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MEASURING AND ASSESSING TRAFFIC CONGESTION: A CASE STUDY

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NOTE:

This paper is related to the analysis methodology used in the SIDRA INTERSECTION software package.

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MEASURING AND ASSESSING TRAFFIC CONGESTION: A CASE STUDY

Cennet YUMLU, Sara MORIDPOUR and Rahmi AKÇELIK

Measuring and assessing traffic congestion can be a difficult task in practice. This paper presents a case study investigating a highly congested signalized intersection in Melbourne. This is the intersection of Alexandra Parade and Wellington Street which has long queues on the westbound approach of the intersection extending upstream onto the Eastern Freeway section during the AM peak period. Real-life traffic data obtained from VicRoads including SCATS data for the intersection, freeway speed and flow data from freeway detectors on the upstream section, and data from special saturation flow and lane blockage surveys conducted at the intersection were used in a detailed paired intersection model developed using the SIDRA INTERSECTION 6.0 software. The paper demonstrates various difficulties encountered in the analysis of congestion in practice. The importance of using demand flow data under congested conditions and the impact of queue spillback in reducing saturation flow rates and intersection capacities is emphasised.

1. Introduction

Traffic congestion is part of our daily lives in cities all around the world. It is a growing problem with considerable impact on economy, land use and environment (BTRE 2007; ECMT 1999; Lay 2011, 2012). This paper reports a case study of a highly congested corridor in Melbourne. The study has been undertaken as part of research that aims to examine the existing methodologies to assess congestion and develop improved measures and models of congestion to assist in better understanding of traffic congestion and the influence it has on travel costs.

The purpose of the paper is to highlight various basic difficulties experienced in measuring and assessing traffic congestion. Long queues are observed regularly during AM peak periods on the westbound approach of the intersection of Alexandra Parade and Wellington Street. This is a *paired intersection* with a wide median that allows queuing on internal (median) lanes. The westbound traffic queues at this highly congested signalized intersection extend for a long distance onto the upstream Eastern Freeway section.

Real-life traffic data collected for measuring and assessing traffic congestion included the SCATS volume, operational parameters and timing data for the intersection (Lowrie 1990; Akçelik 1997; Akçelik, et al 1998, 1999) as well as the speed and flow data from freeway detectors provided by VicRoads. Special saturation flow and lane blockage surveys were conducted at the intersection. Using these data, the SIDRA INTERSECTION 6.0 software was employed to develop a detailed network model of the intersection (as a paired intersection) and the upstream basic freeway section. This particular software was employed because it is based on some concepts of interest, and provides related output that can be used, in assessing congestion. A number of queue length surveys were conducted using floating car surveys with GPS video equipment on the upstream Eastern Freeway section.

The model development had two stages, namely analysis based on *capacity* flow rates obtained from SCATS data, and analysis based on *demand* flow rates obtained from upstream freeway flow data. These will be referred to as the Capacity Model and Demand Model, respectively.

The Capacity Model was calibrated using the intersection stop-line volume counts per lane (SCATS volume data), information from saturation flow and lane blockage surveys for westbound traffic lanes and signal timing data from SCATS. The Demand Model was based on additional calibration using Eastern Freeway volume data obtained upstream of queues that developed at the intersection of Alexandra Parade and Wellington Street and spilled back onto the upstream Eastern Freeway. Model estimates were compared with real-life observations of queue length.

As expected, the Capacity Model underestimated queue lengths at the Alexandra Parade - Wellington Street intersection and their impact on the freeway section whereas the Demand Model reflected the observed conditions at the intersection and the upstream freeway section closely. This demonstrates the importance of using demand flow rates rather than the capacity flow rates based on stop-line volume counts that would be observed under congested conditions. The intersection saturation flow surveys indicated the need to take into account the lane blockage (queue spillback) effects.

2. Study Location and Data Collection

The study location and the effort to collect real-life traffic data used for calibrating the traffic model are described below.

While the SCATS volume and timing data were provided for the intersection as a whole, the effort to collect detailed calibration data focused on three westbound through lanes of the Alexandra Parade - Wellington Street intersection (*Figure 1*). These are exclusive through lanes with very long queues extending onto the upstream Eastern Freeway section reaching the Chandler Highway interchange location (*Figures 2 and 3*).

Figure 1 Alexandra Parade - Wellington Street intersection

Figure 2 Eastern Freeway section upstream of Wellington St and Hoddle St intersections

Figure 3 Queues extending from the Hoddle St and Wellington St intersections onto the Eastern Freeway during the AM peak period

2.1 Volume data and selection of the analysis period

SCATS volume data for the intersection and the speed and flow data for the upstream freeway section were provided by VicRoads for the period 4 - 9 March 2013. The initial analyses were carried out using data for the 15-min peak period (7.45 - 8.00 AM) on Monday, 4 March 2013. The analyses were repeated for the same peak period on Wednesday, 5 March 2014 to match the more recent conditions of saturation flow surveys at the intersection.

The peak period used was determined for the intersection as a whole, i.e. the 15-min AM peak period with the highest total volume for the intersection. The peak period for the Westbound through traffic (which is the focus of this study) was also considered.

Heavy vehicle volume (3.9%) for the Westbound Through movement is based on a site survey. For other movements, 2% HV volume was specified. Bicycle volumes were not specified.

The SCATS volume data represent the stop-line *capacity flow rates* under oversaturated conditions. This applies to the westbound through traffic at the intersection of Wellington Street and Alexandra Parade. *Demand flow rates* can be obtained as arrival flow rates upstream of the back of queue. In this case, Eastern Freeway volume data were used to determine demand flow rates.

As seen in *Figure 2*, the total freeway arrival flow rate splits between the Hoddle St and Wellington Street intersections. The percentage of total freeway traffic that travels to the Wellington Street intersection was determined for each 15-min interval assuming 50% flow split between the Hoddle St and Wellington Street intersections for the middle lane that carries traffic to both intersections.

For the 7.45 - 8.00 AM intersection peak period, residual demand (queue) accumulated during the 6.00 - 7.45 AM period was also included in determining an adjusted demand flow rate. A demand volume adjustment factor of 2.998 was calculated to reflect the upstream demand flow rates as well as the effect of residual demand for the analysis period. This factor was specified as a flow scale for the westbound through traffic. *Figure 4* shows the equivalent hourly flow rates (veh/h) of adjusted demand flows used in the analysis.

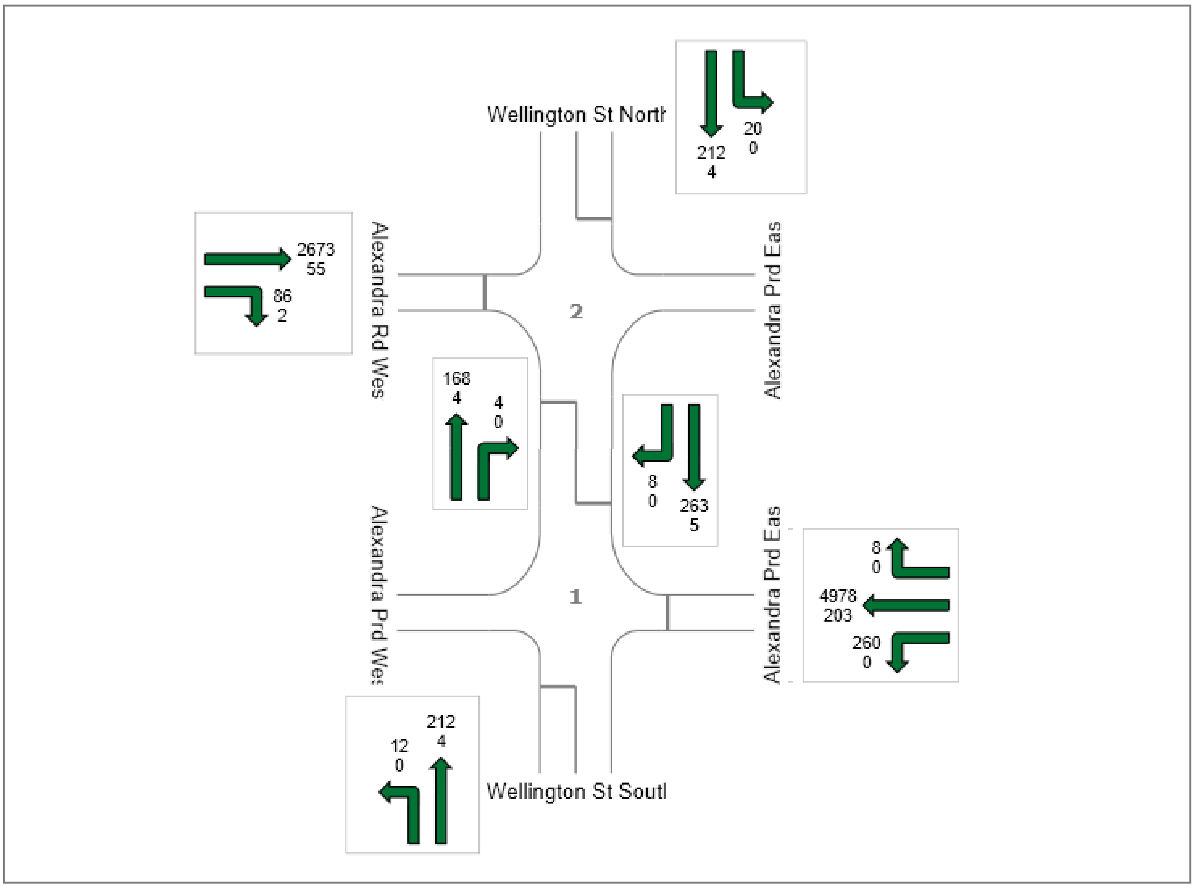

Figure 4 Equivalent hourly flow rates (veh/h) of demand flows used for the analysis of the intersection of Wellington St and Alexandra Parade during 7.45 - 8.00 AM

2.2 Saturation flow surveys

The first saturation flow survey for westbound traffic lanes at the intersection of Wellington Street and Alexandra Parade was conducted during the 7.30 - 9.00 AM period on 19 September 2013 using the method described in Akçelik (1981). This gave very low saturation flow rates of 811, 849 and 890 veh/h for westbound traffic Lanes 2, 3 and 4, respectively. Observations showed that these lanes were being blocked frequently by queues extending from the downstream Smith Street intersection which explained the low saturation flow values.

Subsequently, the survey method was extended to incorporate observations of lane blockages and their effect on saturation flow rates and lost times. A new survey using the extended method was conducted during the 8:50 - 11:30 AM period on 26 February 2014 (the later time period was selected to be able to observe a good number of signal cycles with no queue blockage). Results of the survey are summarised in *Table 1*. Saturation flow rates adjusted for heavy vehicles and short lane effects (adjusted to obtain SIDRA saturation flow rates that are equal to the observed reduced saturation flow rates) are shown in the table. The saturation flow rates, start loss and end gain values seem reasonable. A comparison of full and reduced saturation flow rates implies lane blockage values of 21%, 23% and 33% (proportion of time when lane blockage occurs) for Lanes 2, 3 and 4, respectively as shown in *Table 1*.

However, a comparison of the reduced saturation flow rates of 811, 849 and 890 veh/h of the earlier survey with full saturation flow rates found in the new survey implies lane blockage values above 50% as seen in *Table 1*. A further survey of lane blockage values for Lane 3 was conducted during 6.00 - 8.30 AM period on 21 May 2014 using a clearer definition of queue blockage in terms of its effect on saturation flow rates. This showed very little lane blockage during 6.00 - 6.30 AM but an average lane blockage value of 56% during 6.30 - 8.30 AM. The lane blockage value was 61% during 7.45 - 8.00 AM. A lane blockage value of 60% was used in the analysis for this period.

Table 1 Saturation flow survey results

Lane	2	3	4
Survey conducted on 26 Feb 2014			
Full saturation flow rate (veh/h)	1768	1724	1829
Reduced saturation flow rate (veh/h)	1400	1326	1223
Implied lane blockage	21%	23%	33%
Start loss (s)	2.3	3.2	2.8
End gain (s)	1.2	1.4	1.2
Average saturated green time (s)	72.2	78.1	82.5
Average displayed green time (s)	108.1	109.6	110.5
Effective green time (s)	107.0	107.7	108.9
Full saturation flow rate adjusted for HVs	1813	1767	1875
Basic saturation flow rate adjusted for short lanes, s_b	1916	1813	1685
Survey conducted on 19 Sep 2013			
Reduced saturation flow rate (veh/h)	811	849	890
Lane blockage implied by *Sep 2013* saturation flow rates compared with full saturation flow rates measured on 26 Feb 2014	54%	51%	51%

2.3 Queue length observations

Long queues formed on the westbound approach of the intersection of Alexandra Parade and Wellington Street extending as far as the Chandler Highway interchange on the upstream Eastern Freeway section. A number of queue length surveys were conducted using floating car surveys with GPS video equipment on the upstream Eastern Freeway section.

These surveys confirmed that the queue length formed at the intersection and its influence on upstream freeway flows resulted in queue lengths of the order of 1.9 to 3.7 km (the average value was 2.5 km and the 95th percentile value was 3.5 km).

2.4 Signal phasing and timing data

The signal phasing for the intersection of Wellington St and Alexandra Parade is shown in *Figure 5*. The average phase times reported by SCATS for the 7.45 - 8.00 AM period and adjusted for phase frequency values are Phase A = 110 s, Phase B = 40 s and Phase C = 10 s (cycle time = 160 s). These were specified as user-given phase times in SIDRA INTERSECTION. The Phase A time observed during saturation flow surveys was consistent with values reported by SCATS.

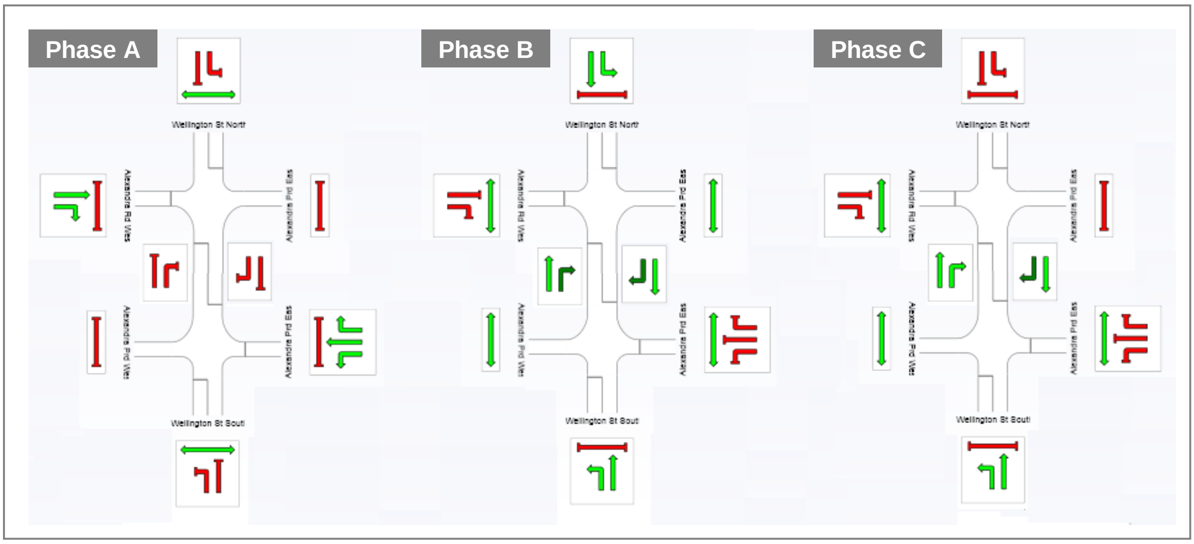

Figure 5 Signal phasing for the intersection of Wellington St and Alexandra Parade

3. Analyses

This section describes the results for the westbound traffic at the intersection of Wellington Street and Alexandra Parade for the two model calibration stages, namely analysis based on *capacity* flow rates obtained from SCATS data, and analysis based on *demand* flow rates obtained from upstream freeway flow data, referred to as the Capacity Model and Demand Model, respectively. The intersection layout picture produced for this case study is shown in *Figure 6*.

Although bicycle lanes were included in the SIDRA INTERSECTION model, a detailed analysis of the bicycle lanes was not undertaken in this case study.

The Capacity Model was calibrated using the intersection stop-line volume counts per lane (SCATS volume data), information from saturation flow and lane blockage surveys for westbound traffic lanes and signal timing data from SCATS. The Demand Model was based on additional calibration using Eastern Freeway volume data obtained upstream of the queues developed at the intersection of Alexandra Parade - Wellington Street and spilled back onto the upstream Eastern Freeway. Model estimates were compared with real-life observations of queue length.

Both the Capacity Model and the Demand Model were based on the calibration of saturation flow rates for westbound Lanes 2, 3 and 4 using the basic saturation flow rates based on the survey conducted in February 2014 after adjustments for heavy vehicles and short lane effects as discussed in *Section 2.2*. The basic saturation flow rate values used are given in *Table 1*. Equal lane utilisation was assumed for westbound Lanes 2, 3 and 4.

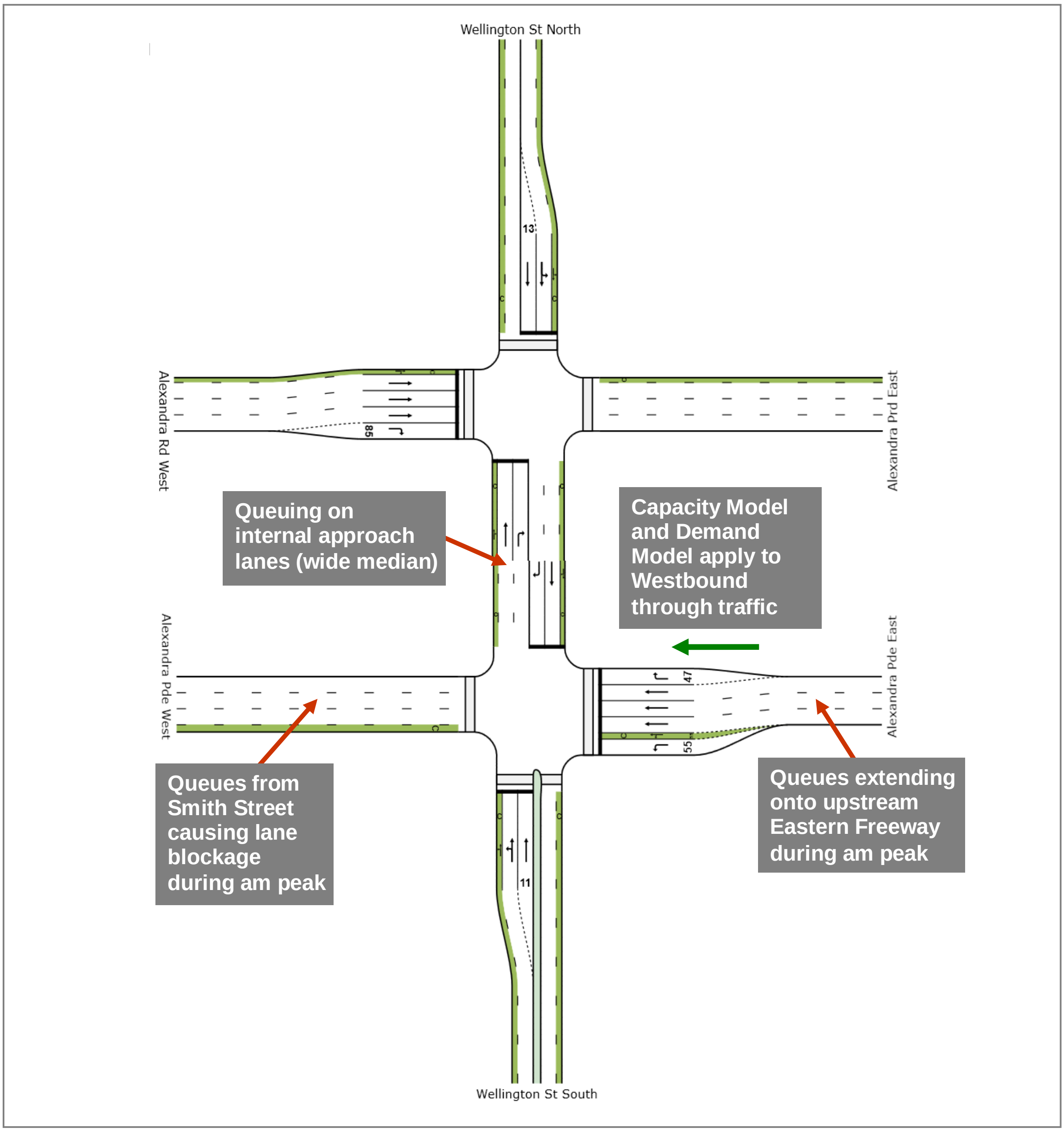

Figure 6 Layout picture of the intersection of Wellington St and Alexandra Parade

The analysis was conducted for the 7.45 - 8.00 AM period which is the peak flow period considering the intersection as a whole as discussed in *Section 2.1*. The capacity model used the SCATS stop-line volumes for this period. Initially, a capacity adjustment value of -25% was used for westbound Lanes 2, 3 and 4 based on the implied lane blockage values shown in *Table 1*.

The Capacity Model calibration aims to obtain x = 1.00 for all lanes due to oversaturated conditions observed for westbound Lanes 2, 3 and 4. The analysis using the capacity adjustment value of -25% for these lanes estimated a degree of saturation of 0.673 which was well below the expected value of 1.0.

An increased capacity adjustment value of -50% was used for Lanes 2, 3 and 4 which gave a degree of saturation of 1.010. This meant that, effectively, the saturation flow rates for this period were lower than assumed but acceptable in view of the implied lane blockage values based on reduced saturation flow rates observed during the survey conducted on 19 September 2013 as shown in *Table 1*.

The Demand Model used the demand flow rates calculated using the upstream freeway flow rates. The capacity adjustment value of -60% was used based on the lane blockage survey conducted on 21 May 2014 as discussed in *Section 2.2*. The 95th percentile back of queue values for westbound lanes estimated for the 7.45 - 8.00 AM peak period were in the range 2.9 to 3.3 km. These were close to the observed value of 3.5 km. The SIDRA INTERSECTION network display showing degrees of saturation and the movement display showing the 95th percentile back of queue values (metres) for the South side of the intersection for this solution is given in *Figure 7*.

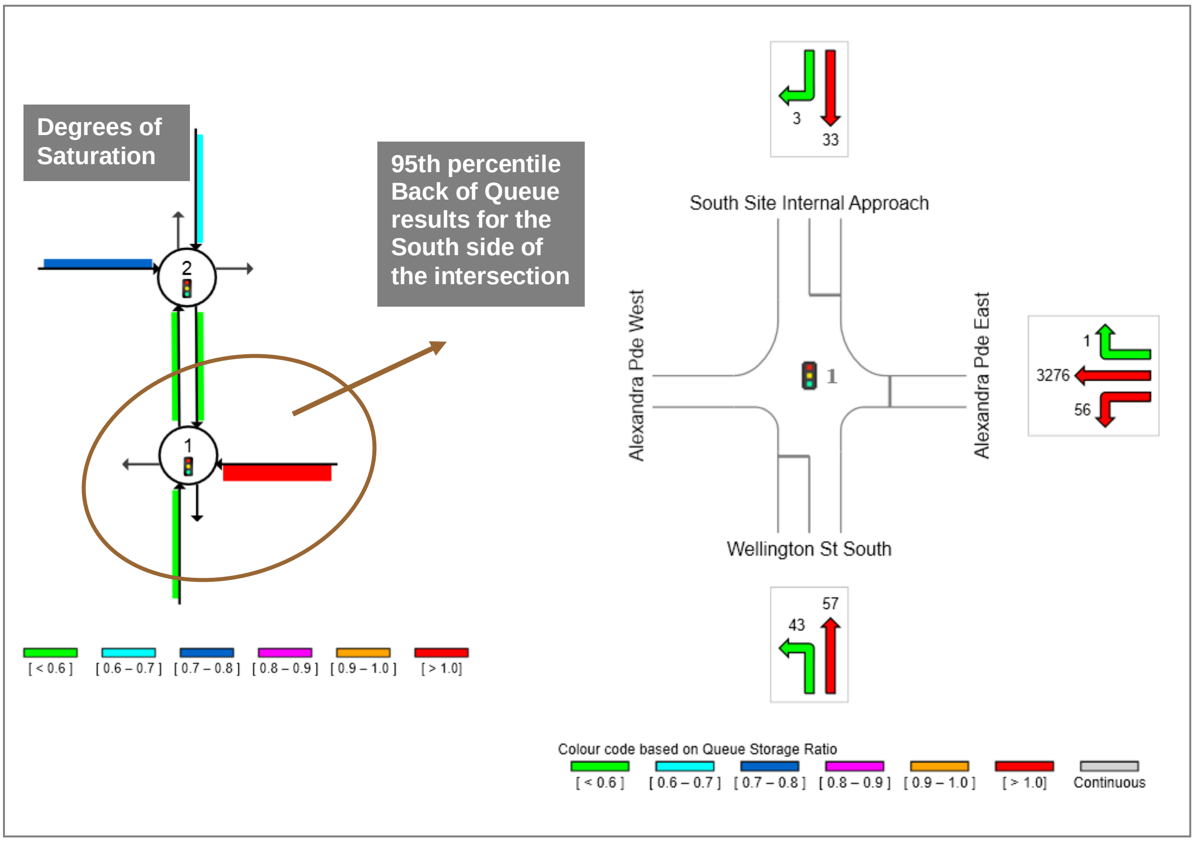

Figure 7 SIDRA INTERSECTION displays for the Demand Model applied to the 7.45 - 8.00 AM peak period

4. Concluding Remarks

As expected, the Capacity Model underestimated queue lengths significantly whereas the Demand Model provided much better reflection of the observed conditions at the intersection of Wellington Street and Alexandra Parade. This demonstrates the importance of using demand flows rather than the stop-line capacity flows that would be measured by the SCATS system or observed during a survey of intersection turning volumes under congested conditions. The impact of residual demand (queue) accumulated during long periods of highly congested conditions on intersection performance is also important.

The intersection saturation flow surveys indicated the impact of queue spillback (lane blockage) on reduced saturation flows, and therefore intersection capacities and performance. A new survey method was developed for recording the lane blockage times and taking the observed values into account in saturation flow and lost time calculations.

The estimates of back of queue discussed in *Section 3* indicate a high level of congestion for westbound through traffic during the AM peak period at the intersection of Wellington Street and Alexandra Parade. The estimated 95th percentile back of queue values for westbound lanes for the 7.45 - 8.00 AM peak period were 2.9 to 3.3 km which is close to the value of 3.5 km observed during surveys conducted using floating car surveys with GPS video equipment on the upstream Eastern Freeway section. The analysis assumed equal lane utilisation which would tend to underestimate queue lengths.

Calibration of SIDRA INTERSECTION saturation flow rates using SCATS MF (maximum flow) values was also undertaken during this case study. The findings of these analyses were similar to those based on calibration using the observed saturation flow rates discussed in *Section 3*. SIDRA INTERSECTION gives estimates of SCATS MF, occupancy time and space time values in the SCATS Parameters table of its Detailed Output report. The estimated and the SCATS-reported values were reasonably close given that the way SCATS derives these parameters does not match the analysis specific to a time period as applied in the use of SIDRA INTERSECTION (Lowrie 1990; Akçelik 1997; Akçelik, et al 1998, 1999).

The case study has demonstrated various difficulties which will be encountered in the analysis of congestion in practice. In particular, establishing the true demand flow rates, accounting for residual demand and measuring lane blockage (queue spillback) effects can be very difficult tasks for the analysis of networks of closely-spaced intersections with queue interactions between intersections. In the case study reported in this paper, determining demand flow rates was easy in technical terms (although it required a significant effort) due to the uninterrupted flow conditions (freeway) upstream of the intersection. Research is recommended on determining demand flow rates in networks of closely-spaced intersections.

The case study also showed the importance of accurate estimation of saturation flow rates under congested conditions where downstream queues interrupted departure flow rates. Further work is recommended to investigate saturation flow rates and the related SCATS MF parameter with a view to lane blockage effects under congested network conditions.

5. References

AKCELIK & ASSOCIATES (2014). *SIDRA INTERSECTION User Guide (for Version 6.0)*. Akcelik and Associates Pty Ltd, Melbourne, Australia.

AKÇELIK, R. (1981). *Traffic Signals: Capacity and Timing Analysis*. Research Report ARR No. 123. ARRB Transport Research Ltd, Vermont South, Australia. (*6th reprint: 1995*).

AKÇELIK, R. (1997). Fundamental traffic variables in adaptive control and the SCATS DS Parameter**.** *Paper presented at the Third International Conference of ITS Australia*, 11-14 March 1997, Brisbane.

AKÇELIK, R., BESLEY M. and CHUNG, E. (1998). An evaluation of SCATS Master Isolated control**.** *Proceedings of the 19th ARRB Transport Research Conference (Transport 98)* (CD), pp 1-24. ARRB Transport Research Ltd, Vermont South, Australia.

AKÇELIK, R., BESLEY, M. and ROPER, R. (1999). *Fundamental Relationships for Traffic Flows at Signalised Intersections.* Research Report ARR 340. ARRB Transport Research Ltd, Vermont South, Australia.

AKÇELIK, R., ROPER, R. and BESLEY M. (1999). *Fundamental Relationships for Freeway Traffic Flows.* Research Report ARR 341. ARRB Transport Research Ltd, Vermont South, Australia.

BTRE (2007). *Estimating Urban Traffic and Congestion Cost Trends for Australian Cities*. Working Paper 71. Bureau of Transport and Regional Economics, Canberra.

ECMT (1999). Traffic Congestion in Europe. *European Conference of Ministers of Transport*. Economic Research Centre, Paris.

LAY, M. G. (2011). Measuring traffic congestion. *Road & Transport Research*, 20, pp. 42-53.

LAY, M. G. (2012). An historical review of the assessment and management of congestion. *Road & Transport Research*, 21, pp. 32-45.

LOWRIE, P. (1990). *SCATS - A Traffic Responsive Method of Controlling Urban Traffic*. Roads and Traffic Authority of New South Wales, Sydney.

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Awards received by Rahmi include the Clunies Ross National Science and Technology award for outstanding contribution to the application of science and technology, the US ITE Transportation Energy Conservation Award, and the ITE ANZ Section Contribution to the Transportation Profession Award.