Investigation Of The Performance Of Traffic Flow Gating Using Signalised And Un-Signalised Design And Research Aid (SIDRA)

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Abstract: Traffic flow gating is widely used in traffic signal management during queue spill back situations, under predicted traffic flows and downstream lane closure situations in case of an incident. Single point and multiple points gating are used for efficient traffic signal operations based on traffic flow patterns and network characteristics. The traditional way of using gating is to restrict green time at upstream location or locations where queue spill back would not affect the cross traffic flows at upstream. The purpose of this research is to evaluate the effectiveness of upstream gating at a single point on a complex road network using a micro analytical tool SIDRA. The results indicate that the performance of the overall network did not improve significantly but it improves safety by eliminating queue obstruction for cross traffic.

Keywords: Transport, Gating, SIDRA, Traffic Signal, Queue Spill back

1. INTRODUCTION

Gating is a technique by restricting traffic flow physically at upstream where upstream approach has enough storage to contain a large amount of vehicles while in the queue. In this study, gating was used to manage traffic congestions and improve network performance, and SIDRA was used for the purpose of evaluation. Gating was applied by modifying signal timing data in one direction where the approach has enough capacity and queue overflow would not spill back to intervene cross traffic flow in further upstream intersections. Eastwood, in Adelaide metropolitan area is selected for detailed studies as the traffic signals are located in close proximity and signals are coordinated. The network is strategically important as they form a triangle and has higher traffic volumes in both directions.

2. LITERATURE REVIEW

As constructing new roads are costly and sometimes may not reduce congestion at all, priorities are given to apply advanced traffic signal management which is considered as a cost-effective solution. The function of a traffic signal is to reduce the number of conflicts, stops and delays in efficient ways so that the performance of the overall network would be improved. If traffic signals are located in close proximity, coordination between movements and gating technique should be applied to avoid queue spill back situation. It is stated that better traffic signal coordination would increase capacity at the network level, reduce delays and stops, and prevent downstream queue spill back effect on upstream signals (Akcelik, 1980).

Traffic signal coordination is to regulate the relations between the start and end of greens of two or more coordinated phases between upstream and downstream intersections with specific time offsets. Figure 1 is a conceptual diagram showing the offset between two signalised intersections.

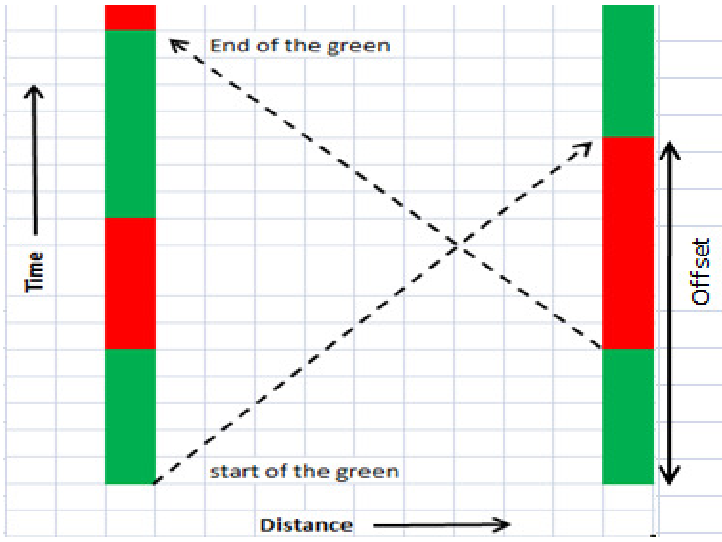

Figure1: Starting and finishing offset

Saturation flow is considered to be one of the most important factors in traffic signal design even though the value is more or less fixed subject to the method of calculations. However, the effect of saturation flow become less effective when overflowing queue spills back from upstream to downstream intersections. Therefore, managing queue is becoming more and more significant to maintain a smooth traffic flow at the network level.

Transport and Road Research Laboratory (TRRL) uses the procedures described in TRRL Road Note 34 (1963) in which three saturated green intervals were considered and in the middle interval vehicular counts were considered against the time interval. Akcelik (1995) considered three intervals: in the first interval uses10 seconds of green, the middle interval uses rest of the green interval and the rest of the interval is the end of the green period. The saturation flow in terms of the vehicle per second is given by the following equation.

$$S^* = \frac{V2}{V4 - 10N4} \quad (1)$$

Where S^* is saturation flow

V2 is the total vehicle in the middle interval

V4 is the total saturation times and

N4 is the number of samples.

Greenshields *et al.* (1946) used headway method after a certain time period of green time which actually considers the headway gaps of a successive vehicle passing through the stop line at a signalised intersection.

It is well known that managing traffic signal under oversaturated condition is very different from under saturation condition, and within limited road capacity it is hard to manage coordination or queue spill back situation while demand exceeds its capacity. The issue is very common in oversaturated transport network even though a lot of efforts have already been put together to solve queue spill back issues and many methods are already available however, in reality, none of these methods has been widely accepted or implemented by practitioners.

Pignataro *et al.* (1978) and Rathi (1988) proposed a negative offset which can clear the residual queue before the upstream platoon arrives at a downstream intersection and thus reduce the chance of stopping the continuation of flows, but this method does not guarantee to eliminate the queue spill back phenomenon. It just removes one of the variables from many to prevent queue spilling to an adjacent intersection. Lieberman *et al.* (2000) and Chang *et al.* (2010) developed an upstream traffic gating method, which aims to reduce the chances of downstream blocking by intervening traffic demand.

Wu *et al.* (2010) evaluated Temporal and Spatial Severity Index (TOSI) and SOSI respectively, where TOSI defines the requirement of extra green at the next cycle to clear the residual queue and SOSI defines spatial effect from downstream blockage which reduces the usable green time at upstream. TOSI and SOSI can be defined mathematically through following equations:

$$\text{TOSI} = \frac{\text{Time for discharging residual queue}}{\text{Total green time allocated}} \quad (2)$$

$$\text{SOSI} = \frac{\text{The usable green time}}{\text{Total green time allocated}} \quad (3)$$

The above approach was examined for a single intersection based on oversaturation severity indices, a maximum flow based method using Forward– Backward Procedure (FBP) was proposed by Hu *et al.* (2013) where the forward strategy tries to maximize green time along an oversaturated route and the backward strategy aims to gate traffic at upstream where available green time is limited. The result indicates that traffic signal performance could be increased at the overall network level. Gating is a process of restricting traffic flow at upstream to protect queuing effect on a particular area where queue spillback can be restricted cross traffic movement. Sydney Coordinated Actuated Traffic Systems (SCATS) and Split, cycle, and offset optimization technique (SCOOTS) are widely used urban control technology at signalised intersections, have options for gating strategy. Gating in SCOOTS can be used to restrict queue overflow at congested intersections and relocate queue at upstream (Oakes *et al.* 1999). Queue balancing technique considers equalize queue at each approach.

Oversaturation happens when the average flow exceeds approach capacity and results in longer queue length. The objective of gating is to prevent queue spill back at downstream locations by restricting inflow at upstream where queue would not block the exit for cross traffic. According to Keyvan *et al.* 2015, gating at upstream improves traffic network performance; however queue management and signal coordination inside the network is still an unsolved issue. Oversaturation queue length can be expressed in any cycle by Akcelik (1980):

$$Ni = Ni\text{-}1 + QC + SG \tag{4}$$

Where Q represents arrival flow;

C represents cycle time and;

SG represents departure per cycle.

Figure 2 shows a typical gating at upstream where traffic flow is restricted and the queue is relocated (all queues are showing vertically).

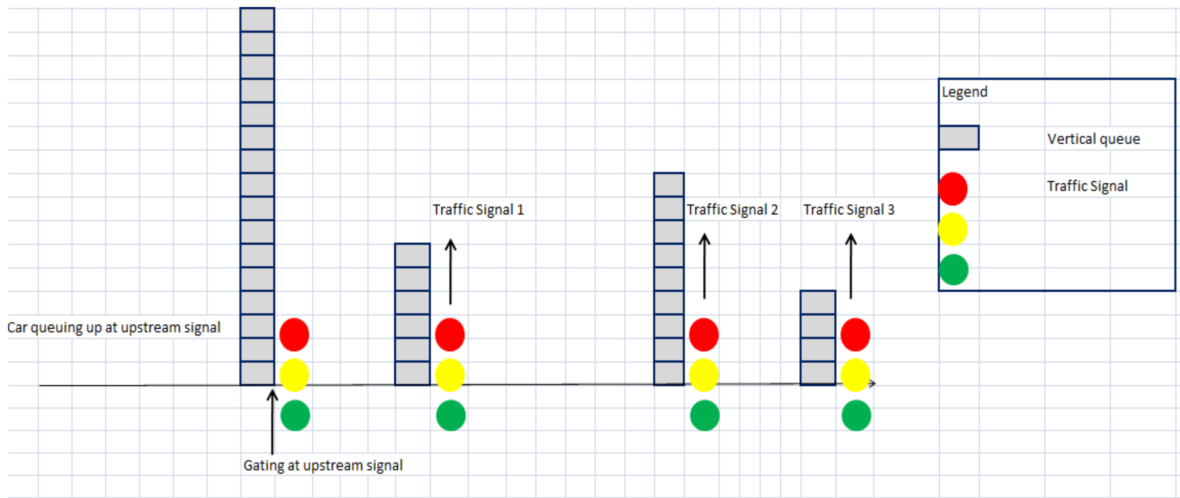

Figure 2: Conceptual diagram of gating point at upstream

3. CASE STUDY

Eastwood area, in Adelaide Australia, is selected for investigations. The network was surrounded by Greenhill Rd, Glen Osmond Rd and Fullarton Rd crossing one another and made one triangle which makes the traffic signal synchronization very complex. Considering the significant and road hierarchy, Greenhill Rd is a major arterial Rd; it serves as a ring route which connects Glen Osmond Rd which carries traffic to and from Eastern Freeway and meet another major arterial Fullarton Rd. Figure 3 presents the location details, and SCATS links these intersections.

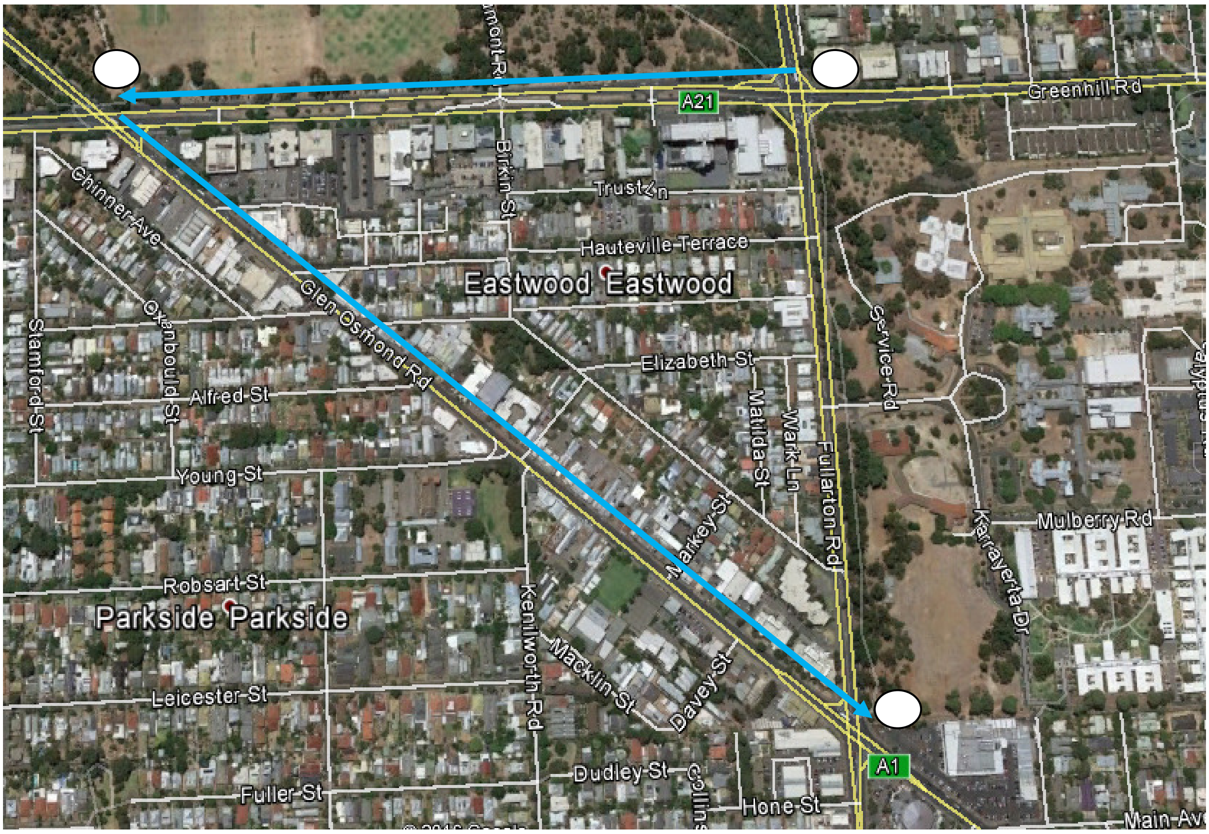

Fig 3: Study area intersections and relative locations (Google Map, 20016)

4. MODELLING AND METHODOLOGY

4.1 Data Collection

Traffic volume and phasing data were collected from Department of Planning, Transport and Infrastructure (DPTI), South Australia. Queue data was collected from site observations. Saturation flow was not modified and considered as SIDRA default value of 1950 total car unit per hour in all cases. Pedestrian volume was not considered but push button data was collected and if the pedestrian push button was pressed two thirds of the modelling period, in modelling it was considered that there were always pedestrian at this site.

4.2 Methodology and SIDRA Network Coding

Trial and error method was used to evaluate the best performance of individual signal and network. To investigate best performance of the individual traffic signal, various phasing combinations were tested based on trial and error basis. Also ranges of green and red proportion were also tested on trial and error basis to evaluate the best outcome of the model with gating option.

Each and individual signalised intersection was coded in SIDRA based on current phasing, geometry and traffic demand. Then, each of the intersection was tested with various sets of phasing to find the best traffic performance and then the phasing was chosen for the individual intersection for network model. Then, all the intersections were connected to form a network and network cycle length was provided to evaluate the performance of the whole network. Statistical analysis was not performed because this is out of scope of the research project.

In Gating option, a simple two-phase intersection was considered in the upstream of Glen Osmond Rd in the network model. The north-west bound phase has limited green time but the exit flow has continuous green time so that the outbound flow would not be affected by gating effect. The proportion of green time for northwest bound traffic was changed on trial and error basis in gating option to find the best network output in SIDRA and compared with the network model without gating option.

In SIDRA models, current site layout was coded where lane length, parking, short lane effect and slip lane facilities were considered. Traffic volume, pedestrian push button data, current phasing and phase overlap data were also included in the modelling process. Right turn ban and filter options were considered in the modelling. To model demand flow variations, peak flow factor was considered based on individual site’s demand characteristics. The peak flow period was considered as 15 minutes based on demand flow though the flow fluctuation happens over the whole modelling period.

From intersection analysis, it is found that Leading Trailing Turn (LTT) on Greenhill Road and Single Diamond Overlap (SDO) on Glen Osmond Road in Figure 4 produces the best performance index.

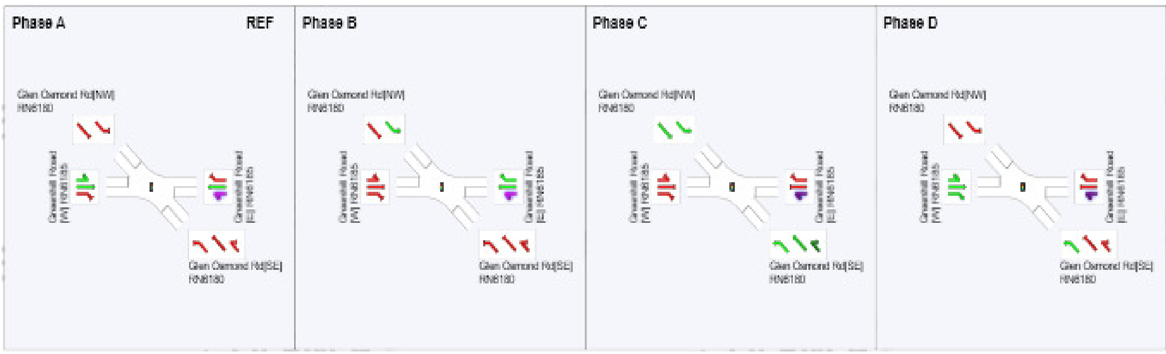

Figure 4: Greenhill Road and Glen Osmond Road phasing - SIDRA.

Double Diamond Overlap (DDO) option produces the best outputs for Greenhill and Fullarton Road which is shown in Figure 5. Glen Osmond and Fullarton Road intersection has SDO on Glen Osmond Rd and conventional phasing on Fullarton Road as shown in Figure 6. A simple gated phasing was evaluated at upstream of Glen Osmond Road where the North Westbound movement was interrupted while the South West has uninterrupted traffic flow.

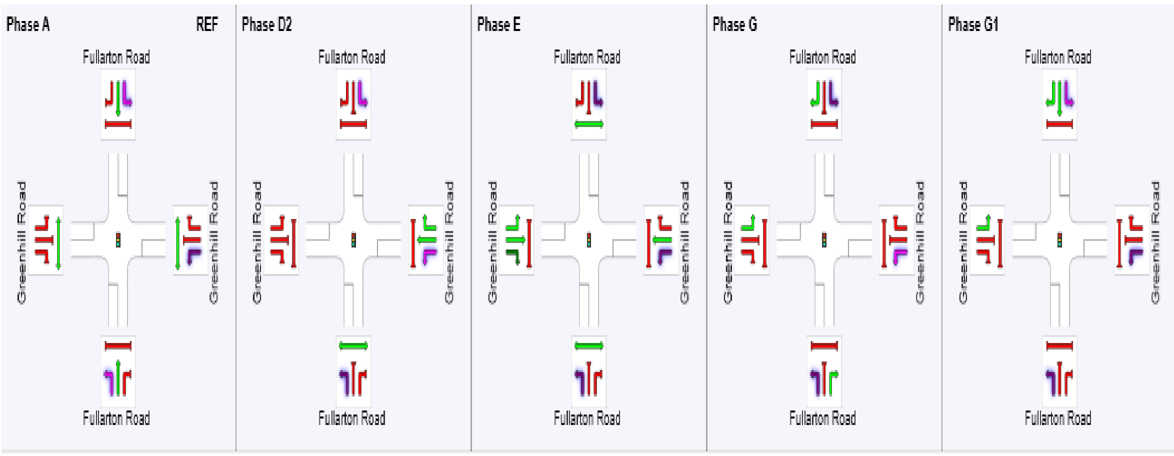

Figure 5: Greenhill Road and Fullarton Road phasing - SIDRA

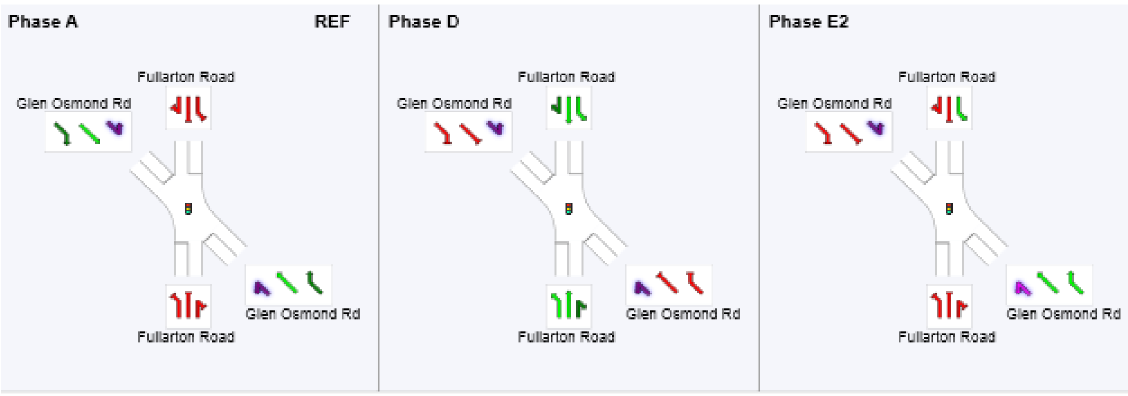

Figure 6: Glen Osmond Road and Fullarton Road phasing –SIDRA

4.3 Model Calibration and Validation

Each of the intersection was calibrated based on the degree of saturation (volume/capacity), phasing, lane utilisation, queue overflow and queue length. A thorough check of under saturated and over-saturated delay was conducted based on the current operation and SIDRA modelling output. Saturation flow was modified in the model of few right turning and left turning lanes where saturation flow was significantly affected. The intersections considered in the models are currently operated by SCATS, and due to dynamic green times and offset facility in SCATS, the network was calibrated against isolated intersection. Each calibrated intersection was connected with other to form a network and use SIDRA to optimise it at a fixed cycle length of 150 seconds. As stated earlier, a trial and error method was used at upstream to gate the amount of traffic flow and allow SIDRA to run its optimisation under similar condition. The results indicate that traffic performance increases over the entire network in terms of speed, queue length and level of service. Figure 7 shows the network overview in terms of approach and exit lanes and phasing at each intersection.

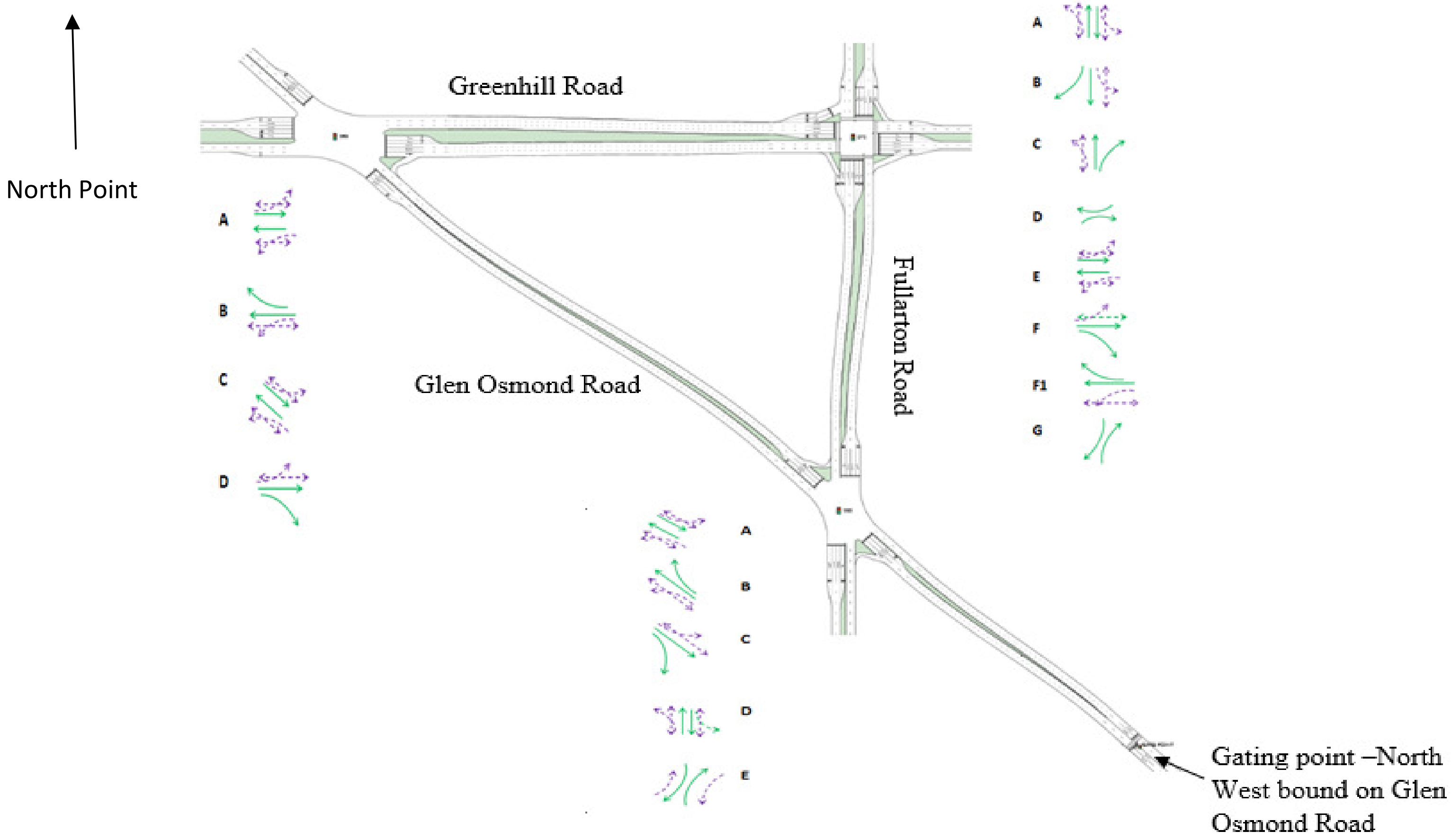

Figure 7: Network diagram and phasing

4.3 Comparison of Modelling Outputs

The output indicates that the overall network performance has been improved, mainly in major traffic flow directions. Before gating, the overall speed of the network was 22 km/hour which has increased to 22.1 km/hour after gating though SIDRA could not perform various phase timing evaluation for gating. The result clearly indicates that on the major route where traffic flow was higher resulted in improved Level of Service (LOS) after gating. However the speed efficiency has not changed in network level. A few minor traffic flow direction routes resulted worse in gating option but have insignificant effect on the whole network performance. Glen Osmond Road North West bound LOS has improved from F to D and Greenhill Road East-bound LOS has improved from F to E. Fullarton Road south LOS has changed from E to D which is presented in Figure 8 and Figure 9. The travel time index has also increased from 2.96 to 2.99 for the whole network after gating. Details of SIDRA output and are shown in the following Table 2. Table 3 shows that the overall network operating costs has also decreased with gating Option.

Table 2: Improvement of LOS between with and without Gating Option

Route	Without Gating	With Gating
Glen Osmond Road North-West Bound	F	D
Greenhill Road West Bound	F	E
Fullarton Road South Bound	E	D

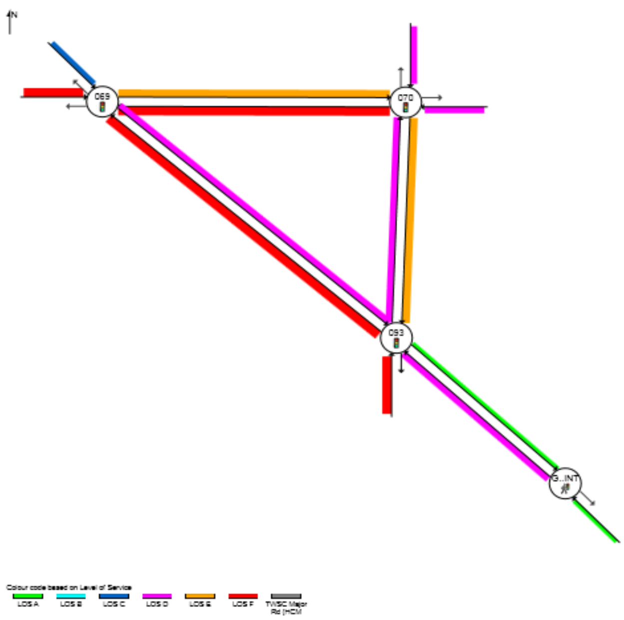

Figure 8: Optimisation without gating LOS

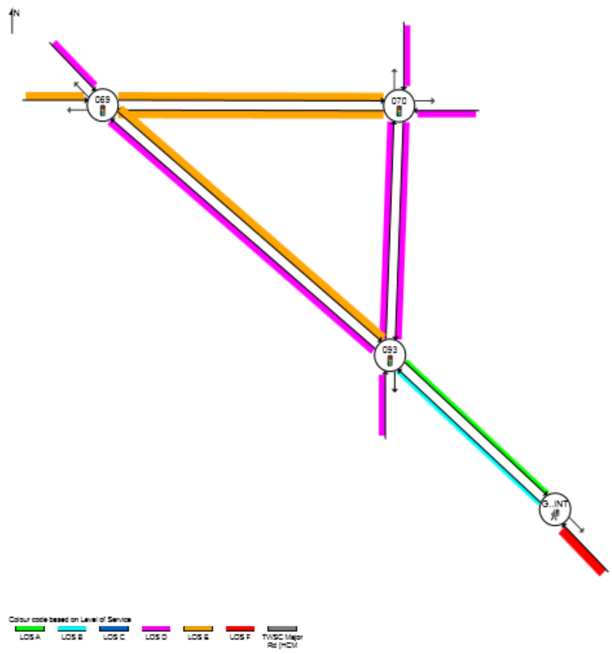

Figure 9: Optimisation with gating LOS

Table3: SIDRA Network Output

Performance Index	Without Gating option	With Gating Option
Travel Time Index	2.96	2.99
Speed Efficiency	0.37	0.37
Congestion Coefficient	2.73	2.71
Vehicles Costs $/y	7,918,850	7,898,313
Persons Costs $/y	7,952,750	7,915,430

5. CONCLUDING REMARKS

This study has demonstrated that the gating option resulted a clear improvement for the linked intersections, the LOS for gated route and other major routes have improved noteworthy compared with non-gated operation model though the average network speed and speed efficiency has not increased significantly. The results also indicate that the gating route without a gating option model has a queue spill back effect from downstream signal to upstream signal and the spill back effect was completely absent in gating option model. This gating measure has improved safety of the signal operation because it removes the physical obstruction and confusion of cross traffic where vehicle queue from downstream signal and spill back on the upstream traffic signal. A further investigation is required as SIDRA cannot optimise all the value provided for trial and error method used for gating. Also, the type of phasing was considered as fixed and considered as the best option for both isolated and network level. In future research gating can be used for multiple approaches which may increase further network efficiency.

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