Supplement to Austroads Guide to Traffic Management

Part 2: Traffic Theory (2015)

Edition 2

JANUARY 2018

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1. Introduction

1.1 General

All road agencies across Australia are working towards greater consistency between States/Territories in how road networks are managed. In order to achieve this, the Austroads Guide to Traffic Management (AGTM) and Australian Standards relating to traffic management have been adopted to assist in providing that level of consistency and harmonisation across all jurisdictions. This agreement means that these Austroads Guides and the Australian Standards are the primary technical references.

Austroads Guide to Traffic Management, Part 2: Traffic Theory (2015) is a nationally agreed guideline document and has been adopted by all jurisdictions, including VicRoads.

All jurisdictions will be developing their own supplement to clearly identify where its practices currently differ and to provide additional guidance to that contained within Austroads Guide to Traffic Management, Part 2: Traffic Theory (2015). This document is the VicRoads supplement and shall be read in conjunction with Austroads Guide to Traffic Management, Part 2: Traffic Theory (2015).

1.2 How to Use this Supplement

There are two key parts to this document:

Classification of Supplement Information: this table classifies supplement information as a Departure, Additional Information or both. This information assists with identifying its hierarchy in relation to the Austroads Guide to Traffic Management, Part 2: Traffic Theory.

- Details of Supplement Information: this section provides the details of the supplement information.

  - **Departures**: where VicRoads practices differ from the guidance in the Austroads Guide to Traffic Management (AGTM). Where this occurs, these differences or 'Departures' will be highlighted in a box. The information inside the box **takes precedence** over the AustRoads Guide to Traffic Management section. The Austroads Guide to Traffic Management, Part 2, section is not applicable in these instances.

  - **Additional Information**: all information not identified as a departure provides further guidance to the Austroads Guide to Traffic Management, Part 2: Traffic Theory and is read and applied **in conjunction** with the Austroads Guide to Traffic Management, Part 2: Traffic Theory, section.

Where a section does not appear in the body of this supplement, the Austroads Guide to Traffic Management, Part 2: Traffic Theory (2015) requirements are followed.

2. Classification of Supplement Information

The classification of each clause as a Departure, Additional Information or both is shown in the table below.

Section	Classification
7.5.2	Additional Information
7.5.5	Additional Information
8.0	Additional Information
8.2	Additional Information

The Austroads Guide to Traffic Management, Part 2: Traffic Theory (2015) requirements are followed for sections not shown in this table.

3. Details of Supplement Information

Section 7.5 - Congestion Management Theory

Section 7.5.2 - Flow Monitoring and Management

Density and occupancy

The three primary variables used to describe traffic flow are identified in Section 2 as volume (q), density (k) and speed (v) , which, in aggregate terms, are related by q =k.v (Equation 2.3), in which the appropriate v is the space mean speed.

It has long been recognised that density is a fundamental measure of the level of service (LOS) being provided on a road at any particular time (e.g. HRB 1965) but, until relatively recently, the difficulties of field measurement of density led to the use of other LOS measures such as volume/capacity ratio. Historically, density (the number of vehicles in a unit length of lane or road)has been measured in the field by one of four methods, as follows:

- **Photographic techniques** measure density directly using photographs along a length of road, taken either from a fixed, high vantage point or from an aircraft. From the photographs, the number of vehicles in each length of road or lane that is of interest are counted and the density is obtained by dividing by the known length of road or lane. This method generally is no longer used for assessment of complex networks. Other methods utilising modern detection techniques are used in this instance.

- **Input-output counts** enable the number of vehicles in a road section to be updated from an initial, known number by adding counts of vehicles entering the section and subtracting counts of vehicles leaving. The passage detectors must be able to ensure accurate countsat both ends of the section and a means of regularly re-initialising the number of vehicleswithin the section is desirable. Such re-initialisation is difficult except in the situation of road sections with no intermediate entry or exit points and no lane changing, in which case the number of vehicles in each lane of the section can be obtained as the count of vehicles entering between the entry and exit of a specifically identified vehicle.

  It is well known that the errors in passive count between two detectors sites accumulate very quickly and the need for reinitialising (or correction through other means) will be continuous - (every few minutes). Hence the density calculations obtained by this type of measurement must take into account the sum of the errors in both input and output measurement points. Practitioners who have used this method for measuring density for real time ramp metering algorithms have often been oblivious to the error accumulation issue and the fact that between two consecutive detector sites that may be 500-1000m apart, the space provides potential for significant levels or traffic bunching to occur resulting in flow breakdown densities which are not always measurable using this method (i.e. if a bottle neck occurs between two count locations, the resulting computation will be misleading). The error problem introduced by this method would calculate a density error that would be outside the error range required to control traffic for managed motorway operations (**refer to VicRoads Ramp signals Handbook**).

- This method is only generally useful for post project performance monitoring and, in this case, should still be used with care.

- **Occupancy measurement** became a viable means of determining density with the introduction of accurate presence detectors. Occupancy (at a given location over a (usually fairly short) period of time) is defined as the proportion of time for which the presence of a vehicle over the detector is recorded. Given that presence is recorded whenever any part of a vehicle length is over any part of the effective length of the detector, occupancy is related to the average spacing of vehicles by the relationship:

$$Occ = \frac{\overline{L_V} + L_D}{s} \tag{7.25}$$

where

Occ = occupancy, expressed as a proportion (veh.s/s)

$\overline{L_V}$ = average length of a vehicle (m)

L_D = effective length of detector (m)

s = average spacing of vehicles as defined in Section 2.1.5 (m/veh).

Then, given that density, k, is inversely related to spacing (see Equation 2.2) but is usually expressed in the units of veh/km rather than veh/m, density is obtained as:

$$k = \frac{1000}{s} = \frac{1000.Occ}{\overline{L_V} + L_D} = \frac{10.(\%Occ)}{\overline{L_V} + L_D} \tag{7.26}$$

where k is density in veh/km, $\%Occ$ is occupancy expressed as a percentage, and all other variables are as previously defined.

Traffic density and per cent occupancy ranges corresponding to different levels of service are shown in Table 7.1, which has been adapted from May (1990) and Transportation Research Board (2010).

Table 7.1: Density and occupancy level of service indicators

Density pc/km/lane[(a)]	Per cent occupancy[(b)]	Level of service	Flow conditions	
0 – 7	0 – 5	A	Free flow operations	Uncongested flow conditions
7 – 11	5 – 7	B	Reasonably free flow operations	
11 – 16	7 – 11	C	Stable operations	
16 – 22	11 – 14	D	Bordering on unstable operations	
22 – 28	14 – 19	E	Extremely unstable flow operations	Near capacity flow conditions
28 – 54	19 – 36	F	Forced or breakdown operations	Congested flow conditions
> 54	> 36		Incident situation operations	

Notes:

a – density in passenger car equivalents per kilometre per lane.

b – assuming $\overline{L_V} + L_D = 6.7$ m.

In relation to Table 7.1, the occupancy measurement calculated by the many different detector devices used in Australia would benefit from having an agreed standard (i.e. the L_D measurement = 2m). This would avoid much confusion amongst practitioners who use different detection types where, for example, Level of Service E occupancy might vary widely between 8% and 25% (not 14-19%) depending on the technology used e.g Sensys, loops, CCTV, TIRTL etc.

Section 7.5.5 - Other Models of Flow Breakdowns

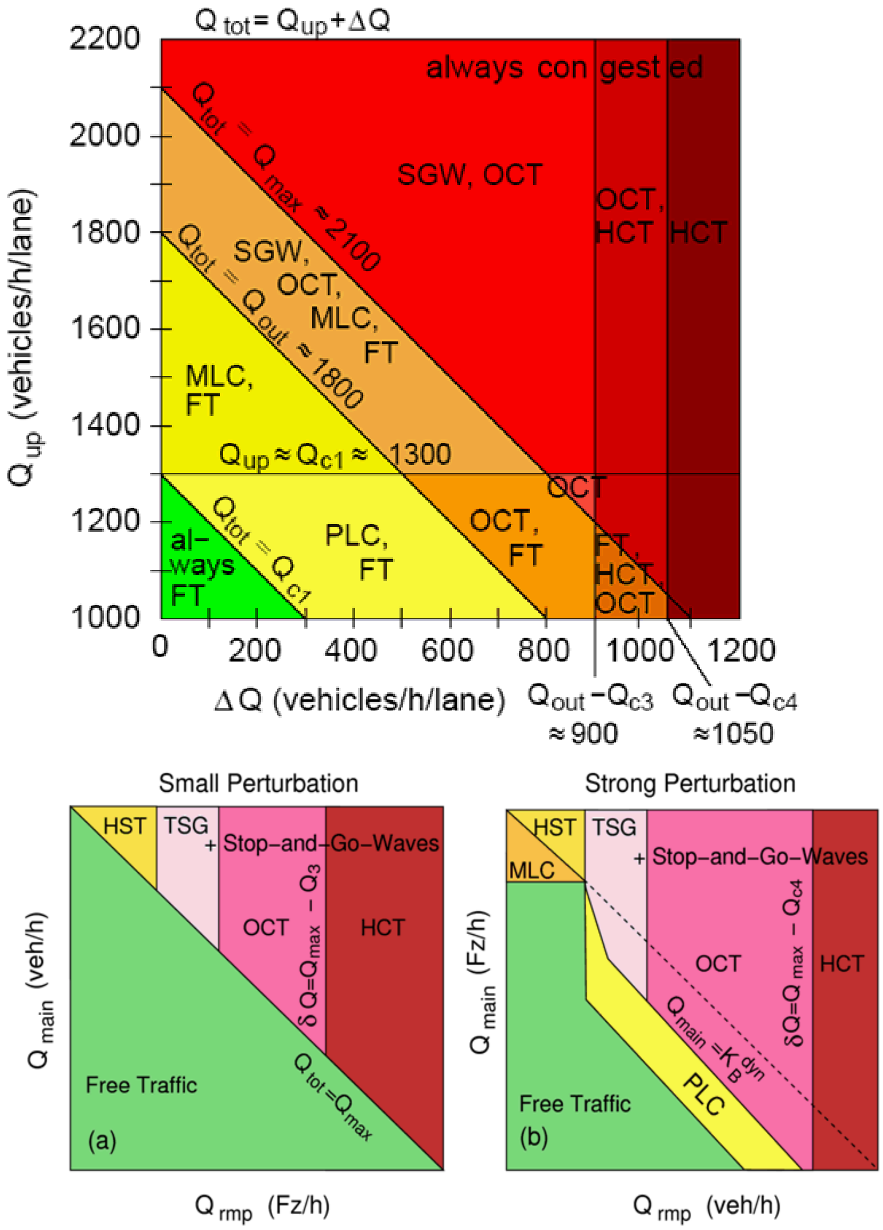
Six traffic state model

Schonhof and Helbing (2007) investigated 1 min data for the same section on the A5 freeway as Kerner and Lindgren. They interpreted traffic flow by six states: free traffic (FT), pinned localized cluster (PLC), moving localised cluster (MLC), stop-and-go waves (SGW), oscillating congested traffic (OCT) and homogeneous congested traffic (HCT). The most frequent states at the investigated freeway were the PLC and OCT states.

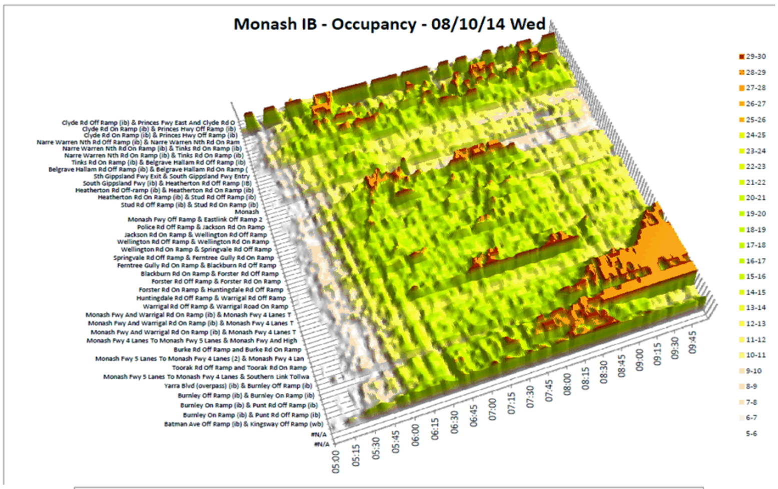
HCT occurs mainly after serious accidents with lane closures or during public holidays. An adaptive smoothing method was used to identify the different traffic states. This method interpolates and smoothes traffic data from successive freeway sections, taking into account the propagation speeds of perturbations in free and congested traffic.

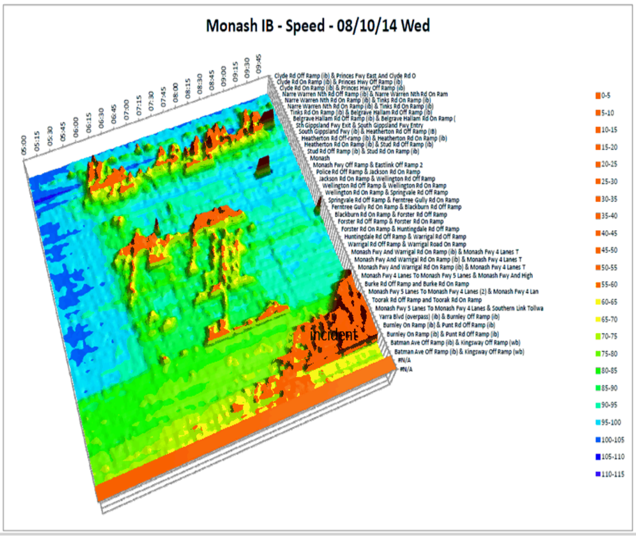
Flow breakdown and the resulting shockwaves types do not occur purely based on volumes alone but are strongly influenced by the delta (lane changing) which is associated with weaving, merging and diverging.

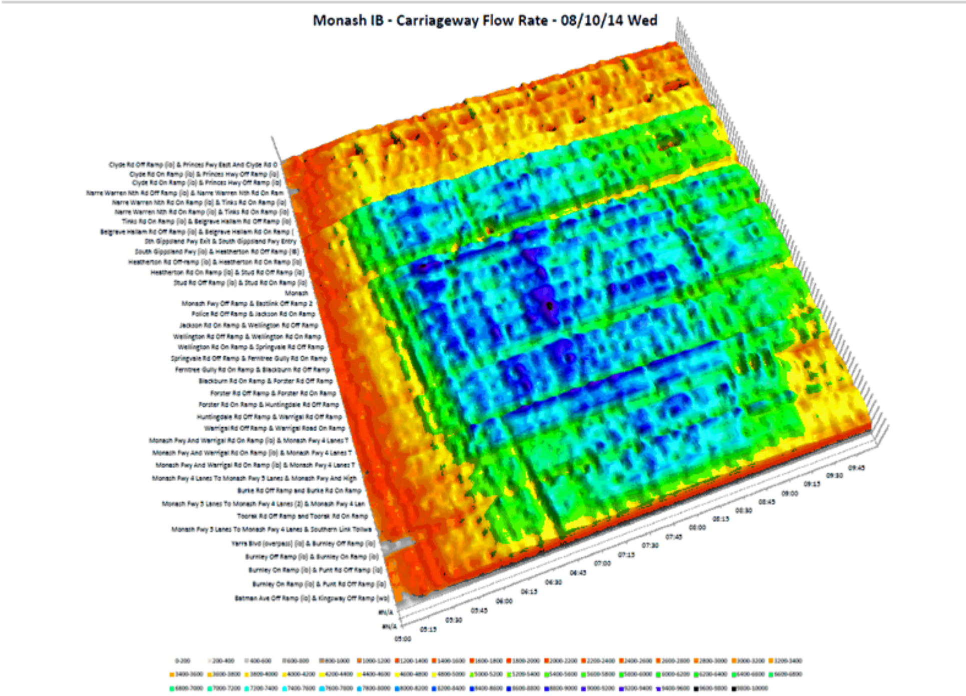
Refer diagrams below showing relationship between lane flows, lane changing and resultant traffic states.



All the bottlenecks shown in Figure 8.3 were not only associated with entry ramps but also geometric constraints such as grades and curvature and occurred just upstream of a mid-block lane gain that induced lane changing spikes e.g delta lane changing. Many of the wave types identified by Helbing et al are discernible in VicRoads data and this has lead to improved understanding of the cause of flow breakdown and assisted with further tuning of managed freeway systems - see VicRoads SVO graphs below:







Schonhof and Helbing (2007) found that the congested traffic states identified by this model were in good agreement with prediction of some second-order macroscopic traffic models and some microscopic car-following models.

Readers should refer to Austroads (2008), Austroads (2009a) and Han and Luk (2008) for further information regarding these flow breakdown models and their applications in the identification and analysis of freeway flow breakdowns.

Section 8 - PRINCIPLES UNDERLYING MANAGED MOTORWAYS

In recent years, road agencies have focussed on the management of motorways under congested flow conditions using e.g. ramp meterings and variable speed limit (VSL) signs. Austroads (2014a) and VicRoads (2013) described the general principles underlying the use of these managed motorway tools.

The simplified approach to the fundamental relationships provided in Section 2 may mask the fact that the extreme maxima/minima relating to feasible headway, speed and density outcomes are of limited value for traffic modelling, road design and traffic operations as, whilst limits on the speed-density-volume diagrams shown are theoretically and operationally feasible, we now know that these points are in fact unstable by nature and need to be used with care when informing traffic operations or modelling or design purposes.

The following diagrams from Traffic Flow Dynamics - Treiber and Kesting Figure 4.12 (refer Fig 8.1x) show that these relationships are not contiguous functions and that the critical points to be used for modelling, design and operations to provide stable on road flow outcomes can fall well below the maxima/minima identified in the curves.

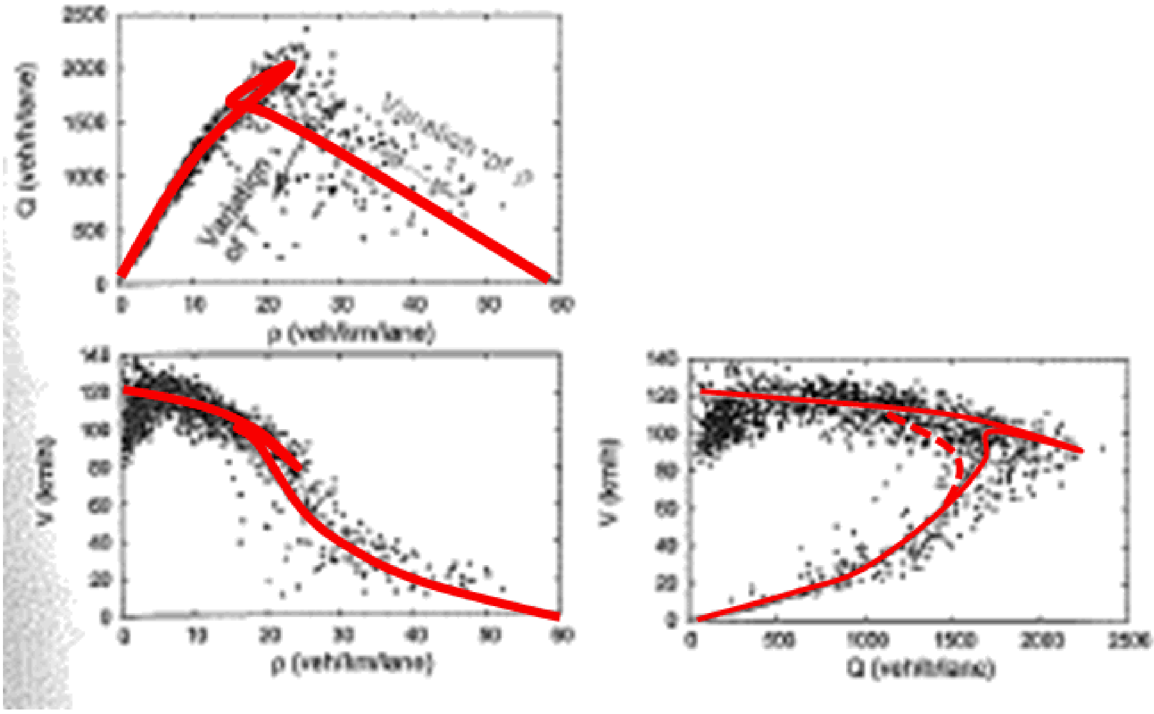


Fig 8.1X (From Treiber and Kesting – Traffic Flow Dynamics – Data, Models and Simulation)

For example, in practice it is possible to operate a managed freeway at higher sustainable flows if it is operated at the stable points which usually always fall significantly below the maximum points indicated by the speed-volume-density relationship diagrams (refer Fig 8.1x above). Note this is consistent with the Stochastic Concept comment documented by Brilon in Section 7.5.5 that the optimum degree of saturation is around 90%. This is essential information for modellers, designers and operators. As an example, the optimum degree of saturation for a 2 lane freeway is 90% of 2100veh/lane = 1890 veh/lane. However, this figure may vary between locations depending on the types of vehicles and other operational constraints.

In addition, the phase diagrams below (Fig 8.2x) demonstrate the boundary between the traffic states discussed in Sections 7.5.4 and 7.5.5 and confirms the statement above that the critical control figures to ensure stable flows occur below the maximum theoretical capacity

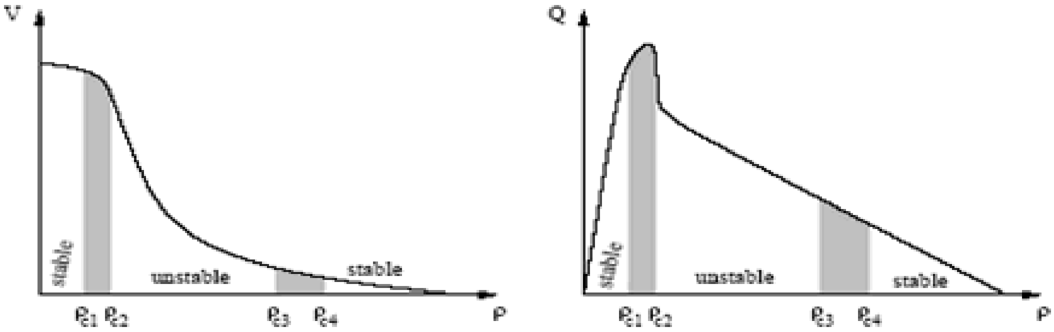


Fig 8.2X (From Treiber and Kesting – Traffic Flow Dynamics – Data, Models and Simulation)

The speed-volume-density diagrams above (Fig 8.2x) and those shown on Figure 8.6, Page 80 clearly show that the recovery flow typically occurs around Level of Service C or typically 1300 - 1400 vehicles per lane per hour, which is worth noting so operational practitioners can build algorithms to recover flow in real time etc.

Section 8.2 - Motorway Operational Capacity

VicRoads' primary reference for the determination of operational capacity is the VicRoads *Motorway Design Volume Guide – Design volumes for increased safety, reliability and productivity on motorways.*

Document Information

Title:	VicRoads Supplement to Austroads Guide to Traffic Management, Part 2: Traffic Theory (2015)
Department:	Investment and Design Services
Directorate:	Network Design Services
Approved by:	Jeremy Burdan Manager Traffic Engineering
Date of Approval:	January 2018

Amendment Record

Edition / Revision	Pages(s)	Issue Date	Amendment Description
Edition 2	10-12	January 2018	Revision of Section 8.2 to reflect new research
Austroads Guide to Traffic Management, Part 2: Traffic Theory (2015)	All	October 2015	First Edition

Previous versions of this document are available on request by contacting the VicRoads Traffic Engineering team.

For enquiries regarding this supplement, please contact the VicRoadsTraffic Engineering team via tem@roads.vic.gov.au or 9854 2417.