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An Integrated Approach to Traffic Modelling – Linking SIDRA, LINSIG & AIMSUN

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Abstract

This paper reports on extensive traffic modelling for the planning of a regional centre rejuvenation in Adelaide. The modelled arterial road corridor consists of three closely spaced signalised intersections. The corridor is complicated further by a signalised pedestrian crossing centrally located between the major two intersections of the corridor. Signal coordination among these four sets of signals is crucial to keep traffic moving and manage traffic queuing, especially under heavy traffic conditions during peak hours.

The modelling approach developed in this project tries to incorporate the strength of three different modelling techniques, namely analytical modelling – SIDRA, empirical modelling – LINSIG, and micro-simulation – AIMSUN. SIDRA modelling was conducted first to perform a quick intersection analysis and to help with lane saturation flow rate estimation. LINSIG modelling focused on corridor signal operation analysis and optimised signal control based on minimising overall travel delay and balancing traffic queues along the corridor. Finally, AIMSUN was employed to assess the dynamic queuing and delay of the modelled corridor taking advantage of its micro-simulation nature and visualisation capability.

This modelling work exemplifies that the seamless integration of the three types of modelling can be achieved in a very efficient way in which the outputs from one model provide key inputs to the other. It demonstrates the integrated modelling approach can help to fill the functionality gaps of each individual modelling technique. It does not triple the modelling effort, but the confidence level of the entire traffic analysis and modelling can be improved significantly.

1. Introduction

This paper reports on extensive traffic modelling for planning the rejuvenation of Port Adelaide centre in Adelaide. The Port Adelaide centre is 12 km north-west of Adelaide CBD. It is the gateway to Lefevre Peninsula which hosts the Adelaide's major port (Outer Harbour) and defence industry shipbuilding and manufacturing zone. As shown in Figure 1, St Vincent Street sits in the heart of Port Adelaide centre. The Port Adelaide city council office, civic centre and Port Mall are located on both sides of the road.

Figure 1 Port Adelaide Centre area

On traffic side, Nelson St – St Vincent St – Commercial Road corridor is a major commuter route between Port Adelaide and Adelaide CBD. The average daily traffic on this corridor reaches 18000 vehicles with two distinct peak periods, AM and PM peaks. Any potential upgrades of this corridor would have a significant impact on traffic performance of the corridor and its adjacent arterial road network, especially during peak periods. A clear understanding of the existing corridor traffic performance and an ability to quantify traffic impact of any future corridor upgrades (e.g. revitalising the area by 'place' making and not encouraging the through traffic) is essential for the Port Adelaide centre planning study.

Traffic modelling helps transport planners and traffic engineers to examine traffic performance of the existing network (base case) and assess the outcomes of proposed network changes (scenarios). It forms an integral part of the planning for Port Adelaide centre rejuvenation. The key section of the Nelson-St Vincent-Commercial Road corridor, which is of our great interest, covers three closely spaced signalised intersections (200 m apart). Figure 1 shows the two intersections along St Vincent Street, and the third one is on Commercial Road south. This section of the corridor is further complicated by a signalised pedestrian crossing on St Vincent Street between Nelson Street and Commercial Road. Signal coordination among these four sets of signals is essential to keep traffic moving and manage traffic queues and during peak hours. Operationally, traffic signal control and coordination is performed by SCATS system (SCATS 2000). Maintaining signal coordination would be crucial for any future upgrades of the corridor.

The above features of the Nelson-St Vincent-Commercial Road corridor suggests

- a corridor traffic model, which consists of the three signalised intersections and the pedestrian crossing, would enable a better assessment of traffic performance at both corridor level and individual intersection level, and
- a strong traffic signal modelling/optimisation capability would be the essential feature of any candidate modelling package.

These modelling requirements make LINSIG (JCT 2009) a good and natural selection for the modelling task.

The paper is organised in the following three major sections: key challenges to the proposed LINSIG modelling and an integrated modelling approach to deal with them are discussed in section two. In section three, detailed modelling works using SIDRA (SIDRA SOLUTIONS 2007), LINSIG and AIMSUN (Barcelo J and Casas J 2002) are presented. Finally, the experience gained from this extensive traffic modelling is summarised in section four.

2. An integrated modelling approach

2.1. Challenges to LINSIG modelling

In general, modelling techniques can be broadly categorised as Analytical Modelling and Simulation (Austroads 2009). Each category has two levels: macroscopic and microscopic. LINSIG is a traffic modelling package for the assessment and design of traffic signal intersections, either individually or as a network that comprises of a number of intersections. It is a type of macro-simulation package in which vehicles are represented as a traffic stream or platoon rather than individual identities. The concept of cyclic flow profile (CFP) is used by LINSIG to effectively model traffic moving through the network. Hence, the LINSIG model outputs are deterministic and relatively stable.

2.1.1. Challenge 1 – Lane Saturation flow rate

Lane saturation flow rate, which is specified in passenger car units (pcu), is one of the key inputs to LINSIG models. It affects the intersection performance significantly. In LINSIG, lane saturation flows can be specified manually or be calculated from a lane's geometry using an extended version of formulae published in the TRRL report RR67 (Kimber et al. 1986).

As the RR67 formulae does not allow for all significant factors to be considered when estimating lane saturation flow rate, it is recommended in the LINSIG manual that wherever possible at least a brief saturation flow survey is done for an existing intersection. In addition, a possibly small difference between estimated and true saturation flow rates can lead to potentially much more significant differences between modelled and surveyed queues, as queue predictions are very sensitive to inaccurate saturation flow rates in LINSIG models.

In the proposed LINSIG corridor model, the foreseeable saturation flow estimation error would happen to the following lanes should the TRRL method is used

- the short turning lanes at the key intersections – especially where lane overflow is occurring regularly during peak periods,
- approach lanes at the intersection, where traffic merges immediately downstream.

To overcome the difficulty of intensive saturation flow survey on site and improve the lane saturation flow estimation in LINSIG, SIDRA analysis of individual intersections can provide valuable insights into traffic lane performance. SIDRA is an advanced micro-analytical traffic evaluation tool. It employs lane-by-lane and vehicle drive-cycle models coupled with an iterative approximation method to provide estimates of capacity and performance statistics of an intersection. SIDRA models can be calibrated for local conditions to capture vehicles lane selection and inter-blocking behaviour, which is critical to lane saturation flow rate estimation.

2.1.2. Challenge 2 – Dynamic Queue and Delay

The LINSIG modelling is based on the concept of cyclic flow profile. This method takes advantage of the fact that when all intersections in a network run at the same cycle time, the pattern of traffic and queues on under-capacity lanes will be very similar during each cycle throughout the modelled period. That is the flow and queue profiles on each lane will repeat cyclically. In its simplest case, each cycle is assumed to be identical which can then be extrapolated throughout the modelled period.

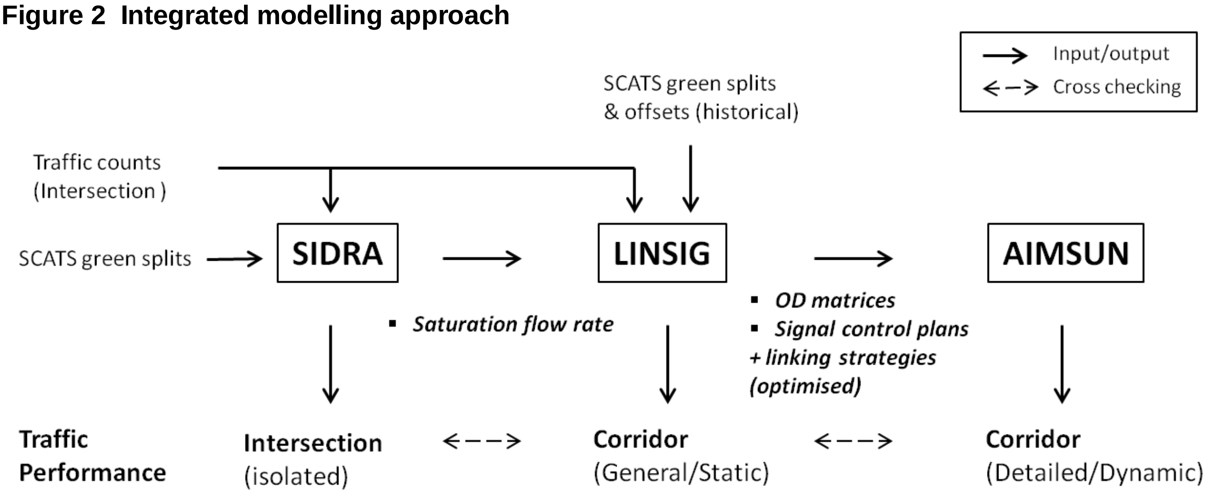
Given the facts that a) the key intersection of the modelled corridor (i.e. St Vincent Street/Commercial Road intersection) is currently working at capacity, and b) the random nature of traffic arrival and pedestrian movements, the optimised signal linking used in SCATS system between the intersections was regularly broken during peak hour operation. The resultant traffic queue on St Vincent Street was not stable, which occasionally went pass the central pedestrian crossing and reached upstream intersection. To capture traffic dynamics and identify the possible worse scenario in terms of traffic queue and delay, a valid micro-simulation model of the corridor is required in addition to LINSIG model.

Micro-simulation modelling has been widely used in areas of traffic and incident management (Hansen et al. 2000, Dia and Cottman 2005, Stazic et al. 2005, Zhang and Taylor 2006 a&b, Zhang and Excell 2011, Zhang and Excell 2013), traveller information systems (Zhang et al. 2008, Zhang et al. 2009), and other advanced ITS applications. The micro-simulation package AIMSUN (Barcelo J and Casas J 2002) can provide highly detailed and accurate traffic network representation, it distinguishes between different types of vehicles and drivers, and most importantly, it can model traffic signal operation in very fine details. In an AIMSUN model, the vehicle behaviour is governed by three basic modules, namely car-following, lane-changing and gap acceptance modules. The car-following and lane-changing module implemented in AIMSUN is based on the Gipps model (Gipps 1981 and 1986).

2.2. Integrated modelling approach

The proposed approach to this modelling work (see Figure 2) tries to incorporate the strength of three different modelling techniques, namely analytical modelling – SIDRA, empirical modelling – LINSIG, and micro-simulation – AIMSUN. The development and application of this approach has been driven by the complex nature of the modelled arterial corridor and the challenges facing the LINSIG modelling.

Figure 2 Integrated modelling approach



In the integrated approach, SIDRA is used first to perform a quick intersection analysis. The detailed outputs from SIDRA model are then used to help with lane saturation flow rate estimation, especially for short turning lanes and traffic lanes with immediate downstream traffic merging. LINSIG modelling would focus on traffic signal operation assessment of the Nelson-St Vincent-Commercial Road corridor and the optimised signal control plan generation. It aims to minimise overall travel delay and balance traffic queue along the corridor. Meanwhile, it would provide a general corridor performance measures. Finally, AIMSUN is employed to assess dynamic queuing and delay of the corridor taking advantage of its micro-simulation nature and visualisation capability. It tries to identify the worse case scenarios for both existing and future traffic operations, and other potential issues.

The initial concern of the proposed approach is the potential of tripling the modelling efforts associated with its application. As discussed before, SIDRA models provide detailed information which helps lane saturation flow estimation, and lane saturation flow rates are a critical input to LINSIG modelling. At individual intersection level, SIDRA models can serve as a useful reference point for LINSIG model when assessing traffic performance, which is based on the assumption that the similar signal control plans are used at the same intersections in both models.

To provide a reliable and representative traffic performance of the modelled corridor, AIMSUN modelling requires

- accurate and optimised signal control plans for each individual signalised intersection of the corridor, and
- the corridor traffic demands in the form of origin-destination (OD) matrices.

These essential inputs to an AIMSUN model can be generated by its corresponding LINSIG model as part of the LINSIG model outputs. This capability of LINSIG indicates that the most important/difficult tasks of AIMSUN modelling (i.e. input data preparation) can be effectively undertaken in LINSIG modelling.

The above natural links among the three types of models suggests that the overall modelling effort would not be tripled when the proposed approach is implemented. Since the critical inputs to both LINSIG and AIMSUN models can be produced with the help of another reliable modelling work (i.e. SIDRA and LINSIG respectively), the overall accuracy of the modelling would be improved significantly.

3. Traffic modelling

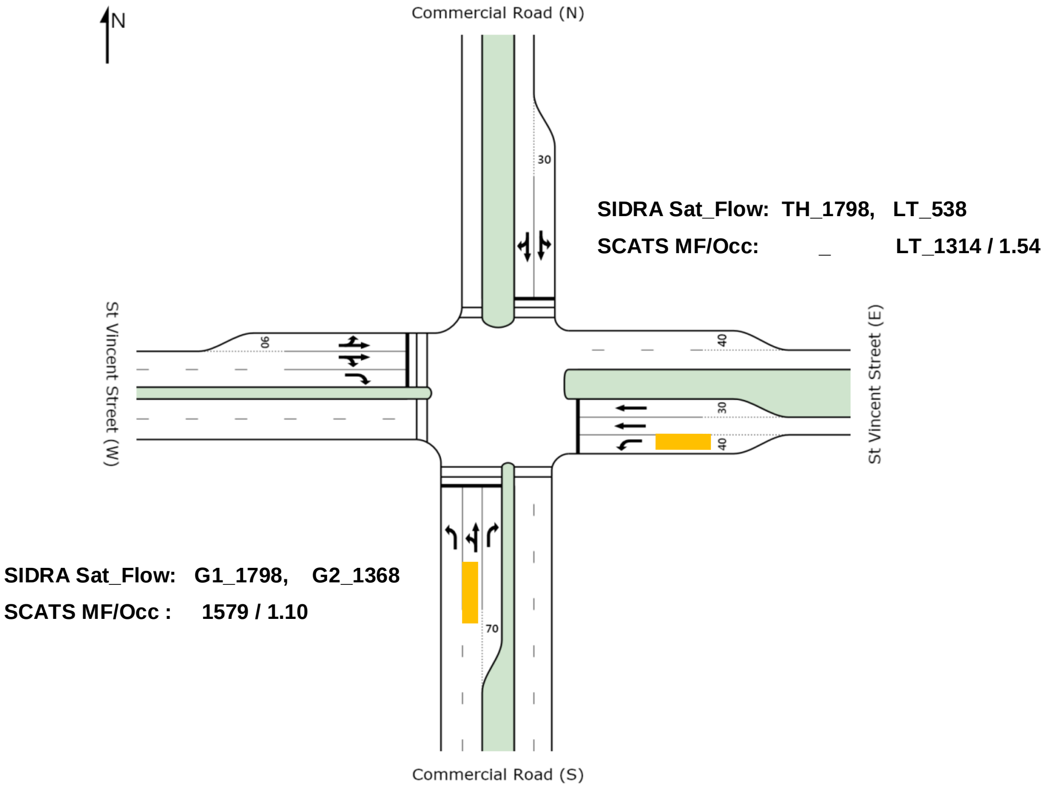
In the following sections, the Nelson-St Vincent-Commercial Road corridor base case models are used as an example to illustrate how the proposed integrated modelling approach was implemented in this project step by step.

3.1. SIDRA modelling – lane saturation flow rate estimation

In this section, the discussion is focused on lane saturation flow rate estimation using the detailed outputs from an intersection SIDRA model (i.e. St Vincent Street / Commercial Road intersection). The available SCATS MF values are used here to test the accuracy of the estimates. “SCATS” stands for the Sydney Coordinated Adaptive Traffic System. SCATS MF is a moving average of the weekday daily lane Maximum Flow rate (veh/hr) captured by the stop line loop detector. The assumption is made by SCATS that the maximum flow occurs when vehicles of an average length are travelling at optimum speed. This makes the SCATS MF pcu/hr (passenger car units per hour, in LINSIG) or tcu/hr (through car units per hour, in SIDRA) equivalent in most of the cases.

Figure 3 shows the layout of the St Vincent Street / Commercial Road intersection, which is the key intersection of the modelled corridor. As highlighted in Yellow, the short left turn lane on St Vincent Street east and the shared through and left turn lane on Commercial Road south are used here as two examples of lane saturation flow rate estimation.

Figure 3 SIDRA model of the St Vincent Street/ Commercial Road intersection



3.1.1. Example 1 – short left turn lane on St Vincent Street east

As discussed in Section 2.1.1, lane saturation flow estimation errors tend to happen when the TRRL method is applied to a short turning lane. As shown in Figure 3, the left turn lane on St Vincent Street east is such a type of lane which overflowed regularly during peak hour operation.

The calibrated SIDRA model results showed:

- the estimate of saturation flow rate of the short left turn lane was 538 veh/h ('LT_538', in Figure 3), and this lane reached the degree of saturation of 1.0 (oversaturated).
- meanwhile, around a half of the total left turn demand was handled by the adjacent continuous through lane instead of the short left turn lane. This proportion of the left turn demand accounted for 43 per cent of the through lane capacity. And the through lane saturation flow rate was 1798 veh/h ('TH_1798', in Figure 3).

If the two parts of left turn demand are combined, the maximum practical left turn lane saturation flow rate for the LINSIG modelling would be 1300 veh /h.

The most recent SCATS MF value for the left turn lane is 1314 veh/h ('LT_1314', in Figure 3). It confirmed the estimated lane saturation flow rate from SIDRA results is reliable. In addition, the detector occupancy associated with the SCATS MF value is 1.54, which suggests the left turn lane was congested when the MF value was recorded. The normal range of the detector occupancy value associated with SCATS MF is between 0.8 and 1.2.

3.1.2. Example 2 – Shared through & left turn lane on Commercial Road south

The second example of saturation flow estimation using SIDRA is of a continuous traffic lane, the shared through and left lane on Commercial Road south (see Figure 3). Because of the high demand of right turn movements, the adjacent short right turn lane on Commercial Road south overflowed regularly during both AM and PM peak periods, which significantly affected the saturation flow of the shared though and left lane. Meanwhile, the left turn movements from Commercial Road south ran in two distinct green periods every cycle (i.e. G1, and G2). However, the through movements from Commercial Road south could only run in the G1 period. The stopped through vehicles during the G2 period would regularly block the left turn movements (the major movements) on the shared lane.

Due to the limitation of LINSIG package, the shared through and left turn lane is modelled in LINSIG as a continuous through lane and a very short (3 m) separate left turn lane attached to it to mimic the inter-blocking behaviour. Each lane can only have one saturation flow setting for the modelled period. In this case, the SIDRA results are particularly useful because a) the saturation flow estimates of the shared lane for the two green periods are provided ('G1_1798, G2_1368', in Figure 3), and b) the adjacent right turn lane overflow effect has been taken into account when providing these estimates. We may simply assign the G1 saturation flow rate to the through lane and the G2 figure to the short left turn lane in LINSIG model by acknowledging that the saturation flow rate for left turn movements is slightly underestimated.

Given the two green periods have the similar effective phase lengths (when the left turn delay caused by pedestrian movements during G1 was factored in), the saturation flow rate estimate of the shared lane (for combined through and left movements) would be 1600 veh/h - the average figure of G1 and G2 periods. The measured SCATS MF value of the shared through and left is 1579 veh/h, which suggests the 1600 veh/h is a reasonable estimate.

3.2. LINSIG modelling – general corridor performance assessment

Traffic performance is the result of traffic demand and road capacity balancing. The mismatching between road capacity provision and traffic demand would see increasing travel delay and traffic queue along the road corridor. Traffic modelling tries to capture this balancing process.

The objective of the base case LINSIG model is to produce a representative corridor traffic performance based on the current traffic demand. The traffic demands used in the LINSIG model were estimated from the most recent traffic count (2011) at major intersections on the corridor. The current SCATS green splits and offsets of the individual intersections were implemented in the model to reflect the existing road capacity. By achieving the objective, the LINSIG model would be ready to provide both the traffic demand matrices and their associated corridor signal control plans for AIMSUN modelling. Meanwhile, the LINSIG modelling results would set a relatively stable performance benchmark for the AIMSUN model to be compared with.

3.2.1. Traffic demand representation – OD matrix

Traffic demand used in LINSIG modelling can be both an OD matrix of the entire modelling area or traffic states (traffic turning counts) of the modelled individual intersections. In LINSIG, the use of matrix based methods can obtain a fully disaggregated breakdown of traffic passing through each lane, which is used to refine the modelling of queues, delays and capacities on each lane. In addition to the increased accuracy of modelling, the use of OD matrices also means that techniques such as automatic delay based assignment is possible.

Using such techniques can dramatically speed up the specification and entry of network traffic flows when changes are made to the modelled traffic network.

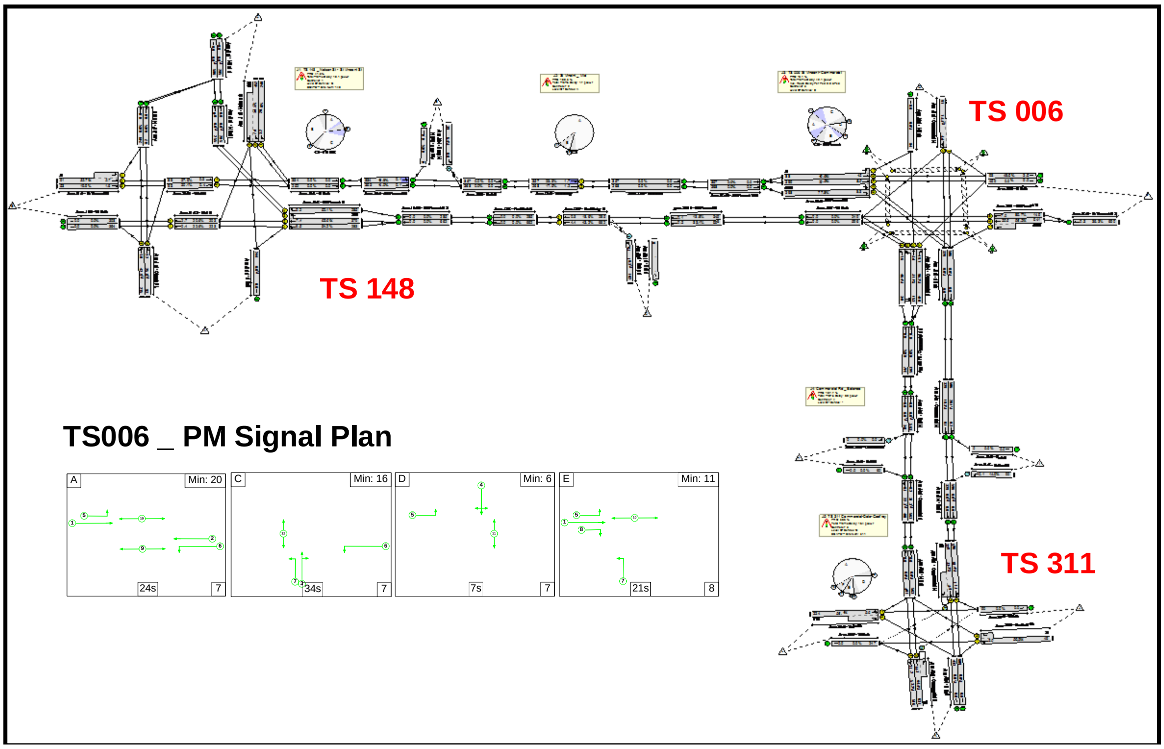
OD matrices can be estimated using relatively less expensive intersection turning counts. LINSIG uses one of the most common methods - entropy maximisation, a tried and tested method. In simple terms, where a set of traffic counts could be reproduced by many different OD matrices, the entropy maximisation technique aims to estimate the most probable OD matrix which will fit the traffic counts. As discussed in Section 1, the major traffic on the Nelson-St Vincent-Commercial Road corridor are vehicles travelling from Nelson Street north to Commercial Road south and vice versa. Both the Nelson Street / St Vincent Street, and Commercial Road / Gale Street intersections (the two ends of the modelled corridor) did not reach their capacity during peak hours. Hence, the OD matrices estimated from the intersection traffic counts in LINSIG would be a reasonably representation of peak hour traffic demand.

While producing OD matrices, LINSIG produces a GEH figure associated with each entry flow at individual intersections to show how well the LINSIG assigned traffic flows fit the traffic counts when the estimated OD matrices are used. The GEH statistics (GEH stands for Geoffrey E. Havers, a GLC transport planner who invented the statistic in the 1970s) measures a combination of relative and absolute error between a traffic count and a modelled flow. It is commonly used to test the goodness of fit of modelled flows to observed counts. Since the modelled traffic network is a linear corridor, very good GEH values (i.e. GEH < 2 for all flows) were obtained at the end of OD estimation.

3.2.2. LINSIG Model

As shown in Figure 4, the LINSIG model focused on the key section of the Nelson-St Vincent-Commercial Road corridor. The modelled traffic network consists of three signalised intersections (i.e. TS148 - Nelson Street/St Vincent Street, TS006 - St Vincent Street/Commercial Road, and TS 311 - Commercial Road/Dale Street intersections) and the pedestrian crossing on St Vincent Street. The individual intersection signal control plans and linking strategies used in the model were extracted from SCATS system. The impact of pedestrian movements at the signals was factored in the signal control plans. As mentioned before, the OD matrices were estimated from the most recent intersection traffic counts to represent traffic demands. Both AM and PM peak traffic operations were modelled.

Figure 4 LINSIG model of the Nelson–St Vincent– Commercial Road corridor (base case)



The LINSIG modelling results suggested the traffic performance of the corridor was dictated by the St Vincent Street/Commercial Road intersection. This key intersection was currently working at capacity and heavy queues were experienced by its three major approaches (i.e. St Vincent Street west, St Vincent Street east and Commercial Road south) during both AM and PM peaks. There was virtually no spare capacity left for the modelled corridor. These results are consistent with the SIDRA results of individual intersections when SCATS historical green splits and offsets (instead of SIDRA optimised signal plans) are used.

In the base case model, the traffic signal coordination along the corridor is designed to keep traffic moving on St Vincent Street and to prevent the queue generated from one intersection blocking the others. Given the short distance between the Nelson Street/St Vincent Street and St Vincent Street/Commercial Road intersections and the randomness of pedestrian movements, the intended linking between intersections was not achieved in practice.

3.3. AIMSUN modelling – dynamic traffic queue and delay

3.3.1. Traffic demand – OD matrix

As discussed in Section 2.1.2, to capture the dynamic aspect of traffic queues and delays, AIMSUN modelling was used in this study in addition to LINSIG modelling. In AIMSUN models, OD matrices are a better representation of traffic demand (TSS 2010). The available of OD matrices helps AIMSUN models to produce more reliable route choice/ lane changing behaviour, which is critical for micro-simulation modelling. Using OD matrices to represent traffic demand also makes future scenario testing / comparison easier to manage should no traffic demand change be assumed. In the Nelson-St Vincent-Commercial Road corridor AIMSUN modelling, the OD matrices used in an AIMSUN model were estimated by its corresponding LINSIG model from the most recent intersection traffic counts.

3.3.2. Road capacity – signal control plans

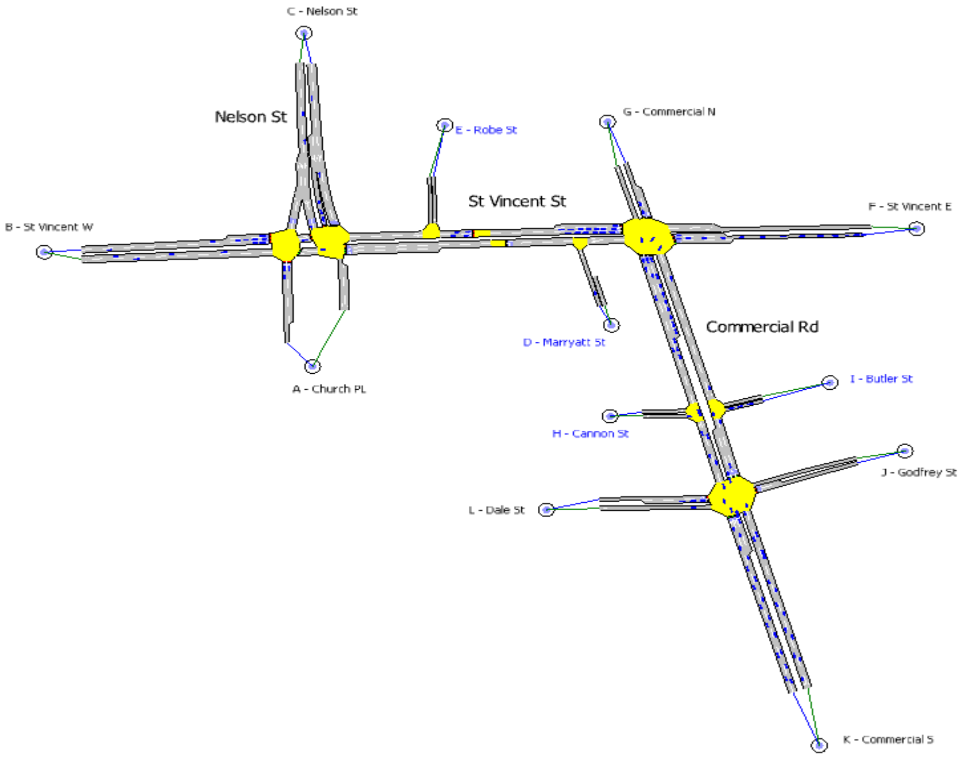
The LINSIG modelling suggested that signal operation at individual intersections and their interaction had a huge influence on road capacity of the modelled corridor. In LINSIG, intersection signal control plan are signal group based (i.e. TS 006, in Figure 4). The AIMSUN model uses a similar way to define intersection signal operation, which mimics how the SCATS system works. This similarity enables all signal settings produced by LINSIG to be directly translated into AIMSUN control plan with virtually no adjustment. In addition, the use of time dial to display signal control plans in LINSIG makes it much easier to work out the offset values between intersections (how they coordinate with each other).

In base case models, the SCATS green splits and offsets were translated into both LINSIG and AIMSUN models. There was no real need for the LINSIG model to produce optimised signal control plans for AIMSUN modelling. On the other hand, the AIMSUN package has no built-in capability to optimise signal control plans in response to either intersection geometry changes or traffic demand variation. It would be difficult and very time consuming to produce optimized signal control plans for the modelled corridor through trial-and-error. For scenario testing where the proposed road geometry changes would affect the way signal contolled intersection may operate, signal optimisation by LINSIG becomes essential.

3.3.3. AIMSUN Model

Figure 5 shows the AIMSUN base case model of the Nelson-St Vincent-Commercial Road corridor. The traffic demand matrices used here were imported from the LINSIG base case model. The signal control plans implemented in the AIMSUN model were similar to the ones used in LINSIG model, which reflects the current SCATS operation on site. Only minor adjustment was made to the LINSIG signal control plans and their offset settings.

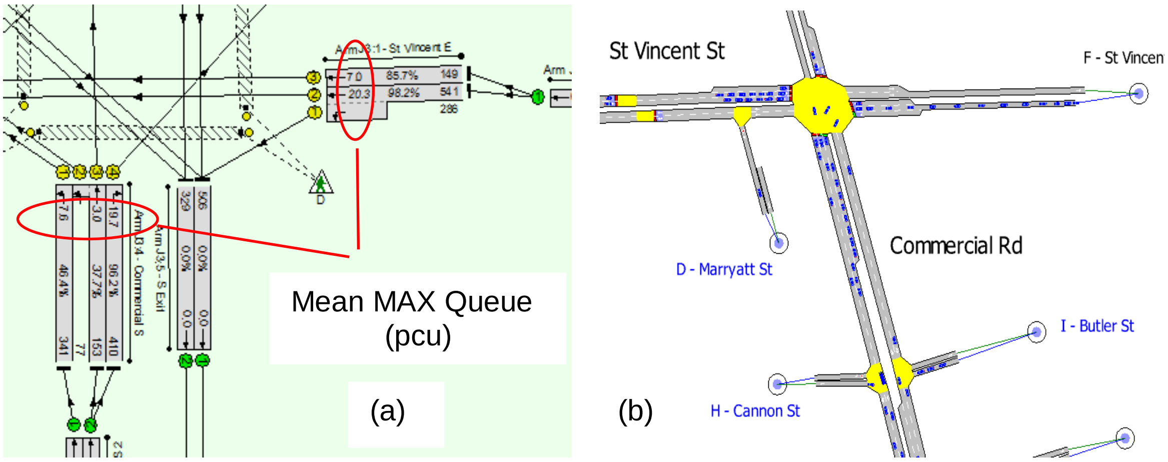
Figure 5 AIMSUN model of the Nelson–St Vincent– Commercial Road corridor (base case)



Virtually, the AIMSUN model is a stochastic representation of the base case LINSIG model, from which detailed traffic queue and travel delay information can be extracted. Importantly, the detailed vehicle behaviour and corridor traffic performance can be visualised and verified in a more user friendly manner.

The AIMSUN modelling results confirmed that traffic performance of the corridor was dictated by the St Vincent Street/Commercial Road intersection. The right turn lane on the Commercial Road south approach overflowed regularly during both peaks. And the heavy traffic queue experienced by the St Vincent Street east approach was the results of the priority being allocated to the Commercial Road south approach (see Figure 6 (a) and (b)). Even though the other intersections of the modelled corridor performed well under capacity, there was virtually no practical reserve capacity left for the corridor.

Figure 6 Performance comparisons between LINSIG (a) and AIMSUN (b) models



When compared with the LINSIG mode at individual intersection level, especially at the St Vincent Street / Commercial Road intersection, traffic queues experienced in AIMSUN model was slightly worse. Note that the queues shown in Figure 6 (b) do not reflect the worse queue experienced on each approach. The random arrival of traffic sometimes worked against the optimised signal control plans and produced longer traffic queue. The worse queue on St Vincent Street occasionally went passed the central pedestrian crossing, which was not picked up by the LINSIG model.

4. Conclusion

This paper presents an integrated approach to traffic modelling of an arterial corridor of Port Adelaide. Three different types of traffic models, namely SIDRA, LINSIG and AIMSUN models were developed and each model played a different role in the corridor traffic analysis.

The LINSIG model was the central piece of the corridor traffic analysis in which four sets of closely spaced traffic signals along the corridor were modelled and optimised. To improve the reliability of LINSIG model and to capture travel time variation and dynamic queue along the corridor, both the intersection SIDRA models and the corridor AIMSUN model were also developed. Since the SIDRA analysis facilitated the development of the key input to the LINSIG model (i.e. lane saturation flow rate estimate), and the primary inputs to the AIMSUN model (i.e. OD matrices, optimised signal control plans and offsets) were readily available from the calibrated LINSIG model, the entire modelling efforts under the integrated modelling approach were slightly more than that of the LINSIG modelling alone. On the other hand, the robustness of the traffic modelling was improved significantly as the proposed approach helped to address the limitation of each individual traffic model.

This modelling project suggests that the seamless integration of the three different types of traffic models can be achieved without tripling the modelling efforts. Meanwhile, the confidence level of the traffic analysis and modelling can be improved significantly.

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