Chapter 3

Principles of Freeway Ramp Metering

3.1. A Managed Freeway System

An integrated freeway management system may interface a number of real time on-road traffic management tools such as:

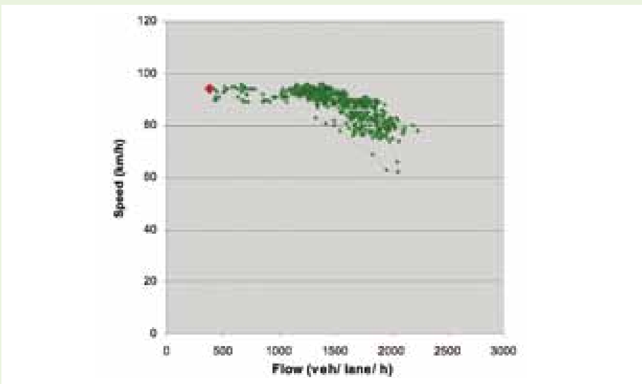
- A coordinated freeway ramp signals system to manage freeway access and assist in preventing flow breakdown
- Congestion management. This may be used to supplement the overall freeway access management strategy. The ramp metering operation would restrict entry to assist in preventing a worsening of congestion and to assist in flow recovery
- Traveller information including travel time. Information for drivers is provided on the freeway mainline and on the arterial roads at entry ramp intersections. This may include information about planned future events, e.g., roadworks, current incidents ahead or travel time information to enable drivers to make informed decisions relating to route choice. Travel time information on the arterial road includes travel on the mainline as well as ramp delays
- Incident management. Effective detection and management of incidents assists in minimising flow disruption. This requires integration with lane use management, variable speed limit, congestion management and traveller information systems in the support of incident management personnel
- Lane use management. This system assists in dealing with incidents or events on the freeway. The system is integrated with the traveller information system
- Variable speed limits. This system assists in controlling vehicle speeds during incidents, events or adverse weather.

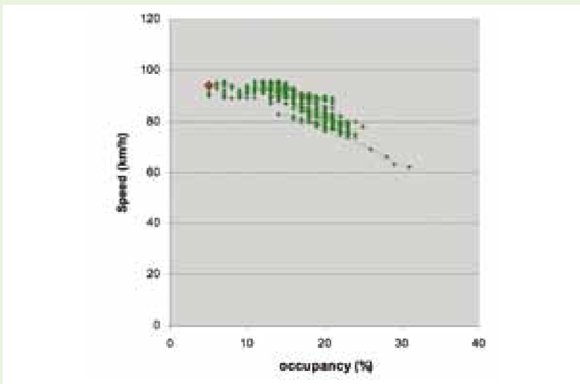
3.2. Freeway Ramp Signals in a Managed Freeway

3.2.1. Context and Effectiveness

Within the context of a 'managed freeway' which may incorporate a range of traffic management tools, controlling the entering traffic with a coordinated freeway ramp signals system that incorporates a technically effective algorithm is the most effective tool in managing flow to prevent flow breakdown and optimise capacity and travel time on the mainline.

Figure 3.1 shows an example of a high entry merge where mainline flow is managed to prevent flow breakdown and optimise freeway throughput and speed.





The occupancy at this freeway bottleneck downstream of a high flow entry ramp merge is managed to:

- Prevent flow breakdown
- Optimise speed
- Optimise flow (throughput).

Location: Monash Freeway inbound between Ferntree Gully Road and Blackburn Road (Midblock Data Station 7972), 28/07/2008. Morning peak period.

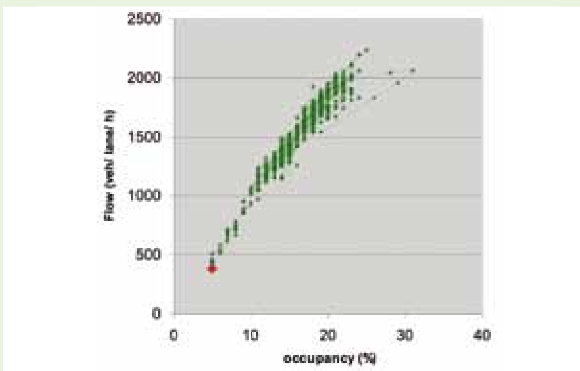


Figure 3.1: Example of Flow, Speed and Occupancy relationships (Fundamental Diagrams) at a Bottleneck Managed with Ramp Metering Source: VicRoads

3.2.2. Principal Aims of Freeway Ramp Metering

The principal aims of metering traffic on freeway entry ramps are:

1. To optimise freeway throughput, travel speed and travel time reliability

This is achieved by minimising the possibility of flow breakdown on the freeway and the consequential rapid development of congestion. Travel time reliability is provided by reducing variability from day to day. The principal actions are:

- Headway management of entering traffic, i.e., dispersing platoons (bunching) of vehicles entering from the ramp to achieve an evenly distributed flow of traffic into the merge area
- Managing the flow rate of entering vehicles in a ramp merge area when the freeway is near capacity, i.e., by managing the entry flows within limits beyond which the mainline traffic flow would typically transition to an unstable condition
- Ensuring the overall mainline freeway volume is within the bottleneck capacity at critical bottlenecks along the freeway, generally by coordinating traffic from a number of ramps.

2. To improve safety

This is achieved by:

- Reducing the potential for incidents due to braking and stop-start flow during unstable conditions or when flow breaks down
- Assisting merging
- Minimising lane changing, particularly in the vicinity of an entry ramp, eg. lane changing caused by drivers trying to avoid delays in the left lane when there is no metering
- Minimising turbulence in areas of high weaving.

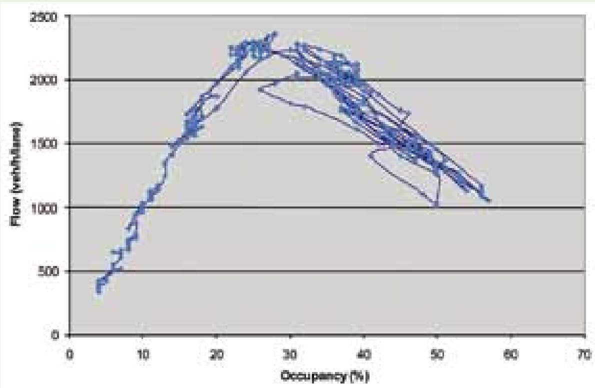
3.2.3. Ramp Metering as a Management Tool

Metering of freeway entry ramps provides an effective traffic management tool for managing the mainline traffic in a number of ways including:

- Controlling and coordinating all entry ramps along a route to manage the mainline freeway at a number of critical bottleneck locations This will ensure that the best overall freeway service is delivered under a wide range of conditions and contribute to reducing the variability of travel time from day to day, thus enhancing improved reliability
- Managing the freeway flow (occupancy) in a way that would prevent or delay freeway flow breakdown at an isolated bottleneck
- Controlling entry ramp traffic to facilitate faster restoration of free flowing conditions after congestion caused by a crash or other unplanned incident
- Managing the headway of entering ramp traffic onto the mainline. This can assist in merging and improve safety even when the ramp traffic does not need to be restricted to optimise mainline capacity
- Discouraging short trips on the freeway during periods of high demand or congestion.

Figure 3.2 shows charts of freeway flows for unmanaged and managed situations. In the managed freeway example, controlling the vehicle access has prevented flow breakdown and maintained free flowing conditions.

Unmanaged Freeway

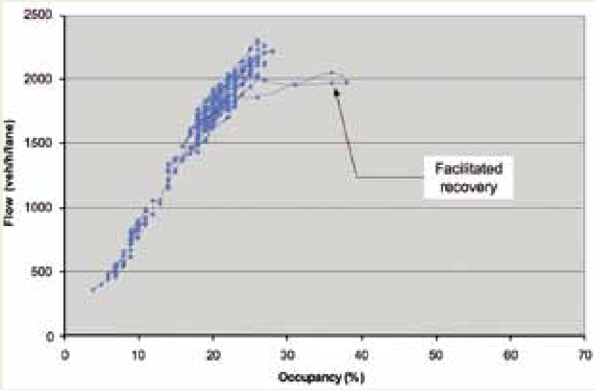


Flow Breakdown Occurs

Note:

- Reduced throughput
- Reduced speed
- Congestion
- Lost productivity.

Managed Freeway



Flow Breakdown Avoided

Ramp signals with HERO control:

- Prevent flow breakdown
- Maintain optimum throughput
- Maintain optimum speed
- Facilitate flow recovery.

Source: VicRoads

Figure 3.2: Example of Unmanaged and Managed Freeway Flow

3.2.4. Benefits of Ramp Metering

There are a number of benefits that result from the principal aims of ramp metering. These include:

- Reduced delay for users of high-volume freeways
- A more reliable service to freeway users
- Reduced number of mainline traffic incidents and the consequential impacts of such events
- Increased freeway throughput at critical times and locations
- Enhanced overall road network travel times. The gain in better operation of the freeway more than offsets the additional time taken for traffic to enter the freeway and the localised congestion occurring at arterial roads near interchanges
- Equitable use of the road network including redistributed traffic in keeping with infrastructure capacity and discouraging the use of the freeway system for short trips during periods of high flow
- Improved road safety due to safer management of merging traffic and more stable freeway travel speeds i.e., reduction in stop-start traffic conditions
- Reduced fuel consumption and emissions as a result of efficient travel conditions.

3.3. Interface at Arterial Road Interchanges

3.3.1. General Principles

The arterial road interchanges and the road network connecting with the freeway need to be integrated and then managed for an effective freeway / arterial road interface.

The VicRoads Freeway Operational Objectives (2004) indicate that:

> *The economic imperative is that, when necessary, the freeway network is to be given priority over the arterial road network 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.*

Generally, if the freeway is able to carry more traffic in the peak periods, it follows that the operation of arterial roads may also improve, compared to a situation where freeways remain unmanaged.

The implications at arterial road interchanges relate to the management, capacity and operation of entry ramps and exit ramps. Interfacing of the freeway management system and the arterial road signal system (SCATS) is also necessary at some locations.

It is also desirable to provide information for motorists on the arterial road relating to estimated freeway travel time or incidents before they enter the freeway. This is achieved with strategically located signs to assist motorists with their route choice decisions (refer Section 6.4.12).

3.3.2. Entry Ramps

The management of traffic entering the freeway will produce an increase in the freeway throughput at critical locations, and generally, the freeway as a whole (refer Sections 2.3.2 and 3.2.4). As demand for freeway travel increases it will be necessary to limit the amount of entering traffic so that the mainline capacity at any point is not exceeded, i.e., to ensure that high levels of freeway service are sustained.

Metering will create local delays at entry ramps, i.e., the ramps act as a 'retarding basin' to ensure the freeway traffic flow is optimised, rather than excess demand 'flooding' onto the freeway and causing vehicles to 'store' on the freeway. While ramp signals may be perceived as a cause of delay, for most freeway trips the improved freeway flow will result in lower overall delay.

At some locations excess demand will need to be constrained to achieve the overall benefits and the overflow of queues onto the arterial road may need to be addressed (refer Section 6.3.5 and 8.2), particularly when there is inadequate entry ramp storage. An interface with the arterial road SCATS system is also able to transfer information that enables integrated control strategies to be implemented.

A concern about 'overflow' effects on a connecting arterial road needs to be seen alongside the overall traffic management objective. Experience has also shown that trip diversion from metered ramps to other routes also occurs, e.g., the initial installation of ramp signals on the Monash Freeway / Warrigal Road outbound entry ramp resulted in significant redistribution of ramp demand. As well as changes to travel routes, motorists have also changed their times of travel to achieve acceptable journey travel times. This has resulted in a spread of the peak travel periods.

There will be situations where a redistribution of demand should be sought as a managed outcome. In these situations, the availability of alternate routes and the adequacy of the arterial network to accommodate route diversions need to be considered. The diversion of traffic is most effective where there is a well connected arterial road network and/or a significant proportion of entering traffic is undertaking short trips.

Generally, when compared with not having ramp metering, congestion on arterial roads with freeway ramp signals is not worse and in some cases can be improved. In situations where managing freeway flows at a bottleneck leads to creating undesirable conditions on a connecting arterial road, consideration should be given to increasing capacity at the critical freeway bottleneck, increasing storage capacity of the ramp or providing additional storage on the approaches as outlined in Section 8.2.

3.3.3. Exit Ramps

Traffic flow on the freeway mainline is affected when traffic queues on an exit ramp extend back to block the left lane of the freeway or cause traffic to slow down prior to exiting. In these situations the accessible freeway capacity is reduced through reduced availability of the left lane for through traffic. Vehicles also change lanes to avoid the left lane which increases turbulence and potential for flow breakdown on the mainline. A significant safety concern is also created for left turning vehicles as well as through vehicles.

The management of entering traffic with ramp signals will generally produce an increase in the freeway throughput which will also result in increased exit flows. This problem may also become significant when existing freeways are upgraded without increases in capacity at interchanges.

Further information relating to the management of exit ramp queuing is provided in Section 8.3.

3.4. Ramp Metering Control

Ramp signals for a managed freeway would generally be part of a route treatment that operates as a system under dynamic, coordinated control.

When ramp signals are coordinated in a system, the ability to manage the mainline occupancy and flow by matching total entry ramp inflows to the capacity of a critical bottleneck along the freeway is significantly improved. System control also has the advantage of distributing entry ramp queues and waiting times across a number of ramps to provide equity between access points.

Generally all entry ramps would be signalled, including ramps leading to added lanes on the freeway and freeway to freeway (system interchange) ramps. Management of all entering traffic maximises the ability to control and manage downstream traffic conditions.

Ramp meters may operate under the following levels of control:

- Local Control – when a single ramp is operating independently and does not interact with adjacent entry ramps. Isolated ramp signals on a freeway without connection to other upstream ramp signals would operate under local control, and
- Coordinated Control – when ramp signals along a freeway operate within an interlinked and coordinated ramp metering system. Ramp signals within a coordinated system may operate under local control when they first switch on or when downstream entry ramps can manage inflows without needing to enlist the assistance of upstream ramps to manage queues

The broad principles associated with operating ramp meters under local and coordinated control are described below. The detail relating to the real time operation of ramp signals and an overview of the algorithms used by VicRoads is in Chapter 7.

3.4.1. Local Control

Local ramp meter control may be appropriate where it can be demonstrated that entering traffic causes flow breakdown in the mainline flow at an isolated bottleneck that generally has no impact on, or from, other interchanges along the route.

The function of a local ramp meter is to manage the entering rate of traffic to overcome the impact of large uncontrolled platoons of traffic coming from the ramp's upstream intersection signals. An isolated meter may also be used to control the total entering volume to maintain stable conditions when the freeway is nearing capacity.

In its simplest form, calculation of the metering flow to minimise the likelihood of downstream flow breakdown is shown in Figure 3.3 and is based on:

- Bottleneck capacity flow (q_{cap})
- Upstream flow (q_{us})
- Entry ramp arrival (demand) flow (q_{ra}), and
- Maximum metered ramp flow (q_r).

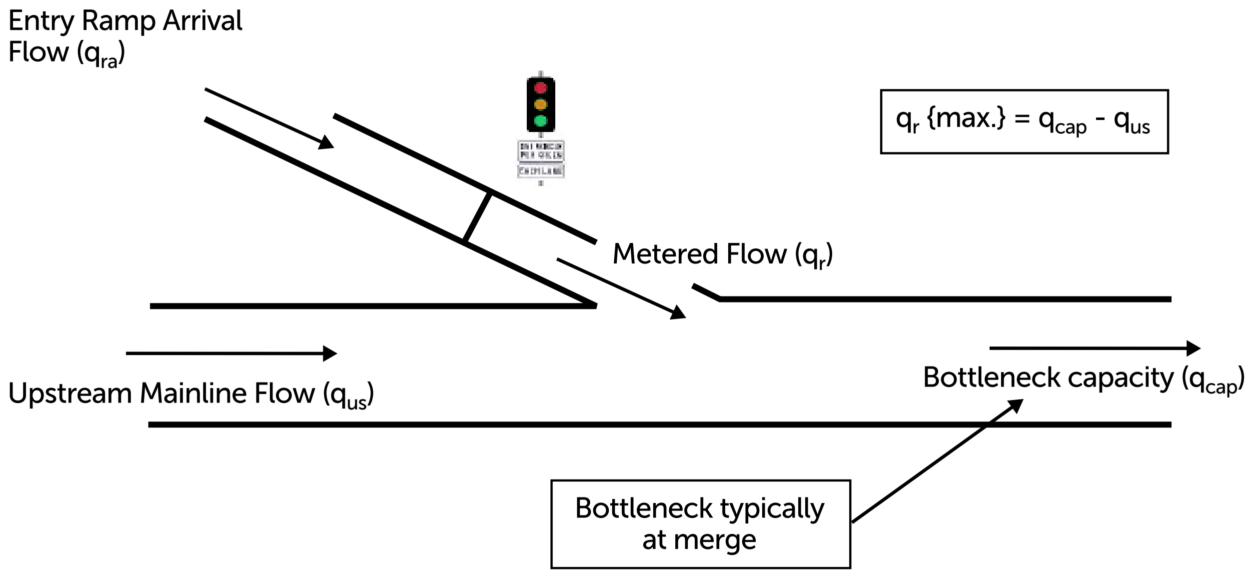


Figure 3.3: Metering Traffic Flow at Merge Bottleneck

Local control for isolated ramp metering installations may be effective in providing reductions in merging problems and improvement of freeway traffic flow where there is a high merging flow, but:

- It has limited functionality and ability to balance operation along a route when compared with coordinated control, e.g.,
  - If the bottleneck capacity is less than the upstream flow there is no ability to control demand on the mainline
  - Subject to the algorithm operation and applied queue management strategy, this may result in earlier initiation of ramp queue override actions and premature flow breakdown at the merge
  - It provides reduced equity relative to upstream ramps, i.e., the ramp at the active bottleneck takes 'all the pain' while the upstream ramps, while contributing to bottleneck activation, are either not controlled or do not share delays equitably
- Is unlikely to be able to maintain optimum freeway throughput if there is congestion related to other bottlenecks along the route, and
- Is not generally recommended for heavily trafficked freeways where a number of entry demands need to be managed or where flow breakdown may occur at a number of locations.

The bottleneck flow capacity is used in ramp signal design to determine the maximum metered ramp flow rate, q_r. This is then compared with the arrival (demand) flow, q_{ra} to determine whether the ramp demand can be satisfied (refer Section 6.3). The principle is also used in some control algorithms. The algorithms in best practice systems use occupancy values related to the downstream bottleneck (refer Section 3.6).

3.4.2. Coordinated (Route-Based) Control

Best practice dynamic control allows for ramp signals to operate in an isolated manner or to engage, when needed, upstream ramps in a master/slave relationship.

When ramp meters are coordinated in a system it improves the ability to manage the mainline freeway flow by matching traffic inflows from a group of ramps to the capacity of a critical bottleneck along the route. It also has the capability of balancing the queues and wait times between ramps.

With coordinated control the freeway ramps are grouped into a manageable number of ramps that can operate together as a control system when traffic conditions require coordination. Typically, a coordinated control group would include a minimum of 6 to 10 ramps to provide control over a section of freeway within an overall freeway length. Control groups of this number provide a balance between long and short trips where, typically, only 50% of traffic entering at a particular ramp will travel more than 6 interchanges[2] .

Within a coordinated group, bottlenecks could occur at many locations including each entry ramp merge and other locations of restricted capacity. The bottleneck where flow breakdown generally occurs first is the critical bottleneck. Other locations also need to be managed within the coordinated system but would be less dominant bottlenecks. The management and control of traffic flow along a length of freeway usually requires metering at all points where traffic enters the freeway. This may include:

- Entry ramps with merging traffic
- Entry ramps leading to an added lane
- Freeway to freeway entry ramps or metering of upstream ramps on the intersecting freeway, as appropriate (refer Section 4.4), and
- The start of the freeway in some instances[3] .

The general principle of managing metered entry ramp flows within a coordinated system to match the capacity of a downstream critical bottleneck on the freeway, is shown in Figure 3.4 and the following paragraphs. Managing the freeway flow also takes into account the traffic leaving the freeway at exit ramps.

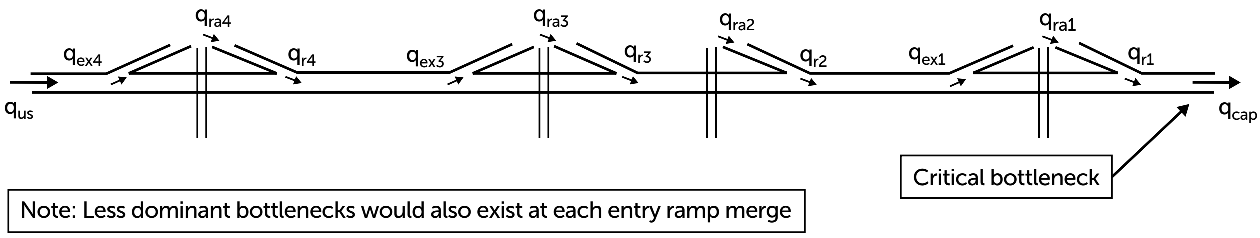


Figure 3.4: Metering Traffic with Coordinated Control

In this example:

$$\Sigma q_{rn} \{max\} = q_{cap} - q_{us} + \Sigma q_{ex} \quad \text{where } q_{cap} \text{ is the bottleneck capacity.}$$

The control system would control the total flow allowed to enter the freeway, Σq_{rn} {max}, from the individual ramps to manage q_{r1}, q_{r2}, q_{r3} and q_{r4} according to local control needs and an appropriate balancing of ramp queues and/or delays. Local control is also used to avoid flow breakdown at each localised entry ramp merge, i.e., each of the individual metered entry ramp flows would need to be managed so that the freeway capacity at each local ramp merge is not exceeded (refer Section 3.4.1).

The ramp metering signals immediately upstream of the critical bottleneck generally becomes the 'master' and controls a coordinated group of ramps. Other upstream ramps are activated to become 'slaves' in the coordinated group to provide assistance in managing the overall entry flows.

2 Internal VicRoads reports relating to travel on Monash Freeway and Western Ring Road.

3 Although not discussed in this handbook consideration may need to be given to the phase times of traffic signals at the start of a freeway to match the required capacity of down stream sections

Coordinated ramp metering has the following benefits:

- Reduces mainline demand at a downstream bottleneck when local control cannot manage flow
- Provides equity by balancing of queues and delays between a number of ramps, i.e., shares the "pain"
- Reduces the likelihood of queue overflow on short ramps by transferring delay to ramps with more storage.

3.4.3. Fixed Time Operation

Fixed time ramp metering operation generally switches on according to time of day settings and then uses a fixed time signal cycle. In some situations a different cycle time is chosen based on ramp demand. Fixed time operation is able to drip-feed vehicles into the mainline that arrive on the ramp in platoons, but the operation does not adapt to changing freeway flow conditions. This form of operation can provide some benefit to mainline flow but has limited effectiveness in preventing flow breakdown and optimising freeway throughput.

3.4.4. Dynamic Operation

A dynamic ramp metering system adapts to changing traffic flows on the freeway and ramp. The system can manage traffic at the local level and in a coordinated system along a freeway corridor. A dynamic system generally includes the following capabilities:

- Switch-on occurs automatically when the freeway flow at a local merge or bottleneck is approaching unstable conditions. The dynamic system will fall back to fixed time operation if there are data problems from the system's vehicle detectors or communications system,
- Automated response to freeway conditions by continually adjusting ramp inflows, i.e., cycle times, along the route to optimise freeway flow and travel speeds as well as balancing queues and managing traffic delay on the ramps. A range of parameters in the control system algorithm can be adjusted in real time to refine the operation, and
- Enhanced capability to prevent flow breakdown occurring at bottlenecks due to uncontrolled demand. It also provides more effective identification of, and response to, flow breakdown caused by an unplanned incident and can then manage inflows to the freeway to facilitate faster recovery as outlined in Sections 3.7 and 7.7.

Note:

Historically, ramp metering practice was often based on vehicles entering gaps in the left lane of the freeway. The important determinant is generally the total flow across all lanes and the related density of traffic. The contemporary approach considers traffic flow in all lanes across the whole carriageway. With a technically effective control algorithm this generally results in optimum flow in all lanes as well as optimum entry ramp flows.

3.5. Managing Ramp Demands

While all ramp metering operates to control the rate of traffic entry into the freeway, there are situations when the control may satisfy demand and situations when the ramp demand cannot be satisfied.

3.5.1. Satisfying Ramp Demands

Ramp demands are satisfied when the entry ramp flows can be metered into the freeway flow within acceptable limits of delay. This form of control 'drip feeds' entry ramp flows into the mainline in a way that, on average, generally clears entering traffic from the signalised ramp intersection before the next platoon of traffic arrives. Residual queuing, with acceptable delays, may occur on the ramp but without extending back into the ramp intersection.

Satisfying ramp demand is the most desirable form of operation and would usually be achieved when the freeway flow warrants initial activation of the metering signals. As the freeway flow or ramp flow increases into the peak period the level of operation may progress to more restrictive forms of metering.

When designing a new ramp metering installation, satisfying ramp demand on average throughout the whole of the design flow period (maximum hourly flows) is the desirable form of operation. In practice, the permitted entry flow at a particular ramp will be subject to the freeway flow condition at the time, as well as operating outcomes relating to the impact that queuing and queue balancing may have when the ramp is part of a coordinated system.

3.5.2. Not Satisfying Ramp Demands

Ramp demands cannot be satisfied when the arrival flow on the ramp within a period is greater than the maximum metering rate, i.e., on average throughout the analysis period, generally the peak period, the entry ramp demand flow cannot be metered into the freeway flow within acceptable limits of queuing or delay. In these circumstances it is likely that some traffic diversion to other routes will occur.

During periods of high freeway flow combined with high entry ramp demand, limiting the entry flow may be the only form of operation that sustains free-flow conditions on the freeway. This metering operation will result in residual queuing on the ramp with high delays and may also involve queues extending beyond the length of the ramp back onto the arterial road.

Where long queues during ramp metering operation are anticipated and cannot be avoided during design, consideration should be given to measures that provide for the queue overflow on the arterial road (refer Section 8.2). In practice, with coordinated ramp metering strategies in place, ramp demands over a group of ramps can generally be satisfied for a longer period due to the balancing of queues.

3.6. Control Strategies and Algorithms

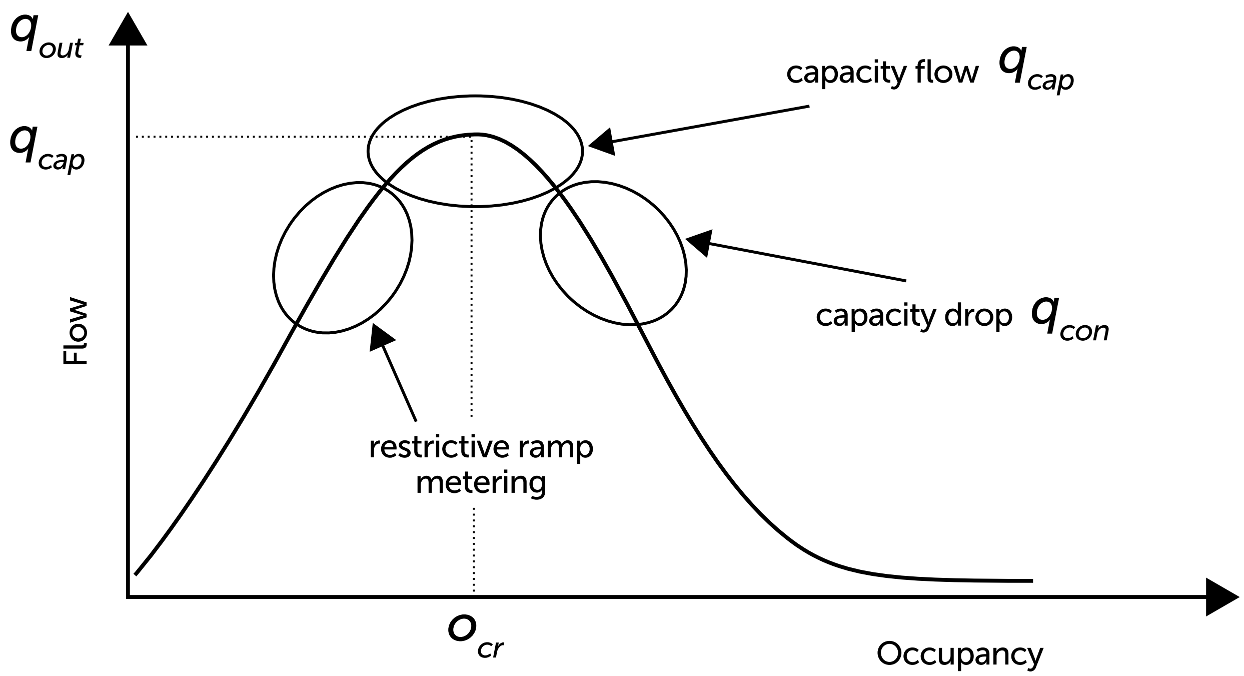
3.6.1. Effective Algorithms

The choice of an appropriate control strategy and technically effective freeway flow control algorithm for coordinated ramp metering is important if the maximum efficiency of a freeway is to be realised. This needs to go hand in hand with sound analysis and an understanding of freeway flow characteristics and geometry as well as appropriately designed entry ramps to provide adequate capacity and storage. These matters are outlined in Chapters 6 and 7.

The Euramp Handbook of Ramp Metering (2007) illustrates in Figure 3.5 the implications of a ramp metering rate that is either too high or too low. In the typical fundamental diagram for flow versus occupancy the maximum flow q_{cap} (capacity), occurs at a critical occupancy value, o_{cr}. At an isolated ramp when merging flow breakdown occurs due to entering traffic, the mainline flow drops to the area of q_{con} (congestion).

Therefore if the ramp flow through metering signals is too permissive, merging congestion will still occur. If ramp metering is too restrictive, the mainline throughput could drop to values similar to q_{con} which would negate any potential benefits as well as disadvantage entry ramp traffic, i.e., create longer ramp queues.

To achieve the full potential benefits of ramp metering, a technically effective ramp metering algorithm that establishes and maintains critical occupancy, i.e., maximum capacity flow conditions around the q_{cap} value, is crucial.



Source: Based on Euramp Handbook of Ramp Metering (2007)

Figure 3.5: Fundamental Diagram Indicating Importance of Correct Metering Rate

Section 7.2 provides a summary of the operation of the HERO suite of ramp metering control algorithms used by VicRoads, including a summary of the features that lead to the choice of the algorithm for freeways in Victoria.

3.6.2. Why Occupancy is used to Manage Freeway Flow

The Euramp Handbook of Ramp Metering (2005) has highlighted the uncertainty of mainline 'capacity' and summarised the conclusions from a number of papers (Elefteriadou et al., 1995; Lorenz and Elefteriadou, 2001; Cassidy and Radjanakanoknad, 2005) that have demonstrated that traffic breakdown in merge areas may occur at different flow capacity values q_{cap} on different days, even under similar environmental conditions, e.g., weather, lighting. These capacity differences become even more pronounced in adverse weather conditions (Keen et al., 1986).

In contrast, the critical occupancy o_{cr} at which capacity flow occurs, was found to be fairly stable (Cassidy and Radjanakanoknad, 2005), even under adverse weather conditions (Keen et al., 1986; Papageorgiou et al., 2007). Therefore, the occupancy measurement is the appropriate parameter for optimising throughput rather than speed or flow rate.

3.7. Managing Heavy Congestion and Incidents

On a managed freeway with coordinated ramp signals flow breakdown is generally prevented, or at least its onset is delayed. When freeway congestion does occur, the management of ramp signals requires an automated and integrated operational strategy that will minimise the worsening of congestion and also assist in flow recovery.

Situations that could lead to heavy freeway congestion include:

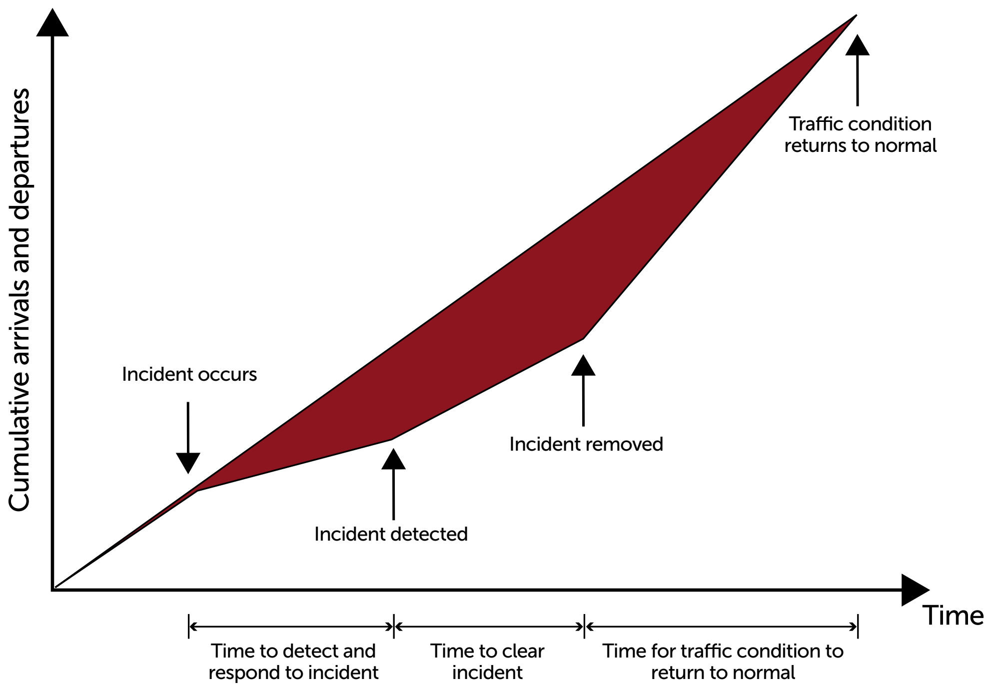
- Insufficient control of entering flows:
  - Some entry ramps are not metered
  - A freeway-to-freeway ramp is not metered and there is insufficient control on the intersecting freeway upstream of the interchange
  - The entry to the managed freeway is not controlled, e.g., the freeway is the continuation of a rural freeway or an arterial road.

- Access control strategies or policy lead to excessive demand:
  - Ramps with free flow priority access lanes
  - Queue management strategy to prevent ramp queues extending onto the arterial road lead to the implementation of high entry flows.
- An incident on the freeway.

Figure 3.6 shows an example to demonstrate incident delay with cumulative vehicle arrivals and departures plotted against time. The shaded area between the arrivals and departures represents the vehicle delay due to an incident. Before the incident, the vehicle arrival rate equals the rate of the departures. After the incident traffic is delayed and the departure rate decreases.

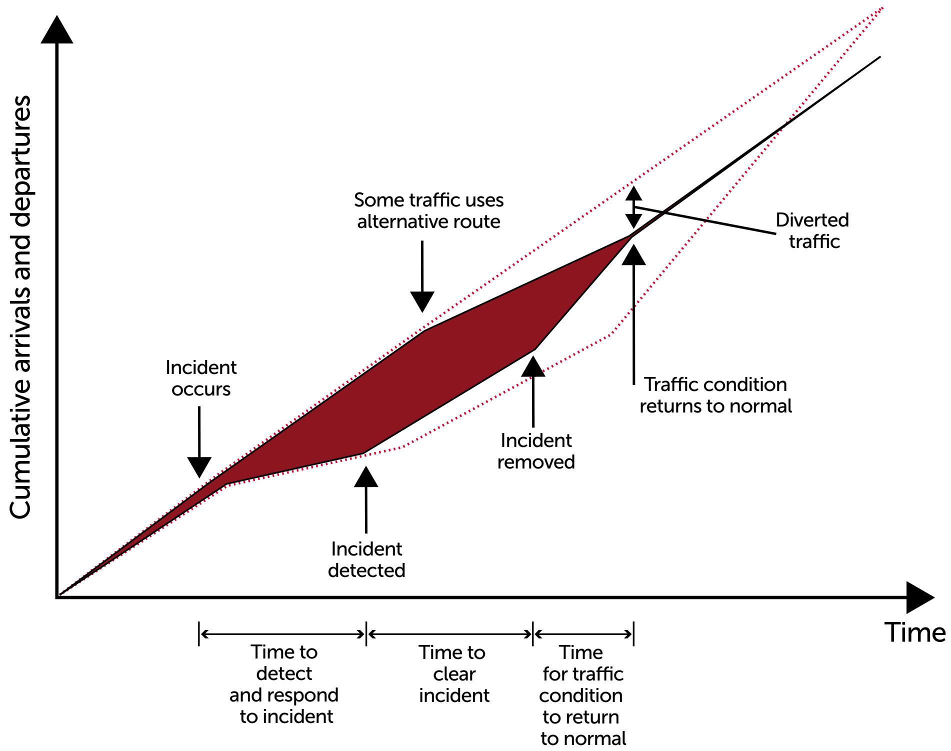
The early identification and effective management of an incident as well as actions to reduce freeway demand can assist in minimising the impact on traffic flow. Figure 3.7 indicates how an effective incident management system reduces the overall impact of an incident as well as the time for the freeway flow to return to normal. This is due to:

- Faster incident detection and response that leads to earlier incident removal
- Diverting traffic away from the incident.



Source: Based on Austroads AP-R298/07 - Improving Traffic Incident Management: Evaluation Framework

Figure 3.6: Incident Clearance without an Incident Management System



Source: Based on Austroads AP-R298/07 - Improving Traffic Incident Management: Evaluation Framework

Figure 3.7: Incident Clearance with an Incident Management System

An integrated approach is required to manage incidents and heavy congestion. This focuses on the following complementary actions:

1. **Management of entry flows to assist in flow recovery**

Freeway ramp signals can be used to limit entry ramp flows upstream of the incident by implementing a high cycle time to minimise the entry flow rate. This reduces the freeway flow at the incident site and also assists in diverting traffic, particularly if traveller information relating to travel time and incidents is provided. An automated response within preset thresholds detects the onset of congestion due to oversupply of traffic or due to capacity limitations at the incident site.

2. **Closing entry ramps and/or the freeway.**

In some situations managing the incident may also include closing ramps or the freeway upstream of an incident.

3. **Traffic diversion by providing traveller information**

Some motorists will use an alternative route if travel advice is available. This can be provided by:

- Real time driver information signs on the arterial road prior to the freeway entrance (refer Section 6.4.12)
- Mainline VMS to encourage motorists to leave the freeway before reaching the congested section
- Traffic condition reports from radio stations, particularly during peak periods.

3.8. When Ramp Metering has Limited Effectiveness

In some situations ramp signals can have limited effectiveness in preventing congestion due to conditions which limit capacity or traffic flow. These include:

1. Planned or Unplanned Events

a) During road works if the capacity of the mainline is significantly restricted

b) During incidents where sudden congestion occurs.

In these situations congestion management using coordinated ramp signals and traveller information advice can provide benefits for the duration of the event and can assist in flow recovery after the incident is cleared (refer Section 3.7).

2. Inadequate Traffic Management

When all entries to a freeway are not controlled, situations can arise where the uncontrolled flows dominate the freeway flow and limit the ability of ramp signals to prevent flow breakdown. In this situation, excessive restriction on entry flows would result in inequitable access to the freeway and excessive ramp delays.

3. Inadequate Infrastructure

a) Where a freeway terminates at an arterial road intersection with limited capacity. If traffic cannot be accommodated at the end of the freeway, queues and congestion develop on the freeway mainline as shown in Figure 3.8. Upstream ramp metering cannot increase the freeway throughput as the intersection at the end of the freeway controls and limits the capacity. Although upstream metering would be able to reduce the extent of queuing, this could result in excessive entry ramp delays, unnecessary restriction of trips to upstream exits and underutilisation of the upstream sections of freeway.

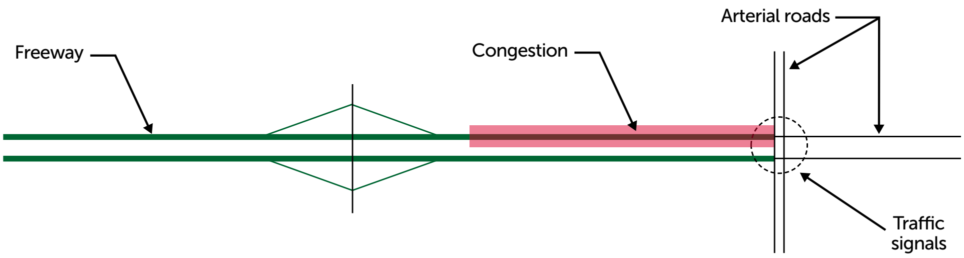


Figure 3.8: Freeway Congestion at a Terminating Freeway

In this situation the provision of upstream ramp signals would still make a contribution to improving the overall freeway flow by providing other benefits such as:

- Headway management at upstream ramps to improve local merging
- Preventing flow breakdown on upstream sections of the freeway at ramp merges and other critical bottlenecks
- Balancing entry ramp queues and delays in a coordinated system.

Where queues from the end of the freeway extend beyond an upstream exit as shown in Figure 3.9, coordinated freeway ramp signals could assist in managing upstream entry flows to keep the exit clear.

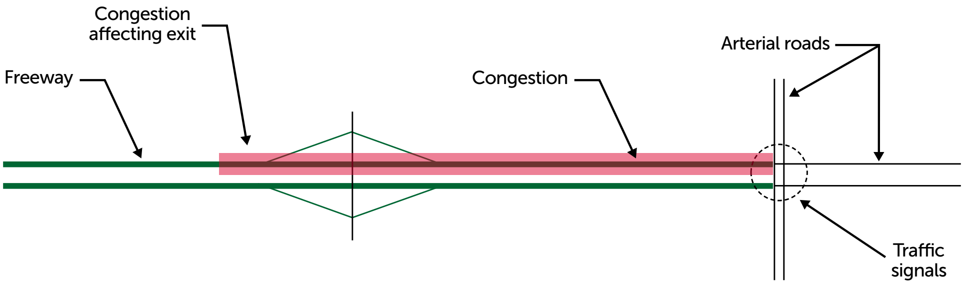


Figure 3.9: Freeway Congestion at a Terminating Freeway affecting an Upstream Exit

b) Where an exit ramp or exit ramp intersection has inadequate capacity and queues extend back onto the freeway and block a freeway lane as shown in Figure 3.10. The management of exit ramp overflow queues is discussed in Section 8.3.

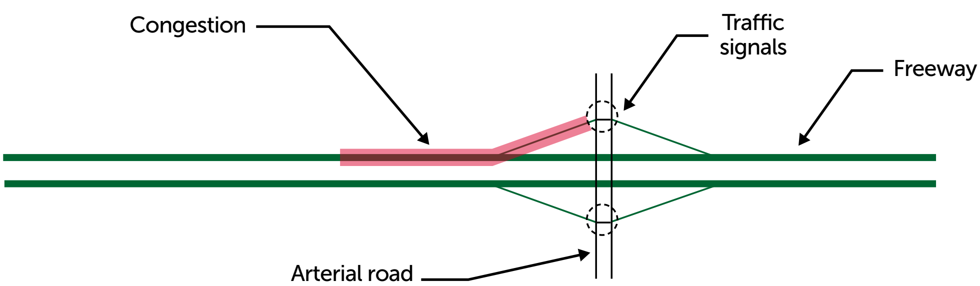


Figure 3.10: Freeway Congestion from an Exit Ramp

Note:

Theoretically, ramp metering by destination could be used to alleviate the problems identified above. This would require lane designation on the entry ramps, separate meters and metering rates as well as enforcement. It has not been trialled at this stage.