approvals for design departures that impact primarily on operational matters.

The EDPTS and the EDNO must give approvals for design departures that affect both road safety and operational matters, where applicable. Where design departures relate to geometric design parameters, they will be reviewed and approved by the Manager Road and Traffic Engineering (MRTE). Otherwise all design departures should be reviewed by MRTE and approved by the DCM.

NDD for parameters that are not part of the 17 controlling criteria identified in the EDD & DE Guidelines

- Justification and recommendation for the adopted design / operational concept
- Confirmation of the review and approval process that has been undertaken.

These matters must be reviewed by the MRTE and approved by the DCM. These matters do not need to be part of the design departure request memo referenced in Section 6.3.2.

EDD, TDE and DE for parameters as listed in Table 6.1 - that are not part of the 17 controlling criteria identified in the EDD & DE Guidelines

Design decisions relating to EDD, TDE and DE indicated in Table 6.1 must initially be considered by the Manager Road and Traffic Engineering (MRTE), in the context of analysis, geometry and road safety – either for approval, if applicable, or for referral to the Director Congestion and Movement (DCM) for matters relating to network operations. Departures would then be either approved by the DCM or recommended to the Executive Director Network Operations (EDNO) for approval or as shown, as applicable. The DCM may need to consult with other relevant specialists before making recommendations.

A design departure request memo referenced in Section 6.3.2 must be prepared for all departures.

The project manager will ensure that an appropriate record of approval is distributed and filed in the Main Roads system.

6.5 Design departures requiring consideration

Due to the high cost and complexity of the freeway infrastructure, the important role of freeways in the arterial road network and the critical nature of design decisions, the design departure items listed in Table 6.1 need to receive the minimum level of approval as indicated.

For a Smart Freeway project, the design departures for performance of the mainline and individual entry ramps also need to be considered in the context of the combined system storage. Any ramp deficiencies relative to the critical bottleneck locations for the purpose of route operations, that is the need for overall project optimisation, need to be considered as well as the needs at individual ramps.

The following abbreviations are used in Table 6.1:

- DCM – Director Congestion and Movement
- EDNO – Executive Director Network Operations
- EDPTS – Executive Director Planning and Technical Services
- MRTE – Manager Road and Traffic Engineering

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Table 6.1: Design departures requiring approval

Subject	Design status and departures	Primary impact	Design exception: review and recommend	Design exception: Approval	Reference
	ITS Technologies				
1. Freeway Type F (Foundation) level ITS	NDD: Meets all requirements.	Geometry, Road Safety and Network Operations			Provision Guidelines Sections 5.2 and 5.3
	EDD: n.a.				
	DE: Not all requirements met.		MRTE DCM	EDPTS EDNO	
2. Functionalities within the Freeway Types C, B or A	NDD: Meets Provision Guideline requirements.	Geometry, Road Safety and Network Operations			Provision Guidelines Sections 5.2 and 5.4
	EDD: n.a.				
	DE: Departures from the Provision Guidelines.		MRTE DCM	EDPTS EDNO	
3. Provision of LUMS	NDD: Type B or A freeway.	Geometry, Road Safety and Network Operations			Provision Guidelines Section 6.5
	EDD: n.a.				
	DE: LUMS not included for Type B or A freeway, or LUMS to be included for Type C freeway.		MRTE DCM	EDPTS EDNO	
4. All lane running	NDD: Type A freeway, subject to analysis and approval.	Geometry, Road Safety and Network Operations			Provision Guidelines Sections 5.2, 5.4 and 6.5.2
	EDD: Type C or F Freeway with a short distance localised ALR and no LUMS.			MRTE	
	DE: Type A or B freeway without LUMS or with insufficient ESB density.		MRTE DCM	EDPTS EDNO	
5. Reversible lanes	NDD: n.a.	Geometry, Road Safety and Network Operations			Provision Guidelines Section 6.5.2
	EDD: n.a.				
	DE: Where lanes are to be adjusted in real-time to improve capacity with tidal traffic demand.		MRTE DCM	EDPTS EDNO	
6. Variable speed limit without LUMS	NDD: n.a.	Road Safety and Network Operations			Provision Guidelines Sections 6.4 and 6.5
	EDD: n.a.				
	DE: Any freeway as a safety treatment, or Type C freeway to link two adjacent LUMS sections.		MRTE DCM	EDNO	
7. Trial of new ITS technology not identified in the Provision Guidelines	NDD: n.a. EDD: n.a. TDE: All trials or pilot studies.	Geometry, Road Safety and Network Operations	MRTE DCM	EDNO	

Subject	Design status and departures	Primary impact	Design exception: review and recommend	Design exception: Approval	Reference
	Mainline Design				
8. Peak hour design volumes from 24-hour models	NDD: K-factor between 9% and 10%.	Geometry, Road Safety and Network Operations			MMDG Vol 2 Part 3 Section 3.3.4.3.3. Supplement to MMDG Vol 2 Part 3 Section 3.3.4.3.3
	EDD: K-factor between 8.5% and 9%, or > 10% for mainline, or > 12% for individual turning movements.			MRTE	
	DE: K-factor < 8.5%		MRTE	DCM	
9. Mainline lanes design volume / MSFR analysis for any freeway section at proposed level of control	NDD: Volume / MSFR ratio (VCR) ≤ 1.0 (100%)	Geometry, Road Safety and Network Operations			MMDG Vol 2 Part 3 Section 4.4 (particularly Section 4.4.2 and 4.4.7) and Section 6.3.2.
	EDD: Volume / MSFR ratio (VCR) > 1.0 and < 1.1 (100% to 110%). Proposals for demand management.		MRTE	DCM	
	DE: Volume / MSFR ratio (VCR) > 1.1 (110%). Proposals for demand management / compensating storage.		MRTE DCM	EDNO	
10. VDS spacing (mainline and ramps): Type F freeway	NDD: 500 m to 2,000 m, within all interchanges and on all ramps.	Geometry and Network Operations			MMDG Vol 2 Part 3 Section 5. Provision Guidelines Sections 5.2 to 5.4.
	EDD: n.a..				
	DE: > 2,000 m, and ramps without VDS		MRTE DCM	EDNO	
11. VDS spacing (mainline and ramps): Type C, B or A freeway	NDD: 400 m to 500 m, within all interchanges and on all ramps.	Geometry, Road Safety and Network Operations			
	EDD: < 400 m, or Between 500 m and 600 m.		MRTE	DCM	
	DE: >600 m.		MRTE DCM	EDNO	
12. Emergency stopping bays spacing: Type F, C, or B freeway. (incl. roadside help phones)	NDD: up to 3,000 m.	Road Safety and Network Operations			Provision Guidelines Section 5.2 and 8.4. Guideline: Emergency Stopping Bays and Roadside
	EDD: not meeting all design criteria.		MRTE	DCM	
	DE: > 3,000 m, or on the right side of the roadway.		MRTE DCM	EDNO	
13. Emergency stopping bays spacing:	NDD: 400 m to 600 m	Road Safety and Network Operations			
	EDD: 600 m to 1,000 m, or not meeting all design criteria.		MRTE	DCM	

Subject	Design status and departures	Primary impact	Design exception: review and recommend	Design exception: Approval	Reference
14. Type A freeway. (incl. roadside help phones)	DE: > 1,000 m, or on the right side of the roadway.		MRTE DCM	EDNO	Help Phones Section 3.
15. Spacing of LUMS gantries	NDD: 400 m to 600 m.	Geometry, Road Safety and Network Operations			Supplement to Handbook for LUMS Section 2.5.3
	EDD: < 400 m or 600 m to 800 m.			MRTE	
	DE: > 800 m.			DCM	
Mainline special use lanes	NDD: no special use lane.	Geometry, Road Safety and Network Operations			Provision Guidelines Section 6.2.3
	EDD: n.a.				
	DE: all proposals for priority vehicle lanes.		MRTE DCM	EDNO	
	Ramp Signals Design				
16. Design life	NDD: ≥ 10 years	Geometry, Road Safety and Network Operations			Provision Guidelines Section 4.1.2
	EDD: < 10 years		MRTE DCM	EDNO	
	DE: n.a.				
17. Number or extent of controlled ramps	NDD: Design volume ≤ managed MSFR capacity. All ramps in an analysed system controlled.	Geometry, Road Safety and Network Operations			MMDG Vol 2 Part 3 Section 4 - particularly Sections 4.3.2.7 and 4.3.2.8
	EDD: Design volume > managed MSFR capacity (including in a partially managed transition zone).		MRTE	DCM	
	EDD: an uncontrolled ramp in a managed system.		MRTE	EDNO	
	DE: n.a.				
18. Priority access lanes on entry ramps	NDD: Ramps that meet priority locations guidance and don't compromise discharge capacity or storage for general traffic.	Geometry, Road Safety and Network Operations Geometry and Road Safety			MMDG Vol 2 Part 3 Section 6.8.1, 6.8.3 and Appendix A Main Roads supplement to MMDG Vol 2 Part 3 Section 6.8
	NDD: Metered priority lane: Option 2.			MRTE	
	EDD: Designs that reduce discharge capacity or storage for general traffic to less than desirable values.		MRTE	DCM	
	DE: n.a.				

Subject	Design status and departures	Primary impact	Design exception: review and recommend	Design exception: Approval	Reference
19. Ramp Discharge Capacity: i.e. number of Stop Line lanes	NDD: Cycle times ≥ 7.5 sec. (1 or 2 lanes), or ≥ 6.5 sec. (3 or 4 lanes), i.e. black figures in MMDG Table 6.1.	Geometry, Road Safety and Network Operations			MMDG Vol 2 Part 3 Section 6.2 and Table 6.1
	EDD: Cycle times < 7.5 sec. (1 or 2 lanes), or < 6.5 sec. (3 or 4 lanes), i.e. orange figures in MMDG Table 6.1.		MRTE	DCM	
	DE: Cycle times < values in MMDG Table 6.1.		MRTE DCM	EDNO	
20. Ramp storage:	NDD: ≥ 4-minutes	Geometry, Road Safety and Network Operations			MMDG Vol 2 Part 3 Section 6.3, Table 6.1 and Section 6.3.2.
	EDD: 3 to 4 minutes, and compensating proposals for storage inadequacy (as per Section 6.3.2).			MRTE	
	DE: < 3 minutes, or Storage required on the arterial road. Compensating proposals for storage inadequacy (as per Section 6.3.2).		MRTE DCM	EDNO	
21. Ramps with very high design volumes, i.e. > 3,000 pc/h (beyond limits of MMDG Table 6.1)	NDD: n.a. EDD: n.a. DE: Ramp designs requiring more than four-lanes at the stop line, i.e. where layouts are not included in Main Roads Guideline Drawings.	Geometry, Road Safety and Network Operations	MRTE DCM	EDNO	MMDG Table 6.1. Main Roads Supplement to MMDG Vol 2 Part 3 Section 6.3.
22. 2-metered lanes ramp signals layout, merging to a single lane at nose	NDD: Use of 80m distance between the stop line and the nose, in retrofit situations where ramp storage is an issue. EDD: n.a. DE: n.a.	Geometry and Road Safety		MRTE	Main Roads supplement to MMDG Vol 2 Part 3 Section 6.5
23. Signal post location	NDD: n.a. EDD: Loop ramp with signal post on right side of ramp. DE: n.a.	Geometry and Road Safety		MRTE	Supplement to MMDG Vol 2 Part 3 Section 6.10.2

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Subject	Design status and departures	Primary impact	Design exception: review and recommend	Design exception: Approval	Reference
24. 3-metered lanes ramp signals layout, merging to a single lane at nose	NDD: Special case layout with staggered stop-line (Dwg 202431-000305). NDD: Special case layout with dynamic metered lane for additional storage and overhead LUMS sign (Dwg 201731-0028)	Geometry and Road Safety		MRTE	MMDG Vol 2 Part 3 Section 6.6, and Main Roads Supplement to MMDG Vol 2 Part 3 Section 6.6.
	EDD: n.a.				
	DE: n.a.				
25. Freeway-to-freeway ramps	NDD: All freeway-to-freeway ramps to be controlled.	Geometry, Road Safety and Network Operations			MMDG Vol 2 Part 3 Section 7 Main Roads Supplement to MMDG Vol 2 Part 3 Section 7.
	EDD: n.a.				
	DE: Ramp signals designs not covered by Main Roads supplement to MMDG (e.g. more than four lanes at the stop line). DE: Ramps without ramp signals.		MRTE DCM	EDNO EDPTS	
	Other matters not included above				
26. Other matters not included above	DE: Any other design aspect where design is inconsistent with the Main Roads Smart Freeway documents.	Analysis, Geometry, Road Safety and Network Operations	MRTE DCM	EDNO EDPTS	

7 Performance-based operations

7.1 Context

While performance-based design can optimise a completed project's performance outcomes, these can only be achieved with sound operating principles for Smart Freeways, and particularly with management of the mainline with coordinated ramp signals.

While the project design needs to reflect best practice and opportunities for successful operations, the principles and rationale for operations are equally important. For example, a design with inappropriate compromises during the design process will result in a project that is problematic for effective operations. Similarly, a good design may not perform satisfactorily unless sound operational strategies and principles are implemented by system operators to optimise operations.

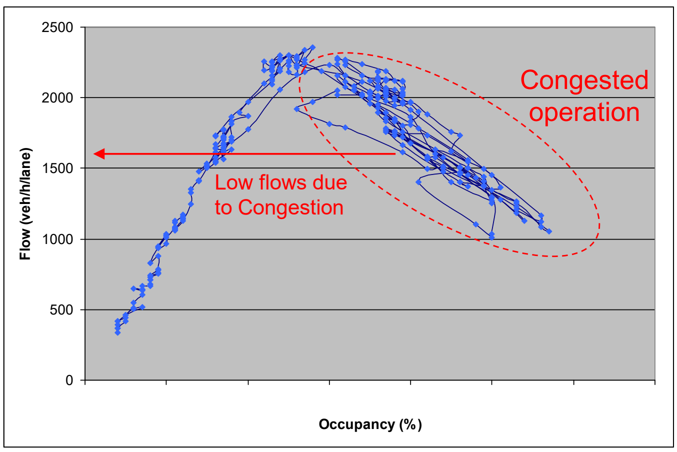
7.2 Mainline and system management concepts

The freeway ramp signalling system controls the discharge flows from entry ramps in order to:

- protect the mainline operation by keeping flows within critical occupancy (density)
- manage multiple bottlenecks occurring along on the freeway (not just at each ramp merge)
- assist with recovery of flow to stable conditions if breakdown starts to occur
- respond to traffic conditions caused by incidents, including management of traffic demand
- protect arterial roads within the constraints of the available and shared ramp storages.

Unmanaged freeways with high traffic demand generally experience flow breakdown as shown in Figure 7-1.

Smart Freeways use coordinated ramp signals to manage the mainline and control traffic demand within the freeway's capacity. This can generally prevent or minimise flow breakdown as shown in Figure 7-2. Optimum operation to minimise flow breakdown aims to keep flow at a target occupancy in the stable range, that is just less than the optimum theoretical capacity where traffic flow is unstable. This target operation (typically in the order of 90 to 95 per cent of measured capacity) optimises productivity (flow and speed) as well as road user safety.



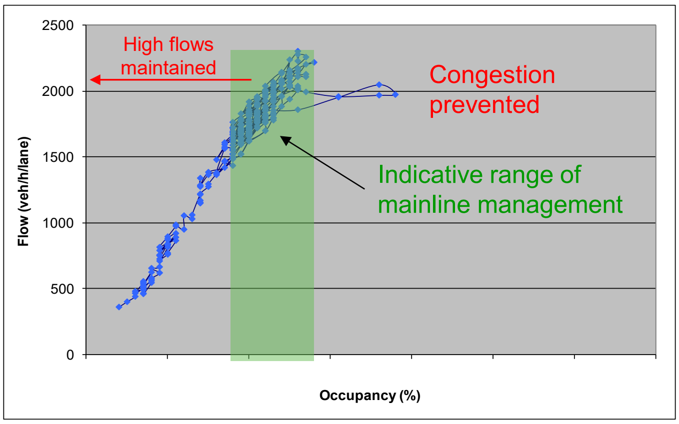
Flow breakdown results in:

- worsening safety performance
- congestion
- reduced throughput
- reduced speed
- lost productivity.

Source: Victoria's MMDG Volume 2 Part 2, Figure 2-5

Note: Horizontal axis values are not shown as occupancy varies according to VDS sensor type and bottleneck capacity.

Figure 7-1: Unmanaged freeway performance with flow breakdown



Smart Freeway management results in:

- prevention / delay of flow breakdown
- safer operation
- improved productivity (optimised throughput and travel speed)
- improved reliability.

Source: Victoria's MMDG Volume 2 Part 2, Figure 2-5

Note Horizontal axis numerical values are not shown to avoid confusion.
Occupancy varies according to VDS sensor type and bottleneck capacity.

Figure 7-2: Smart Freeway performance with managed flow

7.3 Ramp signals operational principles

7.3.1 Usual operations

The usual operation of ramp signals is automated with dynamic and coordinated operation. This includes a sound basis for mainline and ramps system parameter values, together with regular analysis to optimise operations. An overview of ramp signals operation and the control algorithms used by Main Roads are in Victoria's *Managed Motorway Design Guide Volume 2:* Part 2: Managed Motorway Network Optimisation Tools.

Operations must be guided by the following priorities and principles:

- Provide settings to ensure the ramp signals only switch on when necessary and then switch off when no longer needed.
- Avoid potential for mainline flow breakdown as this optimises safety and productivity.
- Manage entry ramp queues in a coordinated manner with traffic demand management and balancing of queues between ramps, that is 'share the load.' Automated system flow parameter settings for queue management (queue control and queue override) should avoid potential for mainline flow breakdown.
- Provide equity of access from entry ramps with appropriate waiting times (may be different for different ramps). Automated system flow parameter settings for waiting time on the ramp should avoid potential for mainline flow breakdown.
- Protect the operation of arterial roads with the effective management of all storage areas. This includes all entry ramps and may also include the use of space on the arterial road, if necessary, to maintain operation according to the higher-level priority principles. Section 7.3.2 provides principles relating to entry ramps with excessive demand.

7.3.2 Excessive entry ramp demand

Traffic demand that creates operational challenges in managing the mainline effectively may occur for a number of reasons, including:

- a freeway and/or ramps not being designed to meet traffic demand
- a well-designed freeway, but where there are short-term traffic demands which are higher than the design volumes.

As traffic demand increases, the policy for control of ramps and optimisation using coordinated ramp signals include the following principles, particularly where consideration is being given to actions that will lead to mainline flow breakdown. These principles recognise the economic importance of freeways in the road network and the cost implications of increased delay due to congestion for high traffic volumes using the freeway. These principles are very important for high flow ramps, and particularly for freeway-to-freeway ramps.

- Manage entry ramps to prevent flow breakdown on the mainline. This would take priority over the extent of queuing on the controlled entry ramps.
- Minimise ramp queues that extend back to interfere with through traffic on the arterial roads. In the case of arterial road ramps, queuing into an exclusive turning lane or into one lane of a three-lane carriageway is generally acceptable. Beyond this point, the coordinated ramp signal system would act to severely restrict all ramp entry flows in order to maintain stability of the mainline.
- Where consideration is being given to operational strategies or ramp management actions that would increase the potential for, or cause, flow breakdown of the mainline, this must only be implemented after analysis of traffic flow implications for the mainline, ramps and arterial roads. This analysis may include safety and economic analyses, such as cost of delay with, and without, flow breakdown, access delays, likelihood of crashes in stable and unstable/congested flow, and other factors that may be relevant.
- Entry ramps may need to be closed during an incident or to recover flow after an incident.
- For freeway-to-freeway ramps:
  - For safety and traffic flow reasons, avoid queues at controlled freeway-to-freeway ramps from extending back to interfere with traffic on the upstream freeway through lanes, or other traffic movements within the interchange, for example a branched ramp.
  - Ramp signals may be operated with lower delays (waiting time) in recognition of their role in the freeway network, provided this does not compromise overall mainline control downstream. This may include lower wait-time thresholds compared to entry ramps from arterial roads, for example if 4 minutes is a target waiting time at ramps from arterial roads, 3.5 minutes may be an option at a freeway-to-freeway ramp.

7.3.3 Heavy congestion management

An integrated approach is needed when managing heavy congestion including the use of ramp signals to manage demand, traffic diversion by providing real-time traveller information, use of existing traffic signals to facilitate appropriate traffic diversions, support for the ramp signal operations and other incident management strategies. Victoria's *Managed Motorway Design Guide Volume 2*: Part 2 (sections 3.6 to 3.9) provides a summary of the benefits of freeway management during incidents and heavy congestion.

Freeway management during an incident or heavy congestion and to facilitate flow recovery, would benefit from additional strategies which could be employed outside of the normal ramp signalling algorithm operation. Special traveller information messages of 'Major Delays' and 'Seek Alt Route' would also be used (see *Guidelines for Variable Message Signs*).

The ramp signalling intervention would restrict the ramp flows to values lower than normal operation, for example with cycle times up to 20 seconds. While this would cause longer ramp queues, the modified operation would reduce the extent of worsening congestion and facilitate faster recovery from congestion. While not automated at this stage, the adjustments to over-ride the ramp signal algorithms could be based on the ratio of estimated travel time to nominal travel time. Road user acceptance of this future potential management strategy would need to be monitored.

Additional strategies to integrate the operation of adjacent traffic signals in response to an incident or heavy congestion should be considered to support the operation of the freeway. The following alternative traffic signal operation methods may be used to manage of heavy congestion along a route, which is not related to an incident.

- **Method 1**: Modifying traffic signals operation to restrict (gating) flow along the feeder arterials to support the operation of the ramp signals. Restricting the flow onto the ramp may sustain the ability to continue to effectively use the ramp signal algorithm. That is, the reduced arrival flow would allow the ramp signal algorithm to continue to support freeway management without a reduction in capacity along the arterial route, due to the ramp queue otherwise exceeding the available storage. In this scenario, the additional cumulative delay, due to gating on the arterials, must be less than the delays that would be experienced had the ramp queue overspilled and reduced the arterial road capacity.
- **Method 2:** Facilitating more efficient travel times along the arterial route to encourage an alternative route choice to the freeway. If restricting the arrival flow to the on-ramp (Method 1) provides little to no benefit to the ramp signal's ability to effectively manage the freeway and is ineffective at mitigating ramp queue overspill, this operating method should be considered. By operating the traffic signals with an induced improvement in travel times along the arterial route, a change in driver route choice is encouraged. This will allow better network usage and minimising delays for the wider road network.

For incidents that have significant impact on the freeway, the detours require vehicles to start exiting at the earliest available off-ramp. This requires timely advice to road users on the freeway using strategic VMS – generally over a relatively long distance (see the *Guidelines for Variable Message Signs*, and particularly Table 2.3). As freeway volumes are generally significant (that is greater than the capacity of a single exit ramp and the intersecting arterial road at that point), 'unloading' of the freeway will generally need to use a number of interchanges for 'wide area network dispersion' (WAND as referred to in Victoria's design guides). Due to the certainty of the required interventions with predefined response plans (if the scenario is predicted), traffic signal modifications can be developed for more efficient and effective intervention across the road network.

7.3.4 Extra-ordinary circumstances

During extra-ordinary circumstances the signals may be switched off, or switched on, according to the situation. Some extra-ordinary circumstances may include:

- If emergency vehicle freeway access is needed, the ramp signals may be manually switched off to clear a queue and hence avoid any potential delay to the emergency vehicle. This may be needed for an incident on the freeway, or when an emergency vehicle is needing access to the freeway for travel to an incident elsewhere on the road network. Communication protocols need to be established with the ambulance service, fire brigade and police to facilitate this operation.
- When there is an incident on the freeway the ramp signals may be switched off and the ramp closed. In this case regulatory control over the freeway access is provided by the 'No Right Turn' and 'No Left Turn' signs at the interchange ramp entrance, supported by a 'Freeway Closed' message.
- During maintenance or construction downstream of a ramp, ramp signals may be beneficial in managing vehicle headways. (They may not be needed to manage mainline flow or occupancy.)

8 References

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Appendix A Definitions

Central control system Management system and user interface for the operation of all ITS field equipment and systems in Western Australia, operable via the Road Network Operations Centre (RNOC).

Efficiency In terms of travel speeds. This refers to the definition of efficiency used in the Austroads National performance Indicators for network operations (Austroads 2007). Efficiency indicators include travel speeds (i.e. spot speeds on freeways) and variation from posted speed limits.

Intelligent Transport Systems (ITS) Integrated application of communications, control and information processing technologies to the transport system, to monitor and manage traffic flow performance.

Smart Freeways Making best use of the existing freeway network, through the controlled use of technology and operational strategies enabling real-time network management led by an informed road operator.

Smart Freeway technologies ITS treatments (that is field equipment, communications and central control systems), supported by mainline and ramp geometric improvements, and dynamic management and operational strategies that are included within the Smart Freeways 'toolkit' as outlined in the *Smart Freeways Provision Guidelines*.

Operational capacity The maximum flow rate that achieves acceptable traffic performance of the facility and beyond which – in case of greater demand – proper operation fails. This is based on a modified definition of capacity as provided by Brilon and Geistefeldt (2009), whose research demonstrates that 'highest efficiency' flows occur if the demand volume reaches 90 per cent of the conventional design capacity.

Operational strategies A pre-determined plan that the traffic operator or central control system implements in response to real-time traffic conditions and events / incidents on the network.

Productivity In terms of freeway productivity. Refers to the Austroads definition of productivity used in the *National Performance Indicators for Network Operations* (Austroads 2007). The productivity indicator is based on the product of speed and flow. Note that productivity is also used to describe community benefits arising from Smart Freeways, such as increases in economic productivity.

Reliability In terms of travel times. The Austroads definition of reliability used in the National performance Indicators for network operations (Austroads 2007) is based on the variability of travel speeds, using the coefficient of variation.

SMART Methodology to set objectives for project management and performance management that are specific, measurable, attainable, relevant and timely.

Throughput The total traffic volume per hour that is achieved at a given point in a given time period.

Road Network Operation Centre (RNOC) The operational management centre for real-time (24/7) monitoring, control and analysis of traffic movements on the Main Roads road network.

Whole-of-Life-Costs (WLC) The total costs of ownership over the life of an asset, which includes road authority costs (maintenance, operations costs) as well as road user costs (vehicle operating and travel time costs) and community / environmental costs (crash costs).

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Appendix B Smart freeways policy

FEBRUARY 2020

Smart Freeways Make sense

Smart Freeways Policy

Main Roads is progressively introducing Smart Freeway solutions[1] into our existing and future road assets, aiming to provide the safest, and most reliable, productive and resilient state road network for our customers.

Objectives

Our objectives are to create a world-class state road network through appropriate implementation and operation of Smart Freeways to:

- provide reliable travel times
- enable efficient movement of people and freight
- improve network productivity contributing to the state's economic prosperity
- improve safety of all road users including road workers
- reduce congestion, emissions and cost of travel
- add additional capacity to the existing roads through targeted improvements and using appropriate technology
- improve network resilience and flexibility to meet abrupt change in demand or available capacity due to incidents
- enhance real-time information to improve customer travel experience
- support connected and automated vehicles, aligned with national guidance.

Principles

This policy is underpinned by the following principles:

- Smart Freeway solutions will be guided by this policy and Smart Freeways guidelines, which are aligned with best practice.
- Smart Freeways are to be part of an integrated transport system and aligned with long-term network planning.
- Smart Freeway solutions will be designed to address specific performance issues identified by network analysis and based on robust data.
- All Intelligent Transport System (ITS) solutions will take into consideration national ITS architecture, systems engineering, whole-of-life costs, and existing and emerging technologies.
- Planning and design decisions will consider the potential impacts of connected and automated vehicles as they emerge.
- All Smart Freeway designs will be subject to operational efficiency audits.
- All roads currently at, or planned to be upgraded to, a freeway standard will, as a minimum, have real-time network monitoring capability and intelligence, and provision for higher-order Smart Freeway treatments when needed.
- Customer perspective and education are essential to the Smart Freeway solutions.
- We will confirm objectives and benefits through on-going performance monitoring, evaluation and operational fine tuning.
- We will encourage innovation and development of skills and expertise through research and development trials, as well as strategic partnerships with other road agencies, industry, research institutions and universities.

Peter Woronzow
Managing Director of Main Roads

mainroads WESTERN AUSTRALIA

smartfreeways.wa.gov.au

Part of the Transforming Perth's freeways initiative

[1] Smart Freeway solutions use, in addition to freeway mainline and ramp improvements, a multitude of Intelligent Transport Systems (ITS) including:
- Vehicle Detection Stations (VDS) and Closed Circuit Television (CCTV) cameras to collect real time traffic data and monitor traffic conditions
- Variable Message Signs (VMS) to provide near real-time traffic and road condition information to road users
- Coordinated Ramp Signals (CRS) to manage traffic flow on to the freeway mainline depending on the current freeway traffic conditions, to reduce stop-start conditions and ease congestion on the freeway, and also to make merging easier and safer
- Lane Use Management System (LUMS) and Variable Speed Limits (VSL) to manage lane closures and if implemented All Lane Running (ALR) where previous hard shoulder is converted to a running lane, and changes to speed limits to improve traffic flow and safety
- Automatic Incident Detection (AID) to automatically detect and report incidents such as a broken down vehicle on the freeway or a vehicle in an emergency stopping bay, enabling us to respond more quickly

Appendix C Design departure request memo template

This template provides guidance, examples and typical wording for a mainline and ramp departures memo.

- Delete, amend or add information as applicable for the specific project design.
- Note that mainline and entry ramp summary analysis tables can be copied and pasted from the Main Roads Excel spreadsheet (refer supplement to the MMDG Vol 3 Part 3), to minimise data entry.
- Links to documents: Main Roads Excel spreadsheet and Design Departure Request Memo Template

Smart Freeways

Design departure request memo

Ref: **Project No. – Name of Freeway and project limits**

To: Indicate - see Table 6.1 for responsible officers and amend as needed
Manager Road and Traffic Engineering (for review / approval)
Director of Congestion and Movement Strategy (for review / approval)
Executive Director Network Operations (for approval)
Executive Director Planning and Technical Services (for approval)

From: Consultant name(s) and organisation

CC: Project Manager, Network Operations Planning Manager,
Project Director

Date: xx xxx 202x

Title: Freeway name – project description / limits - xx% design stage

---

1. Background

This memorandum covers the proposed design departures for the xx% design for the Xxx Freeway Project – indicate description and limits or extent of project, etc.

Sections 0 to 0 of this memo provide overview and summary information. Sections 5 to 0 provide more detailed information and discussion relating to analyses for other design years, as well as comments on design constraints and related matters.

Smart Freeway operations and design departures generally focus on:

- route management requirements which need to be considered as a whole, that is the sum of the parts, relative to operational objectives
- individual site-specific design departures, which are considered relative to specific design targets focussed on safety and/or operations
- targeted use of ITS technologies consistent with warrants based on safe and efficient operation.

Departures from design standards and process for consideration and approval is provided in the *Smart Freeway Policy Framework Overview* (Main Roads, 2024), Chapter 6.

2. Outline of the proposed project design

Details of the project are provided in Section 0. The project generally includes:

- PROJECT scope including section of freeway covered by the project. Further detail is provided in Section 5.
- If it is an existing freeway improvement, existing freeway upgrade, or new freeway design (Supplement for MMDG Part 3 section 1.3).
- Smart Freeway Type of works: F, C, B or A (Provision Guidelines (Section 5.2).
- Overview and nature of proposals – geometry, lanes, ITS technologies, etc. .
- Design year(s) for analyses.

Forecast design volumes for each of the design years analysed are provided in the detailed sections below (0 to 0)and in the attachments.

Reference is made to the following documents:

- **Summarise relevant background design documents (TRIM: D2x#xxxxxx)**
- **Summarise previous design approval documents (TRIM: D2x#xxxxxx)**
- **Xxxxxxx (TRIM: D2x#xxxxxx)**

3. Freeway performance and operational implications

Based on forecast traffic demands, analyses and recommended layouts, the consideration of design departures need to be considered within the following context for anticipated freeway operational performance:

- Briefly summarise relevant and/or significant operational issues (high level overview)

Traffic analyses for the mainline and entry ramps have been carried out in accordance with the Smart Freeway suite of guidelines, Victoria's *Managed Motorway Design Guide,* and use of the Excel mainline and entry ramps analysis spreadsheet endorsed by Main Roads.

Where designs are less than the desirable standard, generally nothing further can be done to meet Smart Freeway guidelines without substantial impact on overall project scope or cost. In some cases, separate reports have previously been submitted to consider available options.

4. Summary of design departures and implications

The design departures and approval requirements for the mainline are outlined in ***Table 1***. Detailed comments and analyses are in Section 6 and Attachment 1 respectively.

Entry ramp design departures are summarised in Table 2. Detailed comments and analyses are in Section 7 and Attachment 2 respectively. The table also indicates the design targets and status (NDD, EDD or DE) for each ramp.

Matters listed should generally focus on performance for the longest timeframe design year.

If details of interim design years and/or at date of opening are also relevant, provide comment and additional information in Attachment 1 (mainline) and Attachment 2 (entry ramps).

Indicate if any of the design departures will affect:

- project scope (and/or budget)
- maintainability
- safety or any other project outcomes.

[Provide further tables for other departures needing approval, e.g. ITS, etc., if relevant]

Design status abbreviations include:

- NDD: Normal Design Domain
- EDD: Extended Design Domain
- DE: Design Exception.

In some cases, designs may meet the normal design domain, however, review and approval may be included if it is a special case alternative (for example dynamic storage lane), if the design modifies an existing ramp signals layout, if additional ramp storage is provided to compensate for ramps with inadequate storage, or to provide additional storage that will assist with management of excessive demand (i.e. downstream mainline has VCR > 1).

Table 1: Example mainline segments - summary of design departures and approval requirements

Section Location	Nature of design departure	20xx performance (based on traffic analysis)	Review / recommendation by	Approval by
Example Fwy NB A Road entry to B Road exit	EDD: volume / capacity ratio (VCR) between 100% and 110% Proposals for demand management.	VCR = 106%	MRTE	DCM
Example Fwy NB C Road entry to D Road exit	EDD: volume / MSFR ratio > 1.1 (110%) Proposals for demand management.	Significant number of sections above capacity. VCR up to 112%	MRTE DCM	EDNO
Example Fwy NB E Road exit to E Road entry (within the interchange)	EDD: volume / MSFR (VCR) greater than 1.1 (110%). Proposals for demand management. Compensating proposals for storage inadequacy.	VCR = 130% (due to bridge width	MRTE DCM	EDNO

Table 3: Example entry ramps - summary of design departures and approval requirements

Location	Nature of design departure	2036 status (based on traffic analysis)	Review / recommendation by	Approval by
F Road entry ramp	EDD: Cycle times less than the desirable 7.5 sec. or 6.5 sec. as applicable, i.e. orange figures in the MMDG table.	6.1s cycle time (less than 6.5s required)	MRTE	DCM
H Road entry ramp	NDD: Ramp storage between 3 and 4 mins NDD: Use of special case layout with staggered stop-line Modification to existing ramp signals	3.7 mins storage Dynamic third metered storage lane (80m long) and staggered stop line	-	MRTE
I Road entry ramp	NDD: Ramp storage between 3 and 4 mins	3.4 mins storage	MRTE	DCM
I Road entry ramp	DE: Cycle times less than the limits in the MMDG table.	4.7s cycle time (less than 7.5s required)	MRTE DCM	EDNO
J Road entry ramp	EDD: Cycle times less than the desirable 7.5 sec. or 6.5 sec. as applicable, i.e. orange figures in the MMDG table.	6.1s cycle time (less than 6.5s required)	MRTE	DCM
J Road entry ramp	DE: Designs requiring storage on the arterial road.	Storage on arterial road	MRTE DCM	EDNO

5. Details of the proposed design

The Smart Freeway improvements and civil upgrades below for xx% traffic analysis and design, comprises freeway upgrading and treatments based on the 20xx design year forecast traffic. This includes:

- indicate extent of widening – number of lanes etc. and related sections
- extent of all lane running (ALR), supported by LUMS and ESBs and the applicable sections
- extent of coordinated ramp signals (CRS) and relevant sections
- extent of other traffic management and control such as LUMS
- extent of traveller information signage and types of VMS
- extent of other supporting technologies for control, surveillance and incident management including CCTV, VDS, and AID etc.

Details of the design departures are discussed in the following sections:

- Section 6 – Mainline segments with demand exceeding the maximum sustainable flow rate (MSFR), i.e. VCR > 1.
- Section 7 – Entry ramp discharge capacity and storage
- Provide additional detailed sections for other design departure components, if applicable.

6. Mainline analysis and design

Summarise the mainline analysis and design process relative to the number of lanes and the design constraints etc.

Figure 1 shows the mainline performance assessment for the design year based on forecast mainline design volumes, including consideration of exit ramp and entry ramp traffic at each interchange. Segment capacities plotted in the graphs are for unmanaged operation (red) and managed operation (green).

Attachment 1 provides more detailed capacity analysis summaries which are related to the mainline design departures in in Table 1 above. Entry ramp design departures are summarised in Table 2.

Provide further relevant comment about mainline performance, and particularly for sections where the volume/capacity ratio (VCR) is greater than 100% and / or greater than 110%, i.e. within the Extended Design Domain (EDD) – and hence where approval is required.

Provide further relevant comment on aspects of mainline design, including design constraints, and/or where options have been considered, e.g. weaving, auxiliary lanes, etc.

Comment on varying performance from analyses of different design year forecasts and / or opening date, if relevant. Where applicable, provide further figures below and/or detailed analysis summaries in Attachment 1.

Provide comment if different issues need to be highlighted for the AM peak and PM peak designs.

Further information relating to risk management and mitigating performance impacts are provided in Section 8.

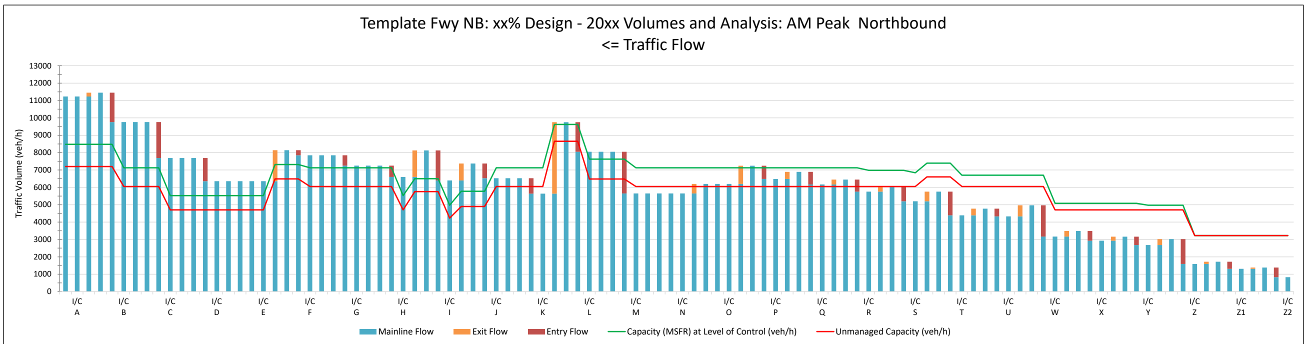


Figure 8-1: Example 20xx mainline performance summary chart – volumes relative to capacity

7. Ramp analyses - discharge rate and storage

The layout assessment of each entry ramp including discharge capacity, storage and freeway entry layout has been undertaken as part of the xx% design development.

Attachment 2 provides the detailed analysis results for all entry ramps including the entry ramp design departures summarised in Table 3 above.

The detailed analyses for each ramp in the tabulation indicate:

- Design volume (preferably pc/h) and include the worst case from AM and PM peak, if relevant.
- Discharge capacity (number of lanes at the stop line) and average cycle time, guideline requirements and design status (NDD, EDD and DE). It is noted that the average cycle times in orange may be appropriate when mainline analysis (summary provided) indicates ramp demands are accommodated within spare downstream capacity (refer MMDG Vol. 2, Part 3, Table 6.1 – Note 7). Otherwise, demand management would be necessary at upstream entry ramps.
- Ramp storage in metres and equivalent minutes, guideline requirement and design status (NDD, EDD and DE).
- Mainline / entry ramp layout design and downstream segment performance.
- Design comment relating to each ramp. Include matters requiring specific approval, e.g. a dynamic metered storage lane with staggered stop line.
- For ramps requiring design departures, provide additional comment in the summary table and/or additional paragraphs within this section, to indicate design constraints, options considered, if any further works may be feasible, etc.
- Overall system storage total (excluding low flow ramps).

Further information relating to risk management and mitigating performance impacts are provided in Section 80.

8. Shortcomings and proposed mitigation

Describe the design departures for mainline sections and entry ramps in the context of overall project design and operation, i.e. combination of the component parts working together to optimise for best route and system operational outcomes.

This section provides discussion on the significance of specific design issues and potential operational matters relative to the design (see *Policy Framework Overview* Section7: Performance-based operations) – for short-term and longer-term operations, as applicable.

Discussion may also be needed on freeway management where significant operational challenges may occur, e.g. for some projects, operations will require as many ramps as possible to ‘share the load’ and fulfil their role in demand management. This will not only improve overall freeway operations but also facilitate operations at each ramp in the local context. Ramps with storage greater than the desirable storage will therefore be an advantage and add to operational flexibility.

Discussion of storage at a system level, e.g. totals as well individual ramps, and the challenge of operating ramps with less than desirable design relative to identified (predicted) bottleneck locations.

9. Risk assessment

The 20xx project designs recommended (mainline and ramps), including those with design departures, have been maximised within design constraints to minimise the risk of flow breakdown and to maximise the project outcomes and success in managing traffic demands.

A risk assessment of adverse freeway operations has been carried out in the context of the maximum sustainable flow rates (MSFR) being used for the mainline project design relative to consideration of the forecast modelling, peak period traffic analysis, and the ability to manage traffic demand along the project with ramp signal designs.

The following risk assessment is provided (modify example below as per project evaluation):

- **Likelihood**: Acceptable likelihood of flow breakdown based on:
  - the MSFR flow breakdown risk (FBR) to minimise flow breakdown based on 1% FBR over a 15-minute period - which is equivalent to ≈ 8% FBR (2-hour peak) and ≈ 10% FBR (3-hour peak) based on ‘survival probability’ statistical analysis
  - assuming excess demand exceeding capacity is managed on controlled ramps
  - assuming optimum operations and system control (software and operators)
  - use of spare storage and longer waiting times at available ramps where there is a need to compensate for areas of design less than desirable requirements.
- **Consequences**: Acceptable impact on operations if flow breakdown did occur.
- **Overall Rating**: Acceptable risk not warranting major expenditure to provide further improvement.

The design recommended aims to minimise the risk of flow breakdown and congestion, and hence weekday traffic and road users being adversely affected.

Summary

The project, with the mainline design and extent of coordinated ramp signalling recommended, provides opportunities to maximise overall system storage (manage traffic demand along the freeway) to compensate for ramps with inadequate storage in the managed system, as well as to optimise operations within the recommended mainline lane configurations for the project.

Detailed summaries of all mainline and ramp design outcomes for the project relative to guideline requirements are in Attachment 1 and Attachment 2.

10. Recommendations

The design departure requirements summarised in Table 1 and Table 2 above be approved (detailed analyses in the attachments).

Author’s name(s)
Consultant name / team

11. Design departure sign off

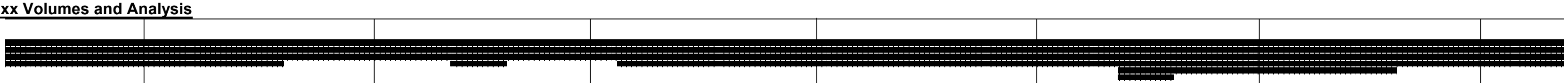
Delegated officers must sign off for review or approval of applicable items as applicable.

Refer Section 4 Tables 1 and 2	Name/Title	Signature	Date	Comments
Reviewed / Approved by	MRTE			
Reviewed / Approved by	DCM			
Approved by	EDNO			

Attachment 1 – Example 20xx mainline capacity analysis

Template Fwy NB: xx% Design - 20xx Volumes and Analysis

Schematic Layout and Volumes



<= Traffic Flow

Northbound																												
		Merge				Add lane		1 x EEL	Aux. lane	Add lane		Taper & Lane Drop		Merge				Merge		3-lane exit		Add lane + merge				Add lane + merge		
AM Peak	**7,848**	599	7,250	-	**7,250**	650	6,600	1,526	**8,126**	1,729	6,398	975	**7,373**	848	6,526	-	**6,526**	887	5,638	4,112	**9,750**	1,705	8,046	-	**8,046**	2,394	5,652	-
Total Lanes:	**4**	4	**4**	4	**4**	3	**3**	3	**4**	3	**3**	4	**4**	4	**4**	4	**4**	4	**4**	4	**6**	5	**5**	5	**5**	4	**4**	4
			I/C G				I/C H				I/C I				I/C J				I/C K				I/C L				I/C M	

Management and Performance Summary:	Managed	Managed	Managed	Managed	Managed	Managed	Managed	Managed	Managed	Managed	Managed	Managed	Managed	Managed
Capacity (MSFR) at Level of Control (veh/h)	7125	7125	7125	5525	6499	4973	5771	7125	7125	7125	9619	7628	7628	7125
AM Peak - Volume / Capacity Ratio (VCR):	110%	102%	102%	119%	125%	129%	128%	92%	92%	79%	101%	105%	105%	79%
Spare capacity / (Excess demand):	(723)	(125)	(125)	(1,075)	(1,627)	(1,425)	(1,602)	599	599	1,487	(131)	(418)	(418)	1,473
% Excess volume cf. capacity:	10%	2%	2%	19%	25%	29%	28%				1%	5%	5%	

Figure 8-2: 20xx mainline performance analysis – volumes relative to capacity

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Attachment 2 – Example 20XX ramp analysis summary

Template Fwy NB: xx% Design - 20xx Volumes and Analysis
Entry Ramp Signals Analysis
Northbound

xx% Analysis and Design	Ramp Volumes and Control		Ramp Discharge Capacity Analysis					Ramp Storage Analysis						Mainline Access and Segment Performance			Ramps Design
Entry Ramp	Proposed Meter (Yes/No)	Design Flow Rate (pc/h)	Lanes at Stop Line	Average Cycle Time (s)	Desirable Min. (s)	Absolute Min. (s)	Design Status	Storage Available (m) Total (m)	Storage Available (m) Total (minutes)	Desirable 4-minutes Storage (m)	Storage cf. 4-min. (m) Surplus (+) Needed (-)	Minimum 3-minutes Storage (m)	Design Status	Mainline / Ramp Entry Geometry	Volume / Capacity Ratio AM Peak VCR (%)	Design Status	Layout Comment - Including overall system storage or to compensate for shortcomings
I/C Z2	No	644		-	-	-	-	0	-	n.a.	n.a.	n.a.	-	Merge	43%	NDD	Ramp not included for ramp signals (relatively low flow ramp). But has potential for providing ramp signals to increase system storage.
I/C Z1	No	526		-	-	-	-	0	-	n.a.	n.a.	n.a.	-	Merge	53%	NDD	Ramp not included for ramp signals (relatively low flow ramp). But has potential for providing ramp signals to increase system storage.
I/C Z	Yes	1,783	4	8.1	6.5	4.8	NDD	1,420	5.6	1,010	410	758	NDD	Add Lane + Merge	61%	NDD	Discharge capacity and storage are adequate with two-lanes of storage plus widening for two auxiliary lanes (no ramp lengthening).
I/C Y	Yes	644	2	11.2	7.5	6.0	NDD	520	5.7	365	155	274	NDD	Merge	62%	NDD	Storage is maximised by using the minimum 80 m distance from the stop line to the ramp nose (no ramp lengthening).
I/C X	Yes	635	2	11.3	7.5	6.0	NDD	790	8.8	360	430	270	NDD	Merge	69%	NDD	Storage is maximised for system operations by using the minimum 80 m distance from the Stop Line to the ramp nose (no ramp lengthening).
I/C W	Yes	2,110	4	6.8	6.5	4.8	NDD	1,500	5.0	1,195	305	897	NDD	Add Lane + Merge	74%	NDD	Storage is maximised by ramp lengthening and providing 4-lanes. The surplus storage will be utilised by the system.
I/C V	No	386		-	-	-	-	0	-	n.a.	n.a.	n.a.	-	Merge	74%	NDD	A low flow ramp with no ramp signals. EDD needed for uncontrolled ramp in a managed section. Future potential for providing ramp signals, if needed.
I/C U	Yes	725	2	9.9	7.5	6.0	NDD	370	3.6	411	41	308	NDD	Merge	71%	NDD	Storage is maximised by using the minimum 80 m from the stop line to ramp nose (no ramp lengthening).
I/C T	Yes	1,669	4	8.6	6.5	4.8	NDD	1,820	7.7	946	874	709	NDD	Add Lane + Merge	78%	NDD	Discharge capacity and storage are maximised by using four-lanes at the stop line and ramp lengthening. System operations can utilise surplus storage.
I/C S	Yes	1,011	3	10.7	7.5	6.0	NDD	940	6.6	573	367	430	NDD	Merge	86%	NDD	Storage is maximised by ramp lengthening and providing 3-lanes. Surplus storage could be utilised by the system.
I/C R	Yes	857	2	8.4	7.5	6.0	NDD	610	5.0	486	124	364	NDD	Merge	91%	NDD	Realignment and lengthening of the existing ramp is included in the design. The surplua storage could be utilised by the system.
I/C Q	Yes	887	2	8.1	7.5	6.0	NDD	650	5.2		650	0	NDD	Merge	97%	NDD	Design includes lengthening of the existing ramp. The storage of 5.2 minutes is greater than the desirable 4 minutes and beneficial for system operations.
I/C P	Yes	904	3	11.9	7.5	6.0	NDD	520	4.1	512	8	384	NDD	Merge	102%	EDD	The current ramp is short with an upgrading design constraint. Additional storage needed with widening over most of the ramp length.
I/C M	No	2,883		-	-	-	-	0	-	n.a.	n.a.	n.a.	-	Add Lane + Merge	105%	EDD	No ramp signals as traffic control occurs upstream on CD road. EDD needed for uncontrolled ramp in a managed section.
I/C L	Yes	2,113	4	6.8	6.5	4.8	NDD	1,080	3.6	1,197	117	898	NDD	Add Lane + Merge	101%	EDD	Storage is maximised by providing 4-lanes. The adjacent PSP and freeway boundary restrict any further ramp widening or lengthening.
I/C K	Yes	1,100	2	6.5	7.5	6.0	EDD	583	3.7	623	40	468	NDD	Merge	92%	NDD	Ramp design uses extension of the ramp nose and widening on the straight for 2-lane storage, and then 1-lane around the loop.
I/C J	Yes	1,072	3	10.1	7.5	6.0	NDD	560	3.7	607	47	456	NDD	Merge	128%	EDD	Design modifies existing ramp signals. Additional discharge capacity and storage needed. Dynamic storage lane review by MRTE.
I/C I	Yes	1,977	4	7.3	6.5	4.8	NDD	1,165	4.2	1,121	44	840	NDD	Add Lane + Merge	125%	EDD	Design modifies existing ramp signals as additional discharge capacity and storage needed. Storage > 4 minutes provides system benefits.
I/C H	Yes	708	2	10.2	6.5	6.0	NDD	520	5.2	401	119	301	NDD	Add Lane	102%	EDD	Design adopts current layout. The storage of 5.2 minutes is greater than the desirable 4 minutes and could be utilised by the system.
I/C G	Yes	672	2	10.7	7.5	6.0	NDD	510	5.4	381	129	286	NDD	Merge	110%	EDD	Design adopts current layout. The storage of 5.4 minutes is greater than the desirable 4 minutes and could be utilised by the system.
I/C F	Yes	355	2	20.3	7.5	6.0	NDD	230	4.6	201	29	151	NDD	Merge	111%	EDD	Design adopts current layout. Storage > 4 minutes would have minimal operational benefit as it is a low flow ramp.
I/C D	Yes	1,529	2	4.7	7.5	6.0	DE	740	3.4	866	126	650	NDD	Merge	139%	EDD	The ramp nose and merge cannot be extended due to the freeway width and the interchange overpass structure.
I/C C	Yes	2,367	4	6.1	6.5	4.8	EDD	1,440	4.3	1,341	99	1,006	DE	Add Lane + Merge	137%	EDD	Design provides a balance of maximising storage and minimising impact on adjacent areas. DE is needed for potential storage on the arterial road.
I/C B	Yes	1,931	3	5.6	6.5	6.0	DE	800	2.9	1,094	294	821	DE	Add Lane	135%	EDD	Extending the ramp nose is not feasible due to downstream constraint. Increasing storage upstream is not feasible due to the ramp structure.
							Overall Total (m)	16,768									
							System Totals (m) - Excluding Low Flow Ramps	**16,538**		**13,491**		**10,118**					