Australasian Transport Research Forum 2019 Proceedings
30 September – 2 October, Canberra, Australia
Publication website: http://www.atrf.info

Determination of Saturation Flows in Melbourne

Julian Laufer[1], Wen Long Yue[1], Zahra Shahhoseini[1], Farid Javanshour[1]
[1]Road and Traffic Design, Engineering and Road Management
VicRoads, the Department of Transport, Kew, Vic 3101
Email for correspondence: wenlong.yue@roads.vic.gov.au

Abstract

The capacity of a signalised intersection is estimated if the geometric configuration has been decided, based on other parameters: the allocated green time, phase plans, cycle time and the saturation flow rate. The allocation of green times for phases and movements are subject to the consideration of traffic demand including the provision of public transport and pedestrian activities. However, the saturation flow rate is very much depending on the locality characteristics of land use, traffic composition, traffic density and driving behavior. The value of base saturation flow rate for a specific site often varies away from recommended ones, such as the ones documented in Austroads Guidelines and Highway Capacity Manual (HCM). This paper attempts to report the procedures in determining the base saturation flow rates in Melbourne. A mesoscopic model, the Detailed Operational Modelling for Intersection and Network Optimisation (DOMINO) covering entire Melbourne metropolitan, is utilised to extract base saturation flow rates from built-in Sydney Coordinated Adaptive Traffic System (SCATS) readings for the signalised intersections. These readings can be applied to form the base saturation flow rates, and provide references to traffic signal designers to conduct further calibration in Melbourne.

1 Introduction

The use of traffic signals is fundamental to the smooth and safe operation of road networks. Saturation flow rate is a basic parameter used to derive signalised intersection capacity and is expressed as an hourly rate with units of vehicles per hour per lane (veh/h/ln). Saturation flow rate is also applied as the input value for the allocation of traffic signal timing and evaluation of intersection performance. In traffic signal design, the determination of intersection capacity is an important step in ensuring the appropriate control type, design, operation and signal timing selected.

Procedures for signalised intersection capacity analysis and performance evaluation often recommended the use of measured saturation flows for a specific site. Despite a location specific saturation flow collected will be the best practice for a new site, due to time consuming in saturation data collections and the variations in measuring locality characteristics, it is impractical to adopt the saturation flow rate from an existing site and even impossible to estimate the performance for the design of a signalised intersection that is yet to be constructed. In these situations, there is a need to form a methodology in quantifying saturation flows that are based on readily and reliable sources. This paper attempts to report a methodology in estimating the saturation flow rates based on Local Government Areas (LGAs) and road hierarchies.

2 Previous Practices

In the design of transport facilities and the development of traffic management schemes, the measure of saturation flow is an important factor for signalised intersections and road capacities. Although it is time and resource consuming to get the saturation flow rate for a new site, the measures for prevailing conditions can be determined directly from field measurement. Researches conducted in the past covered definitions, theories and site observations. The technique for measuring saturation flow rate and the detailed procedures in estimating the adjusted saturation flow rate have been described in Chapter 31, Signalised Intersections Supplemental of HCM (2010), suggested a value of 1900 veh/h/ln with limited conditions.

In Australia, a similar process to those described in HCM (2010) was documented in Austroads Guidelines (2009), the recommended base saturation flow rates in Through Car Units (TCUs) as presented in Table 1 are widely referred by traffic signal designers and practitioners as a starting point.

Table 1 Base saturation flows in through car units per hour by environment class and lane type

Environment class[1]	Lane type		
	1[2]	2[3]	3[4]
A	1850	1810	1700
B	1700	1670	1570
C	1580	1550	1270

Source: Guide to Traffic Management, Part 3: Traffic Studies and Analysis, Austroads (2009)

The saturation flow values in Table 1 were developed by Akcelik in 1981. These references for saturation flows are based on environment classes and lane types for users to select in a very simplified form.

Although these values of saturation flows from HCM (2010) and Austroads Guidelines (2009) may form a base for further adjustment, road hierarchy was not considered, no sufficient and specific calibration method were discussed and recommended.

More researches conducted, for example, Cuddon (1994), Akcelik, Besley and Roper (1999), Rahman, Ahmed and Hassan (2005), Shao, Rong and Liu (2011), Mukwaya and Mwesige (2012), Hamad and Abuhamda (2015), Ah, Yue and Stazic (2016, 2017), were all based on specific situations. Consequently, there is a perceived lack on selecting appropriate saturation flow rates for various conditions. In determining

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[1] The environment classes consider the movement conditions, visibility and pedestrian activities at the intersection.

[2] Through lane – a lane containing through vehicles only.

[3] Turning lane – a lane that contains any type of turning traffic, such as an exclusive left-turn lane, an exclusive right-turn lane, or a shared lane from which vehicles may turn left or right or continue straight through. There should be an adequate turning radius, and negligible pedestrian interference to turning vehicles.

[4] Restricted turning lane – a lane similar to a type 2 lane, but with turning vehicles subject to a small turning radius and some pedestrian interference.

appropriate saturation flow values for specific traffic conditions within different LGAs. The traditional methods and procedures adopted are often inconsistent and the adjustment processes are not clear.

As a fact, the base saturation flow rate is not necessarily a constant value throughout all LGAs, local land use environment, time of day, combination of road hierarchy and network conditions should also be considered. Where possible, it requires that saturation flows of the critical lane(s) of each approach are observed on a specific site, to adjust the base rate from references such as from Austroads Guidelines (2009) and default value of 1950 veh/h/ln in SIDRA. This is a time-consuming exercise and often limited data and short term measures may not fully serve the purpose. Therefore, there is a need to explore a systematic method in selecting base saturation flow values which could be readily referenced by transport modelers, traffic signal designers and transport practitioners.

3 The Mesoscopic Model - DOMINO

Transport models at different scopes are systematic representations of the complex real-world transport and land use systems. Modelling processes are to evaluate the impact of transport infrastructure alternatives and identify how the transport systems are likely to perform in the future and to test the impact of transport and land use options, which is essential in the development of an effective urban planning practice.

Transport systems modelling executes the procedures of “assessing the performances without the reality”, and is now a common practice in transport network planning and capable to measure the performance of different transport components under various scenarios. Transport modelers can develop modifications reflecting current or future challenges on a network or road components in the model, to explore the operational outcomes.

VicRoads has been developing the DOMINO model to explore the network operational challenges since 2015. These challenges include traffic signal design for new development areas, modification of existing ones and journey time estimations under planned/unplanned interruptions, which need to be identified quickly. The mesoscopic model used to determine the base saturation flows based on LGAs in this paper is DOMINO.

As shown in Figure 1, DOMINO model consists of approximately 650,000 links and 250,000 nodes across the Melbourne metropolitan areas and includes 31 LGAs and 3,117 travel zones. There are about 100,000 links related to other transport measures, including railway corridors, bicycle paths (DOMINO User Manual, 2019). The blue lines in Figure 1 represent the boundaries for various LGAs.

Although DOMINO covers the entire Melbourne metropolitan area, the model doesn’t perform in the way that traditional travel demand models carried out. Each road achieves a bespoke capacity as a function of the downstream signal controllers. The focus of the pursuit is not to determine demand but to explore road network variations affecting traffic operations.

DOMINO holds approximately 2,500 signalised intersections including phase plans. Signals are coded as independent external controller files. An example of detail of the density of the traffic control systems within the inner eastern suburbs and the Central Business District (CBD) is presented in Figure 2. This illustrates the connections of road hierarchies, locations of signalised intersections and roundabouts, and the railway lines amongst other thematic data components (DOMINO User Manual, 2019). The model is also capable to explore traffic movements in the context of intersection designs including turning pocket lengths and traffic signal coordination.

Figure 1 LGAs in DOMINO

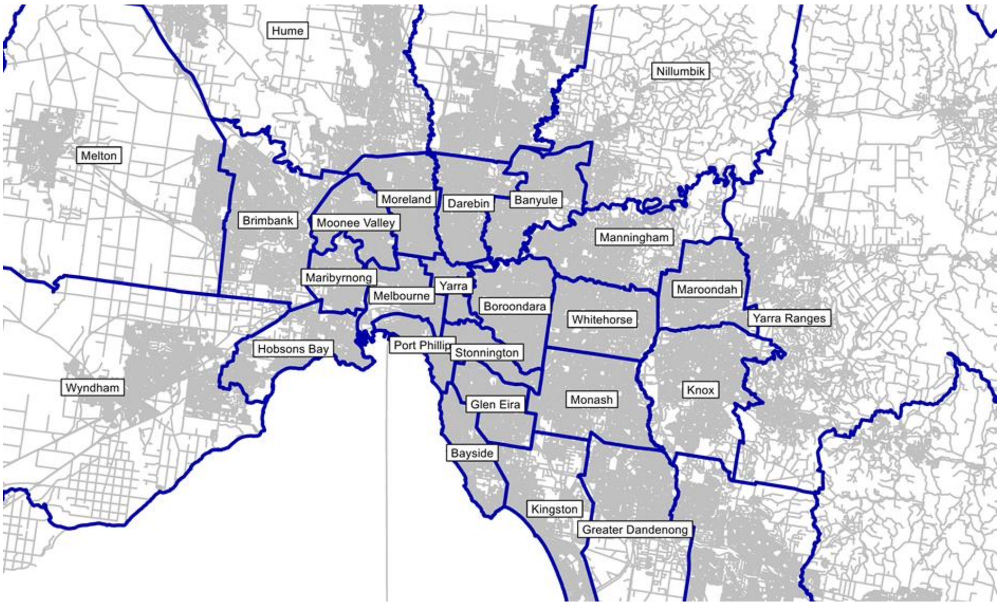
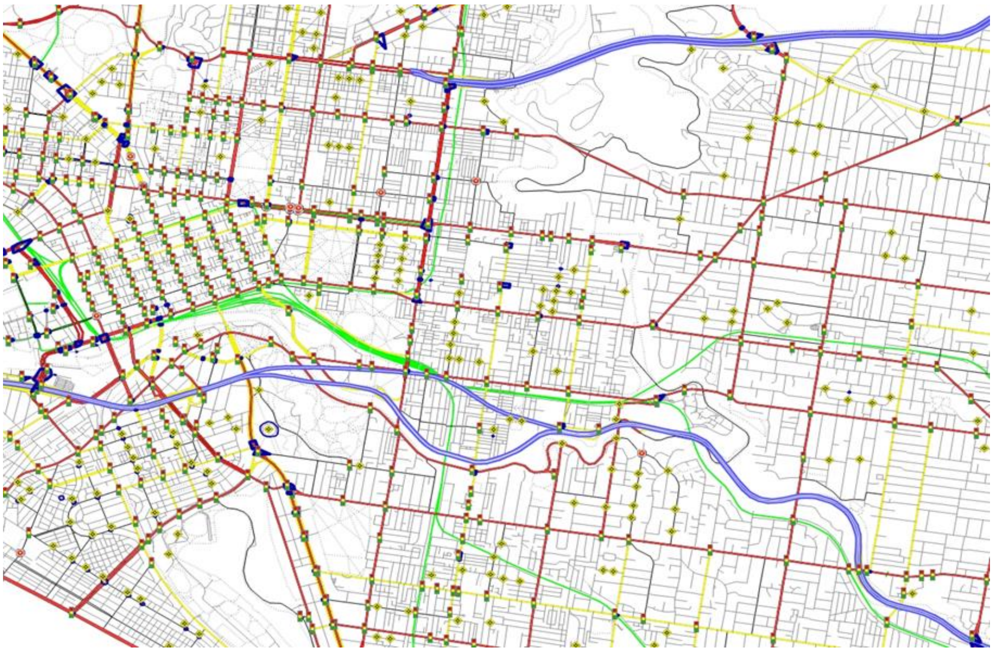


Figure 2 Locations of signalized intersections



4 Methodology

VicRoads, as a part of the Department of Transport in Victoria, plans, builds, and manages an integrated, sustainable and safe transport system for Victorians. In accomplishing this goal, transport modelling tools, such as DOMINO, play an important role at different design and evaluation stages to ensure a successful outcome. It also serves the function in traffic data management. VicRoads operates the road network and manages more than 2500 signalised intersections, and introduces new traffic signals along with the expansion and development of infrastructure to accommodate the growth areas.

Saturation flow rate is a key parameter in transport network modelling and signalised intersection design processes. It has a significant impact on model output and intersection performance.

The mesoscopic model, DOMINO, on the PTV's Visum platform, covers the entire Melbourne metropolitan, including all 31 LGAs. All signalised intersections are incorporated into DOMINO. This has been achieved by coding the intersection geometry, traffic movement, loop detector and traffic signal phase sequence details into the network itself.

To overcome the inefficiency, improve the accuracy, and reflect the local operating conditions, base saturation flows are extracted from DOMINO. The scope of this data extraction focused on lanes contain through vehicles [5] only at this stage. The fundamental is to utilise SCATS data, which have been represented in DOMINO from various resources including lane specific loop detectors, movement groups, intersection historical signal timings and SCATS outputs.

For each loop detector, only the maximum flow, from all signal cycles within 24 hours will be selected as the candidate for base saturation flow. This maximum flow is then reduced by 5% as the base saturation flow rate. The base saturation flows will be converted as a text file and incorporate into DOMINO for extraction purpose.

Using the various Visum built-in filters within the DOMINO model, the base saturation flows from the detectors recorded by SCATS under operational conditions for ALL signalised intersections across all Melbourne metropolitan can be extracted.

5 Results and Discussions

To make the base saturation flows readily accessible for transport modellers, designers and practitioners, the data is further explored. This is based on the all 31 LGAs in Melbourne metropolitan under five road hierarchy categories, forming a base saturation flow matrix. This matrix outlines the associated median saturation flow values. The extraction results are presented in Table 2.

The median saturation flow values listed are scaled down by 5% from the maximum flows to take a conservative approach and rounded down, using 25 as the incremental value.

Table 2 presents the mixed base saturation flow profiles for all LGAs across Melbourne metropolitan, and at a detailed level other than the ones generalised in HCM (2010) and Austroads Guidelines (2009).

As shown in Table 2, for Highway category, in concept, it should demonstrate the highest saturation flows amongst all the road hierarchies. However, thus, only one case out of 31, the base saturation flow of 1950 (in Moonee Valley[6]) is slightly greater than 1900 suggested by HCM (2010) and 100 more than the one from Table 1 in

[5] Through lane only.

[6] At row 21 in Table 2.

Austroads Guidelines (2009). In all the other 30 cases, the saturation flow rates extracted from DOMINO based on LGAs are much less than the ones documented in HCM (2010) and Austroads Guidelines (2009).

There are great differences in terms of driving behavior reflected through saturation flows by driving in Melbourne compared to other benchmarks. The table also reveals that a considerable lower saturation flows for all the other roads than default values recommended.

Table 2 Base saturation flows for all LGAs in Melbourne metropolitan

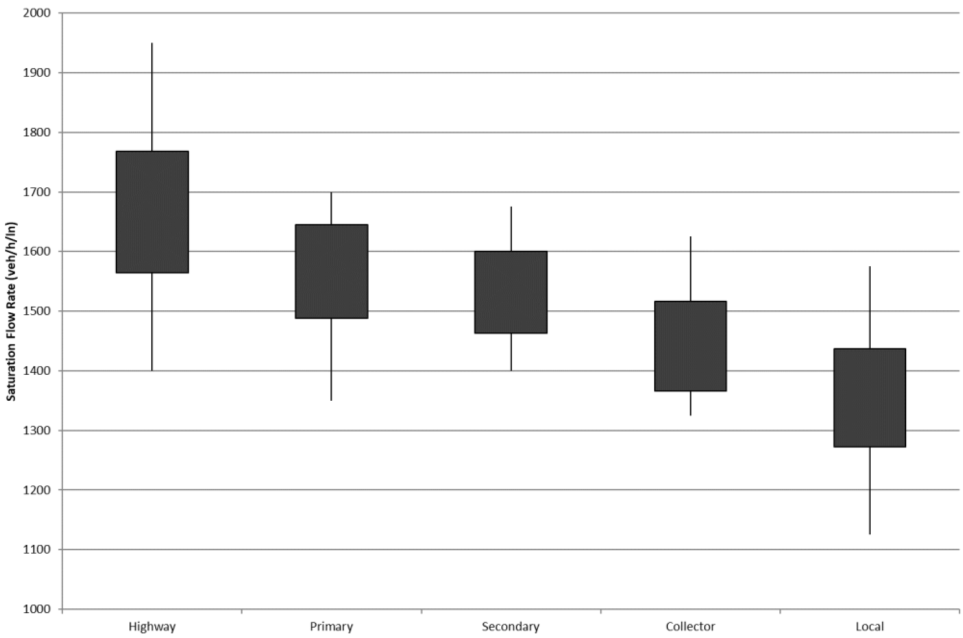
LGA		Road Hierarchy				
		Highway	Primary	Secondary	Collector	Local
1	Banyule	1700	1600	1575	1400	1350
2	Bayside	1775	1575	1525	1425	1275
3	Boroondara	-------	1500	1525	1475	1375
4	Brimbank	1675	1575	1575	1500	1450
5	Cardinia	1675	1625	1525	1475	1425
6	Casey	1575	1550	1575	1400	1325
7	Darebin	1650	1525	1550	1500	1425
8	Frankston	1400	1550	1425	1400	1275
9	Glen Eira	1700	1475	1450	1375	1125
10	Greater Dandenong	1625	1600	1525	1375	1350
11	Hobsons Bay	1500	1500	1475	1350	1350
12	Hume	1675	1650	1575	1500	1425
13	Kingston	1725	1625	1625	1425	1350
14	Knox	1700	1675	1550	1575	1425
15	Manningharm	1625	1650	1600	1500	1325
16	Maribyrnong	1625	1525	1450	1475	1375
17	Maroondah	1800	1700	1575	1625	1425
18	Melbourne	1550	1500	1425	1325	1250
19	Melton	1625	1525	1575	1525	1325
20	Monash	1750	1650	1575	1450	1350
21	Moonee Valley	1950	1550	1575	1450	1300
22	Moreland	1675	1525	1450	1400	1350
23	Mornington Peninsula	1625	1350	1400	1375	1225
24	Nillumbik	-------	1575	1675	1425	1325
25	Port Phillip	1650	1550	1475	1325	1575
26	Stonnington	1700	1475	1425	1425	1350
27	Whitehorse	1725	1700	1600	1525	1375
28	Whittlesea	-------	1650	1550	1500	1425
29	Wyndham	1775	1525	1575	1500	1400
30	Yarra	1575	1450	1475	1325	1275
31	Yarra Ranges	1625	1575	1600	1350	1425

Figure 3 illustrates the dispersions of base saturation flow rates for the of 31 LGAs listed in Table 2. The box plot indicates the minimum and the maximum saturation flows, and the low and high standard deviations. For example, in Highway category, the minimum flow is 1400 in Frankston[7], and the maximum is 1950 in Moonee Valley. The low standard deviation is 1564, the high standard deviation is 1768 and the median is 1666. This would indicate that the most referred saturation flow rates in current practices are overestimated for all road hierarchy categories.

[7] At row 8 in Table 2.

The procedures in extracting saturation flows imbedded the considerations of land use environment features for the specific LGAs, complicity of road network, characteristics of the local area driving behavior at all road hierarchy levels. There is no need to use of a series adjustment factors to reflect the geometric, traffic, and environmental uncertainties that may influence the departure headway of vehicles.

Figure 3 Base saturation flow variations vs road hierarchy categories



Using the LGA based saturation flows as the base values for further calibration may be more appropriate in practical applications.

6 Conclusion and Recommendations

Through the previous discussions and analysis, the saturation flow extraction method for Melbourne metropolitan is more practical. By holding this information in place, some relationships such as the saturation flows to reflect land use environment features, local driving behavior and road hierarchy classes can be explored.

This provides a more appropriate scale on high level calibration opportunities when benchmarked against existing resources such as HCM (2010) or Austroads Guidelines (2009). It is believed that the developed saturation flow matrix can be used as an essential reference for revealing driving behavior in specific LGAs. This may reduce the level of calibration requirements for specific sites within various LGAs for different road hierarchies, to be adopted by transport modeller, traffic signal designers and practitioners.

7 Future Work

As a first attempt, this paper reported a study on the use of a mesoscopic model, DOMINO, to extract saturation flows based on LGAs for Melbourne metropolitan. However, there are more aspects of saturation flows to be explored, such as:

- Saturation flows for left turns;

- Saturation flows for right turns;
- Saturation flows for shared left turn plus through movement; and
- Saturation flows for shared right turn plus through movements.

It is expected that the full suite of saturation flow rates will act as a useful reference in the future.

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