Australasian Transport Research Forum 2016 Proceedings
16 – 18 November 2016, Melbourne, Australia
Publication website: http://www.atrf.info

A multi-modal traffic operations gap analysis of the land transport network in Adelaide

Kun Zhang[1], Zhimin Ma[1]

[1]Department of Planning, Transport and Infrastructure, PO Box 1533, Adelaide SA 5001

Email for correspondence: kun.zhang@sa.gov.au

Abstract

Traffic congestion is an enduring problem facing Australian capital cities. Due to physical and fiscal constraints, it is neither practical nor sustainable to solve congestion problem through continuous infrastructure expansion. To keep traffic moving while achieving the strategic objectives of the land transport network, a proactive network operations strategy is the key.

An effective network operations strategy must target the multi-modal traffic operations gap. The operations gap of each transport mode is a generalised measure of the difference between the existing modal performance and the intended performance target, and the performance target should reflect the strategic road use of the transport network.

This paper reports the analytical work undertaken by South Australian Department of Transport in turning the motor-vehicle based arterial network performance into a multi-modal network operations gap. The major steps of the analysis include:

1. Translating the strategic road use of the network into the level of priority (encouragement) for individual transport modes at each link and intersection so that the performance target for each mode can be determined accordingly. This takes into account time of day operation;

2. Converting the existing vehicle based traffic performance into the people & goods based modal performance, and calculating operations gap for each mode against its performance target;

3. Mapping the multi-modal network operations gap for Adelaide inner area. The comparison of this map with the previously developed vehicle-based network performance map helps to assess the network analysis consistency.

The map of network operations gap creates a seamless link between strategic network planning and daily traffic operation. It quantifies the operational issues associated with individual transport modes and helps to develop balanced network operation strategies to close the gaps. The map is serving as an efficient and powerful means to engage both internal and external stakeholders to develop Moving Traffic Plan for the South Australian land transport network.

1. Introduction

Traffic congestion is an enduring problem facing Australian capital cities. Due to physical and fiscal constraints, it is neither practical nor sustainable to solve congestion problem through continuous infrastructure expansion. To keep traffic moving while achieving the strategic objectives of the land transport network, a proactive network operations strategy is the key.

Any effective network operations strategy must build upon a good understanding of the traffic network capacity and its existing performance. The South Australia Department of Transport has mapped the capacity and performance of the Adelaide inner area arterial network (Zhang and Excell 2015). This study suggests that the arterial network is currently operating at capacity in both the morning and evening peak periods. There would be limited opportunity to squeeze more capacity out of the exiting road network to increase network throughput and reduce travel delay through daily traffic operations. On the other hand, how to balance the competing demand from different user groups for the limited road space and the available green time at key intersections becomes an urgent issue. If we can't address this issue appropriately, the primary network operation objective of safely and effectively moving people and goods would be difficult to achieve.

As the focus of network operation is shifting from merely increasing overall network throughput to balancing competing demands of different user groups, a generalised performance measure for competing transport modes becomes essential. It is impossible to develop an effective network operations strategy without understanding the relative priority each mode is currently experiencing and assessing the true performance gap of each competing transport mode.

The Austroads network operation planning (NOP) framework (Austroads 2013, 3014) provides us with a practical guide to developing proactive strategies for multi-modal transport network operation. The NOP framework consists of seven steps including setting up network operation objectives, establishing strategic road use hierarchy, assessing the existing network performance, and developing and implementing network operation strategies and improvement plans. The third step of the framework, network performance assessment, is the core of the entire NOP process. The multi-modal network operations gap analysis of the Adelaide inner arterial network reported in this paper focuses on the mobility aspect of the network performance assessment.

2. Multi-modal transport network operations gap

2.1. Vehicle based performance measures

The objectives of network operation determine which performance measures are more appropriate to use for network analysis. Traditionally, network operations focuses more on improving network throughput and reducing route travel time and travel time variability for vehicles. Hence, the traffic performance can be measured by average link speed (km/hr), average intersection delays (sec/veh) and intersection degree of saturation (volume/capacity ratio). These measures are predominantly vehicle based and can be obtained by traffic survey and/or detailed traffic modelling. Once a set of thresholds are set up for these measures, we would be able to work out the level of service (LOS) of the links / intersections of the network.

Table 1 below shows an example of the threshold settings used by the intersection analysis software package SIDRA (SIDRA Solutions 2015).

Table 1 SIDRA level of service definition

Delay & v/c (HCM 2010) method for Level of Service definitions based on delay and v/c ratio (for vehicles)

Level of Service for v/c ≤ 1.0	Average delay per vehicle in seconds (d)			Level of Service for v/c > 1.0
	Signals	"SIDRA Roundabout LOS" method (1)	Sign Control (*HCM 2010 default for roundabouts*)	All Intersection Types
A	d ≤ 10	d ≤ 10	d ≤ 10	**F**
B	10 < d ≤ 20	10 < d ≤ 20	10 < d ≤ 15	**F**
C	20 < d ≤ 35	20 < d ≤ 35	15 < d ≤ 25	**F**
D	35 < d ≤ **55**	35 < d ≤ **50**	25 < d ≤ **35**	**F**
E	**55** < d ≤ 80	**50** < d ≤ 70	**35** < d ≤ 50	**F**
F	80 < d	70 < d	50 < d	**F**

v/c (demand volume / capacity) ratio, or degree of saturation: **v/c > 1.0** represents oversaturated conditions.

The level of service (LOS) itself is a good performance measure without setting any target as improving LOS is the goal of traditional network operation. In practice, to achieve a stable network performance especially during peak periods, the performance target would be LOS D or better, which would be universal for the entire network.

2.2. Multi-model operations gap (OG)

For a multi-modal transport network, the primary objective of network operation is to safely and effectively moving people and goods through the network instead of moving vehicles. To achieve this objective, different roads may play different roles according to the strategic road use hierarchy definition (e.g. public transport corridor, primary freight route, etc.) and the primary function of a road could change according to the time of day (e.g. the vibrant street of an urban arterial road network). The multi-modal network operation objectives suggest

- the traffic performance measures should be mode-specific, and
- the performance target setting for each mode on a specific road should reflect the strategic function of the road which may vary according to the time of day, rather than an universal one.

Therefore, the vehicle-based LOS measure itself is insufficient to describe the network performance. A performance measure which highlights the network operations gap between the existing performance and the intended performance target would be more appropriate (see Equation 1). Most importantly, the performance target should be determined by both the strategic road use hierarchy of the network and the time of day operations.

$$OG1 = \Delta LOS = LOS\_existing - LOS\_target \qquad (1)$$

When OG1 instead of LOS is used as the network performance measure, the focus of network analysis is shifted from vehicle-based network capacity deficiency assessment to assessing whether the network fulfils its primary function or not. The results of this analysis would lead us to much targeted strategies which make network operation more effective and strategic in terms of moving people and goods.

2.2.1. LOS_existing assessment

To measure the existing network performance, Table 2 below shows a set of measures for each transport mode at individual user level (VicRoads 2015). These measures are broad definitions of LOS, which can be used in conjunction with the traditional vehicle-based measures (e.g. intersection approach delay experienced by cyclists given a certain signal cycle length) to assess the existing network performance.

Table 2 SmartRoads level of service definition

	Level of Service				
reducing performance	A	No delay. No variability.	Opportunities to cross align with key desire lines. No wait times.	Dedicated minimum 3.0m off road path, grade separated.	No delay. No variability.
	B	Operating speed between 60 –80% of the posted speed limit.	Opportunities to cross close to key desire lines. Small to moderate wait times.	Dedicated minimum 2.0m kerb side lane, separated by parking and/or hard separator.	Operating speed between 60 –80% of the posted speed limit.
	C	Operating speed between 40 – 60% of the posted speed limit.	Opportunities to cross within reasonable distance of key desire lines. Moderate wait times.	Dedicated 1.7m to 2.0m bicycle lane marked on the carriageway.	Operating speed between 40 – 60% of the posted speed limit.
	D	Operating speed between 20 – 40% of the posted speed limit.	Opportunities to cross not close to key desire lines. Moderate to long wait times.	Kerbside bicycle lane, 1.2m to 1.5m.	Operating speed between 20 – 40% of the posted speed limit.
	E	Operating speed between 10 – 20% of the posted speed limit.	Opportunities to cross are an unreasonable distance from key desire lines. Long wait times.	Kerbside 1m bicycle lane or Bus Lane.	Operating speed between 10 – 20% of the posted speed limit.
	F	Operating speed is less than 10% of the posted speed limit.	No opportunities to cross. Excessive wait times.	Wide kerbside lane marking or nothing. Shared lane with traffic.	Operating speed less than 10% of the posted speed limit.

2.2.2. LOS_target setting

The multi-modal network operation focuses on effectively moving people and goods. By providing relative priority to the encouraged transport modes according to the place and time of day, this strategic objective of network operation can be achieved especially when the network is operating at its capacity. The *LOS_target* settings for individual transport modes at a specific location should reflect the road use priority.

We may allow the *LOS_target* having the similar six levels as the *LOS_existing* for calculation purpose (i.e. LOS A to LOS F). The meaning of the *LOS_target* for a mode at a specific location is the relative priority / the level of encouragement this mode should enjoy comparing with the other competing modes (e.g. LOS A for buses means 'strongly encourage' instead of 'No delay'). It captures the performance expectation rather than actual performance such as link delay/speed or intersection degree of saturation.

When we assign both *LOS_existing* and *LOS_target* the same set of values (i.e. 0~5 corresponding to LOS A ~ LOS F), then the LOS difference (ΔLOS) for each mode can be calculated. The meaning of the LOS difference for any transport mode would be the performance gap between the existing traffic performance and the intended performance target. It is important to note that the performance measure itself (LOS) is mode-specific, and we cannot compare the LOS of one mode with the other mode directly. However, the ΔLOS

of any mode shares the same meaning and this generalised performance gap measure can be compared across all transport modes.

2.2.3. Aggregated OG for each transport mode

The operations gap experienced by individual road users of a certain mode should be aggregated to reflect the mode performance, so that balancing the competing demands for the limited road space and available signal green time among different modes could be performed on a solid basis. Meanwhile, the aggregated operations gap must be people and goods based. To achieve this, the simple individual user based OG1 is modified using the relative efficiency factor (see Equation 2).

$$\mathbf{OG2 = \Delta\ LOS \times REF} \qquad (2)$$

The relative efficiency factor, REF, is a product of three variables which is then normalised using a reference value:

$$\mathbf{REF = volume \times vehicle\ occupancy \times unit\ delay\ cost\ /\ reference} \qquad (3)$$

- The ***volume*** is used to produce an aggregated performance for each transport mode;
- We use ***vehicle occupancy*** to turn the vehicle based performance sum into the people based performance sum. As we know a bus normally carries much more passengers than a car;
- The ***unit delay cost*** for each mode is used here as a means to capture the relatively different economical implication of the same level of performance gap. It is particularly important when assessing freight performance and making a fair cross mode performance comparison. The values used in this study were adopted from Austroads Guide to Project Evaluation Part 4 (i.e. $16.6 per hour for general traffic, $13.5 per hour for public transport and $40.5 per hour for freight (Austroads 2010)). Cyclists and pedestrians share the same unit delay cost with the public transport passengers.

To produce a normalised REF value for each mode, the product of the above three variables is divided by a reference value (e.g. $ 40,000, which is equivalent to 2000 cars per hour with average car occupancy of 1.2, or 60 buses per hour with average bus occupancy of 50 passengers). Now, the REF modified operations gap (OG2) can be compared across all transport modes.

By using the generalised OG2 measure, the network operations gap can be calculated based on both the strategic road use hierarchy definition and the detailed network operation data. The operations gap map would highlight the key operational issues associated with each individual mode and guide us in developing the targeted traffic operation strategies to balance and / or reduce network operations gaps.

3. A road use hierarchy for South Australia's land transport network

3.1. Road use hierarchy for SA transport network

The South Australian Integrated Transport and Land Use Plan (ITLUP, DPTI 2015) was released in 2015. The plan captures the state's short, medium and long term land use and transport vision. As an integral part of the plan, a Functional Hierarchy for South Australia's Land Transport Network (DPTI 2013) identifies which corridors are important for what transport modes (e.g. public transport, freight etc). This strategic road use hierarchy is consistent with the '*Movement* and *Place*' concept for network planning and operation.

Figure 1 visualises the strategic road use hierarchy of SA transport network. The coloured lines represent the transport modes which are encouraged on different corridors.

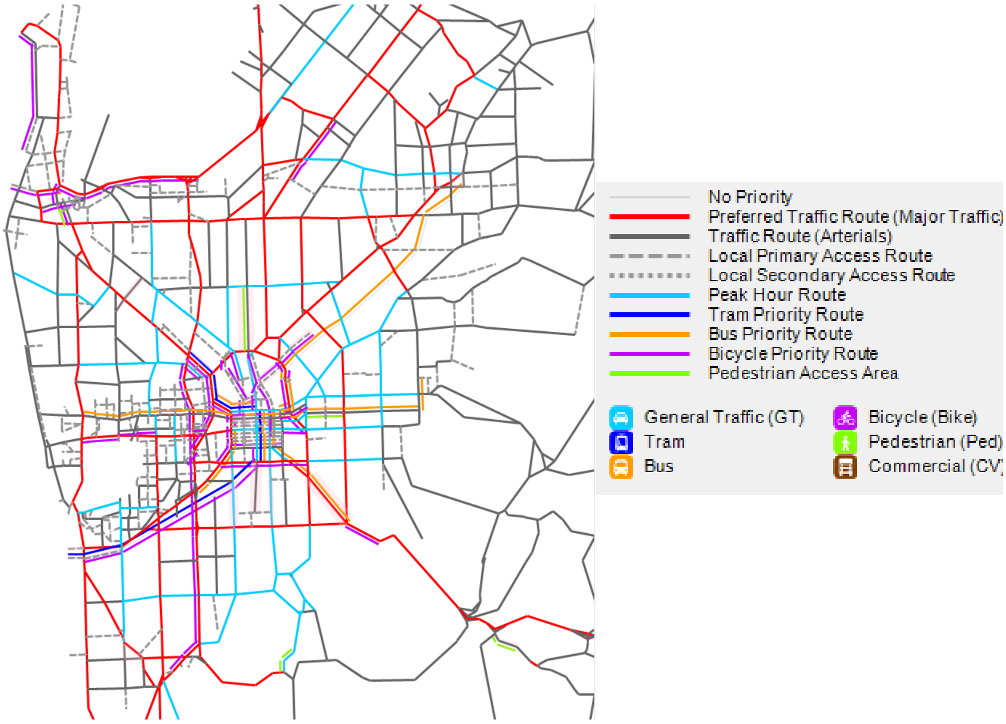


Figure 1 Strategic road use hierarchy for South Australia's land transport network

3.2. Performance target setting

The strategic road use map provides us a quick appreciation of how we intend to manage and operate the multi-modal transport network. To assess the network operations gap, we translated this strategic road use map into a more detailed movement priority map (see Figure 2). It contains the level of priority (encouragement) definition for each individual transport mode at each link and intersection. Importantly, the time of day operations were taken into account when producing the detailed movement priority map.

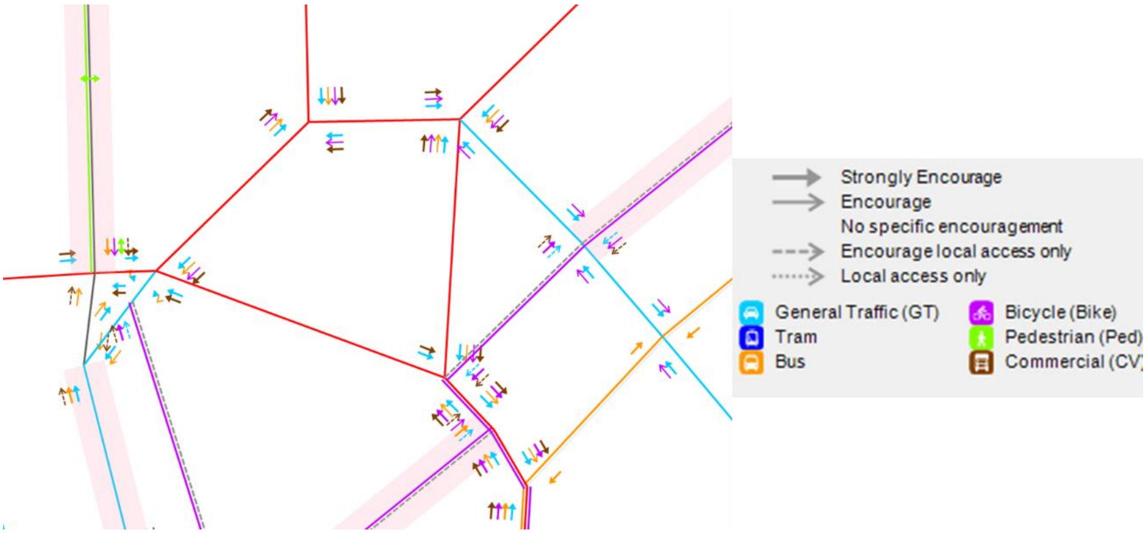


Figure 2 The level of priority definition for each movement at intersections by mode (AM)

In Figure 2, each coloured arrow represents a traffic movement of a specific transport mode. The shape of an arrow defines the level of encouragement (relative priority) of the movement, which is based on the strategic road use hierarchy. The *LOS_target* setting for the OG2 calculation was based on these arrows (e.g. a 'strongly encouraged' movement would have the performance target set to 'LOS A').

4. Operations gap estimation for Adelaide inner area arterial network

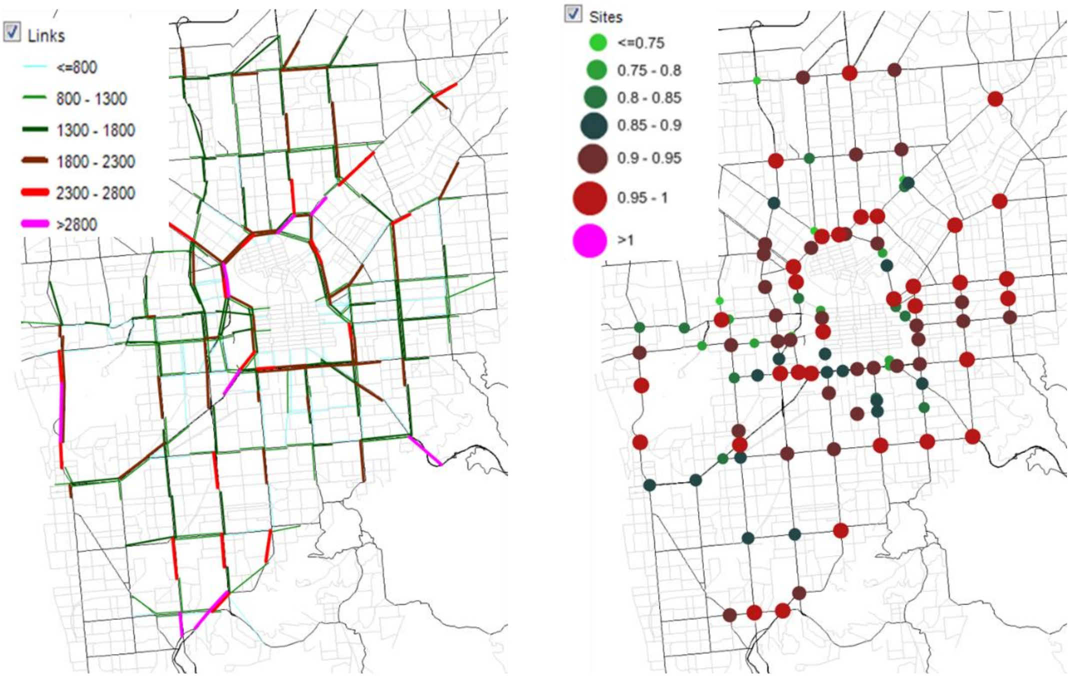
As discussed in Section 2, we need three steps to produce the operations gap for the multi-modal transport network including

1) setting performance targets,
2) estimating the exiting performance, and
3) calculating the generalised operations gap.

The previous section explained how to determine the performance targets for the multi-modal transport network. The following sections focus on the last two steps of the operations gap generation.

4.1. Existing performance estimation for individual users

In mapping the capacity and performance of the Adelaide inner area arterial network, we collected large amount of traffic flow data at the key intersections using SCATS (SCATS 2014) approach lane detectors. The most recent routinely collected intersection turning movement count data by DPTI were also used where the traffic lanes were not covered by SCATS detectors (e.g. left turn slip lanes) or the lanes were shared by multiple traffic movements. In addition, the manual turning count data provided us detailed mode specific data (i.e. counts for trucks, buses, bicycles, pedestrians, etc). The combination of these data painted a clear picture of the existing network traffic flow patterns (see Figture 3 (a), morning peak hour).



(a) Network flow pattern (veh/h) (b) Key intersection performance (v/c ratio)

Figure 3 Traffic performance of the Adelaide inner area arterial network (AM)

Basing on the traffic volume data and the detailed signal operation information which were collected on the same day when the volume data were registered by the SCATS system, intersection traffic modelling using SIDRA and LINSIG (JCT 2014, Zhang and Excell 2013) packages were conducted. The modelling results provided us overall intersection performance (i.e. volume / capacity ratio) and detailed intersection approach delays which were then used as the key inputs of the multi-modal operations gap analysis. The visual presentation of the intersection performance is shown in Figure 3 (b), which suggests the network was working at capacity during the morning peak hour. To gain extra capacity from the existing network through traffic operations changes would be very challenging.

Given the availability of these detailed intersection approach delay and the Bluetooth travel time / speed data between the intersections (Cox J 2013), we were able to estimate the *LOS_existing* for each transport mode at each intersection analysed. Note that the SCATS signal operation data and location-specific infrastructure information (e.g. bike lane, bus lanes, bus priority at intersections, etc) were essential for *LOS_existing* estimation.

4.2. Generalised operations gap calculation

As discussed in Section 2.2.3, the generalised OG2 calculation converts the vehicle based traffic performance deficiency (∆ *LOS*) into the people & goods based operations gap. The calculation also aggregates the performance gap experienced by individual users of each mode into a gap total of the mode. In this study, Equation 4 was used to calculate the actual operations gap (OG3). It is the modified version of Equation 2, and two new factors (RPF and MSF) are introduced.

$$\mathbf{OG3 = \Delta\ LOS \times REF \times RPF \times MSF} \qquad \mathbf{(4)}$$

where

RPF - the Relative Priority Factor,
MSF - the Modal Shift Factor.

The Relative Priority Factor (RPF) was used to accentuate the importance of the strategic priority (encouragement level) of a corridor for a transport mode. The higher the priority assigned to a mode the higher the RPF value would be (see Table 3 below). It should be noted that the RPF value can be adjusted to better reflect the current transport policy settings of a jurisdiction. The base value of 1 is always assigned to the 'No Specific Encouragement' level in all instances.

Table 3 Encouragement Level and the associated RPF (VicRoads 2015)

Encouragement Level (Priority)	RPF
Strongly Encourage	2
Encourage	1.5
No Specific Encouragement	1
Encourage Local Access Only	0.5
Local Access Only	0.33

We also used the Mode Shift Factor (MSF) to capture the potential short to medium term effects of the current transport policy incentives to encourage the growth of the sustainable transport modes such as public transport, cycling & walking. We set the value of MSF to 1.6 with the assumption that there would be a 5% annual growth of the sustainable modes for 10 years, given a continual transport policy support & investment priority. Meanwhile, the MSF for private cars was set to 1.0 – no encouragement.

The SmartRoads tool, which was developed by VicRoads and further improved by Austroads (Austroads 2016), was used in this study to automate operations gap calculation and visualise the results. Figure 4 shows the operations gap map (OG map) of the Adelaide inner area arterial network, AM peak hour. The corresponding vehicle based performance map for the same period is Figure 3 (b).

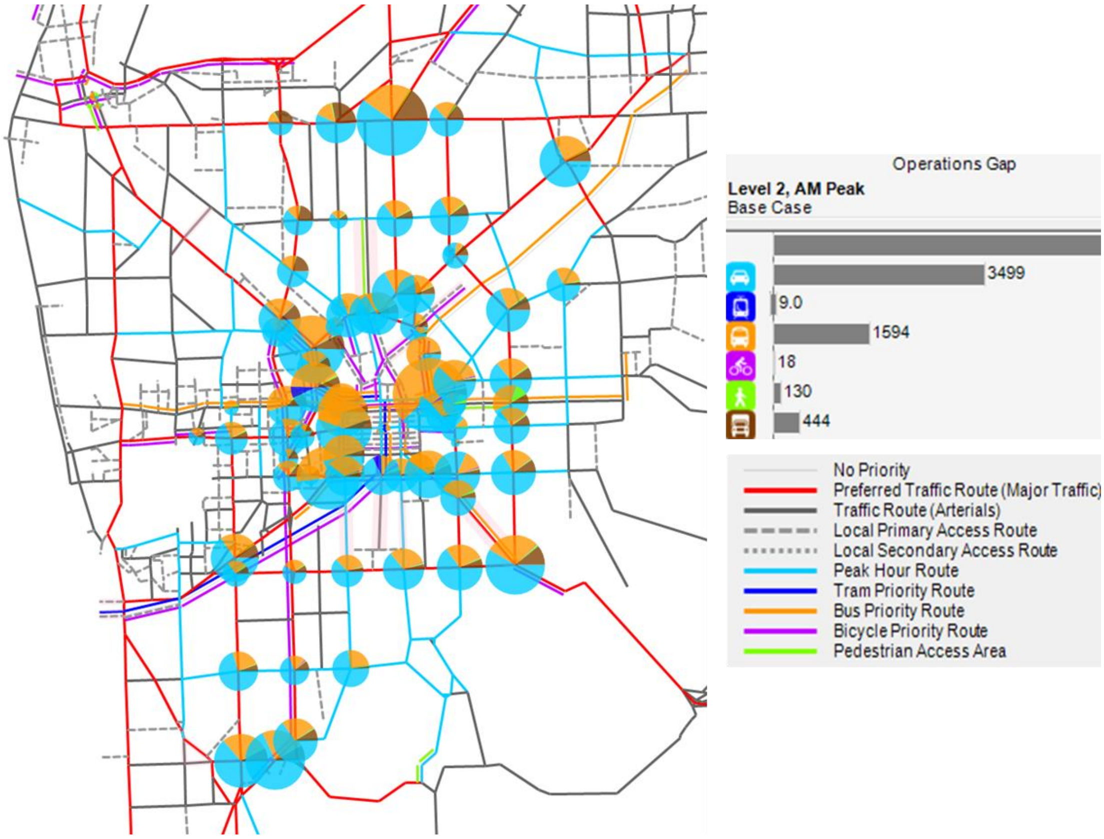


Figure 4 The OG map of the Adelaide inner area arterial network (AM)

In Figure 4, each pie chart shows the operations gap of a key intersection of the network. The size of the circle indicates the magnitude of the overall performance deficiency of the site. Each coloured piece quantifies the mode specific operations gap. A quick skim of the OG map suggests

- Adelaide is still a car dominant city – the general traffic as a mode experiences the largest operations gap as cars dominate the peak hour passenger trips;
- Public transport (especially buses) is currently playing an import role in moving people during peak hours;
- The operations gap of freight is noticeable along key freight routes;
- The operations gap of cyclists and pedestrians are barely visible – this is largely due to the lack of cyclist and pedestrian volumes on the key arterial roads.

5. The implications of OG map for multi-modal transport network management

We may zoom in to have a close look of the two areas of the OG map and see how the map can assist us in network operation.

5.1. Area 1 – northern segment of inner city ring route performance

Figure 5 shows the operations gaps of the northern part of the Adelaide CBD arterial network. The inner ring city route is highlighted in green.

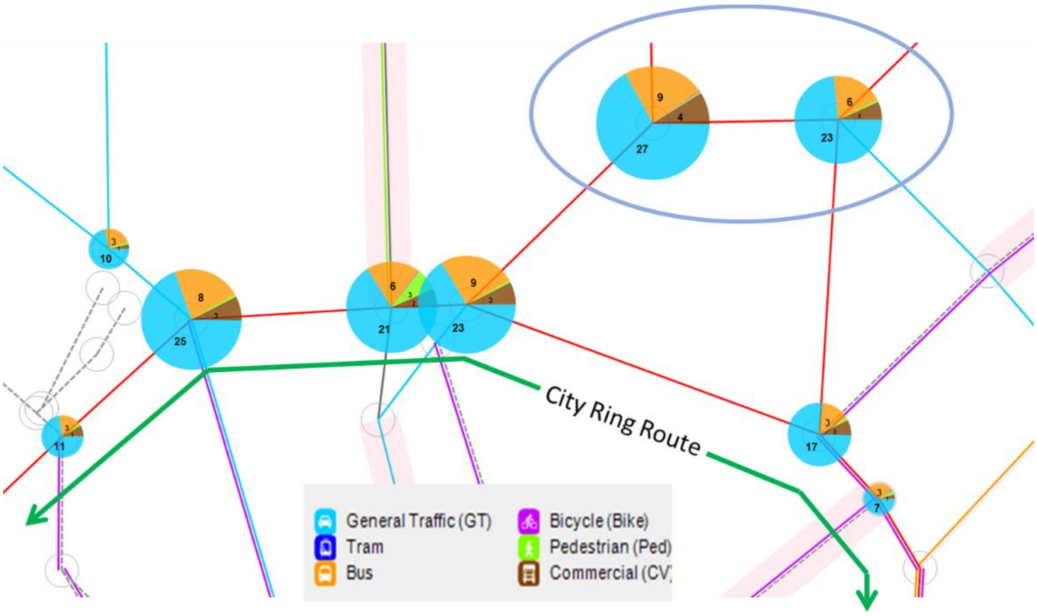


Figure 5 The OG map of northern part of the Adelaide CBD network (AM)

The OG map suggests the key intersection performance along the ring route is consistent in terms of

- The overall operations gap is car dominant;
- The operations gap of buses concentrated on the intersection approaches which intercepts the ring route;
- The operations gap of commercial vehicles on the inner city ring route is still noticeable although the commercial vehicle volumes are not comparable to the car volumes.

Given the tidal flow nature of the Adelaide peak hour traffic, the operations gap of the two major intersections leading to the city ring route (i.e. the intersections inside the blue circle in Figure 5) are very big. These two intersections are the congestion hot spots during peaks (see Figure 3 (b)).

The OG map is a natural extension of the vehicle based network capacity / performance map. The map not only highlights where the performance issues are but also provides an insight into the nature of the issue from a multi-modal perspective according to the road use hierarchy definition of the transport network. This map serves as a bridge between the strategic planning and the daily network operation.

5.2. Area 2 - Eastern segment of the inner city ring route performance

Figure 6 shows the OG map of the eastern part of the Adelaide CBD arterial network. The O-Bahn bus route is highlighted in red. The O-Bahn is a 12 km guided busway system with three interchanges. It is the highest patronised public transport corridor in South Australia connecting the north eastern suburbs of metropolitan Adelaide to CBD. As shown in Figure 6, there is a short section along the O-Bahn bus route where the O-Bahn buses have to leave their guide tracks and join the general traffic on the inner ring route (i.e. Hackney Road).

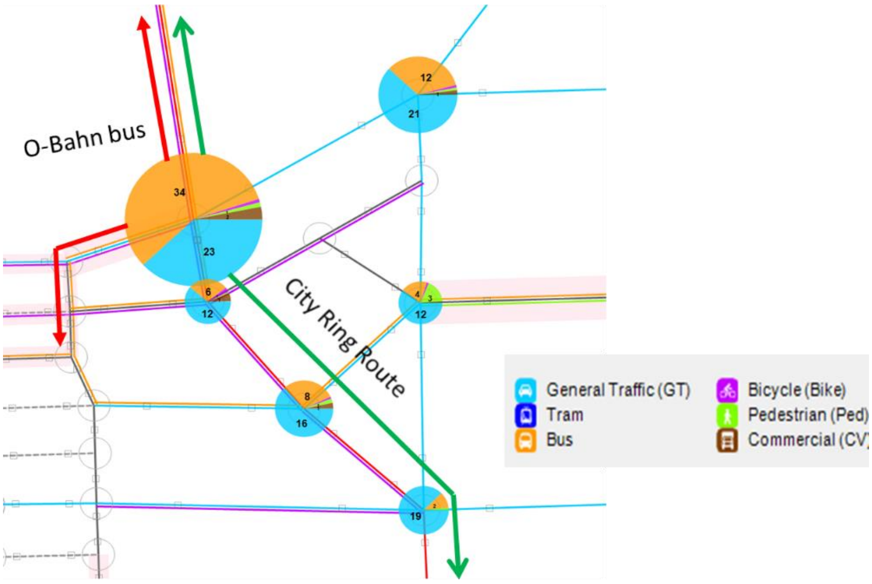


Figure 6 The OG map of eastern part of the Adelaide CBD network (AM)

As shown in Figure 6, there is a very large operations gap experienced by the Hackney Road / Botanic Road intersection. A close look of the OG map suggests

- The operations gap of cars is very large. It is understandable for this intersection to be congested in the morning peak hour due to the large traffic volumes serviced by this key inner ring route intersection (see Figure 3 (b));
- The operations gap of buses is even larger than the operations gap for cars - a very unusual case in the car dominant city of Adelaide. This does not necessarily mean the delay experienced by the individual bus passengers is much higher than the car passengers at this intersection. However, it dose highlight the magnitude of the hidden bus operation issues when more than 100 fully loaded buses (most of them are large articulated buses) are delayed during the morning peak hour.

Bus travel time reliability is a key factor in maintaining the attractiveness of this transport mode, and growing this mode is essential to achieve transport network sustainability in the long run. The vehicle based network capacity / performance maps (i.e. Figure 3 (a) and (b)) are very useful in terms of visualising the network flow patterns and identify congestion hot spots. It is the OG map that provides us an insight into the nature of the congestion issues and leads us to the targeted strategies to address them. In this case, bus priority along the city ring route and at the Hackney Road / Botanic Road intersection becomes an operational strategy in this area.

Currently, the O-Bahn city access improvement project is underway in Adelaide. The project includes two key elements:

1) creating dedicated bus lanes on the inner city ring route between the O-Bahn track entrance and the Hackney Road / Botanic Road intersection;
2) constructing a bus tunnel underneath the city parklands to link the bus lanes and the bus corridor inside the Adelaide CBD. The tunnel will bypass three sets of traffic signals (including the Hackney Road / Botanic Road intersection) on original O-Bahn bus route.

It should be noted that the operations gap analysis focuses on operational issues of the multi-modal transport network. The OG map may help us develop the targeted network operations strategies but may not necessarily point to a specific network improvement solution.

6. Conclusion and future work

This paper reports the analytical work undertaken by the South Australian Department of Transport in turning the vehicle based arterial network performance map into a map of multi-modal network operation gaps.

The strategic road use hierarchy definition of the multi-modal transport network of the Adelaide inner area was used to determine the performance target for each mode at the intersection level. Time of day traffic operation changes were taken into account when setting these targets. The rich traffic data and analytical results generated from the previous study of mapping the capacity / performance of the Adelaide inner area arterial network were used to estimate the existing performance for each mode at each intersection. The gap between the existing performance and the performance target at the individual user level was aggregated and generalised to produce the operations gap (OG) for each mode, based on which an OG map for the Adelaide inner area arterial network was produced.

The OG map is a natural extension of the vehicle based network capacity / performance map. The map not only highlights where the network performance issues are but also provides an insight into the nature of these issues from a multi-modal perspective according to the road use hierarchy definition of the transport network.. This map serves as a birdge between the strategic planning and the daily network operations.

The real target of the multi-model operations gap analysis is the entire transport network including local road network as well. From the road use perspective, a major local collector / distributor can perform arterial road functions in terms of effectively moving people through the network. Meanwhile, a major arterial road may change functions according to the time of day to become an active place and support local business activity (i.e shopping strip corridors). This target leads us to the next stage of operations gap analysis and Moving Traffic Plan development for the Adelaide metropolitan area. Using the OG map as a platform, we can actively engage important stakeholders and make joint and transparent decisions on how the road network should operate.

Acknowledgement

The authors would like to thank Mr Andrew Every, Mr David Mill and Ms Gemma Kernich for providing bus operation data and cycling data for this study. We also want to thank Ms Pong Suan Yeo for helping with data analysis and Dr Ian Espada for technical support of SmartRoads tool application.

Reference

Austroads (2010) Guide to Project Evaluation Part 4: Project Evaluation Data.

Austroads (2013) The Application of Network Operations Planning Framework to Assist with Congestion Management and Integrated Land Use and Transport, *Austroads Research Report*, Sydney.

Austroads (2014) Guide to Traffic Management Part 4: network management, Sydney.

Austroads (2016) Network Operation Planning Decision Tool: Requirements and Development, *Austroads Report NS2003*, Feb 2016, Sydney.

Cox, J (2013) Development of a permanent system to record and analyse Bluetooth travel time and SCATS lane count data, *AITPM National Conference 2013*, Perth.

DPTI (2013) A functional hierarchy for South Australia's land transport network, June, 2013, Adelaide.

DPTI (2015) Integrated transport and land use plan, July 2015, Adelaide.

JCT (2014) Linsig 3.2 User Guide, UK: JCT Consultancy Ltd, June 2014.

SCATS (2014) SCATS Access Version 6, Roads and Maritime Services, NSW, 2014.

SIDRA SOLUTIONS (2015) SIDRA intersection 6.1 user Guide, Akcelik & Associates Pty Ltd, September 2015.

VicRoads (2015) SmartRoads Guidelines, Feb 2015, Melbourne.

Zhang, K and Excell, A (2013) Modelling A Complex Give-way Situation – AIMSUN vs LINSIG, *Road & Transport Research*, ARRB Group, vol. 22 No. 2, pp. 16-26.

Zhang K and Excell A (2015) Mapping the capacity and performance of the arterial road network in Adelaide, *Australasian Transport Research Forum 2015,* Sydney.