Traffic Impact Study for The New Development of Festival Plaza Tower, Adelaide

by

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DECLARATION

I certify that this work does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Chathushika J. Kalubowila: ____________ Date: 16 October 2023

I certify that I have read this thesis. In my opinion it is/is not (please circle) fully adequate, in scope and in quality, as a project proposal for the master's degree in civil engineering. Furthermore, I confirm that I have provided feedback on this project proposal and the student has implemented it minimally/partially/fully (please circle).

Dr. Nicholas Holyoak
(Supervisor)

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EXECUTIVE SUMMARY

As South Australia's population and infrastructure continue to expand, the traffic congestion through signalized intersections within the Central Business District (CBD) would definitely worsen. This research analyzes the influence of a new large-scale development of Festival Plaza Tower in Adelaide's CBD, on the signalized intersections and pedestrian crossings in the close vicinity and thereby on drivers, pedestrians, the economy, and the environment by conducting a traffic impact study (TIS).

The solutions to mitigate such influences were to be found within the existing constraints in the road network while meeting all the functional requirements in smooth vehicular traffic and smooth pedestrian crossings at the worst traffic flow that could be expected and meeting other critical attributes in pedestrian and vehicle safety, minimized emissions and noise etc.

This research approach consists of several critical stages aimed at gaining an in-depth understanding of the traffic dynamics in the study area. To begin the investigation, a detailed analysis of the current road network was conducted to get insight into the current traffic situation. Cross-referencing statistics from the Department of Infrastructure and Transport (DIT) with on-site observed data was highly useful in determining the current volume of vehicle in the study region, which is critical for modelling its existing condition.

The next step was to evaluate the effect of new development on the volume of vehicular traffic in the area of study. Trip generation estimates aided this assessment enabling a quantitative understanding of how the development affect the flow of traffic. Two advanced computer tools, SIDRA and AIMSUN, were used to assess the overall effects of these adjustments. These software programs were crucial in determining the capacity of the infrastructure and the flow of traffic, providing vital details about how effectively the road system was performing. Both software programs were strategically used; SIDRA focuses on intersection analysis, while its outputs were simply incorporated into the AIMSUN model, providing a thorough simulation of traffic performance across the entire area of the study.

SIDRA and AIMSUN software were used to model intersections and road network near the development site for the years 2023 (Existing Model), 2024 (after Flinders at Festival Plaza opens), 2025 (after the redevelopment is finished), the future scenarios (10 years), and to model with optimum solution.

This study involved data collection, model design using SIDRA and AIMSUN, model calibration and validation, and recommending an optimum solution. In summary, this study offers the optimum recommendations for reducing the negative effects of traffic. The proposed recommendations include adding one lane in each of the four directions at the intersection TS001 together with converting short lanes used for South Exit and West Approach to full lanes covering the entire distance between TS001 and TS055. Additionally, the short lane on the South Exit at TS055 was proposed to be extended up to 100m. Also, the network cycle time was changed from 100s from 110s as a result of solution optimization. The expected development cost was estimated at $10.8 million. Further a sensitivity analysis was done to identify any other factors that may impact on vehicle traffic.

These suggestions focus on improving the road system and optimizing traffic signal settings, which will ultimately lead to increased traffic efficiency and the overall well-being of the local community. This data would be useful for future development ideas and research in the field of transportation engineering.

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1 INTRODUCTION

1.1 Project Background

Adelaide Festival Tower as a part of the development of a new Festival Plaza towards the rejuvenation of the Riverside precent in Adelaide is expected to be completed in 2024 and the overall Festival Plaza reconstruction is expected to be finished in 2025. Situated in one of the most significant public locations, it has been identified as one of the major infrastructures that not only enhances Adelaide's economic growth but also emerges as a compelling travel destination of choice for local, interstate, and international tourism, cultural and sports sectors.

With the expected increase in activities and visitor movement generated by these developments, high concern on the likelihood of affecting the existing local traffic could not be ignored.

As such, this project report provides a traffic impact assessment by conducting a complete Traffic Impact Study (TIS) in order to determine how the future transport system would meet the expected traffic. This study also needs to propose solutions that would fit for all future conditions. The forms of solutions have to be found within the existing constraints in the road network limiting any changes on existing intersections and road widenings while meeting all the functional requirements in smooth vehicular traffic and smooth pedestrian crossings at the worst traffic flow that could be expected, and meeting other critical attributes in pedestrian and vehicle safety, minimized emissions and noise etc.

The study needs collection of various data that are needed to forecast future conditions as the basis for determining solutions for increased traffic. Determining all connected stakeholders including primary stakeholders and other indirect stakeholders that may include state authorities related to the cause, and collection of comprehensive data from all of them are the primary material in this study. Followed by is the carrying out of literature survey to learn about tools like SIDRA and AIMSUN that have been used in similar situations and their effectiveness for this project.

The primary goal in the study can be considered as the preventing of adverse consequences on the existing safety and service quality standards. Analyzing the impacts on these effects and recommending effective mitigation measures are the key aspects of the assessment.

The scope of the assessment is determined by the amount of traffic generated by the new development and its possible impact on the road network (Austroads, 2020). The primary reference guideline relevant for the traffic impact study of this project is the AUSTROADS guidelines, as there is hardly any designated Traffic Impact Study (TIS) guideline specific to South Australia. A decision to carry out a Traffic Impact Study depends on the changes identified in the number of trips generated by the site, the size and type of development, and other developments or area aspects (Austroads, 2020). In general, a TIS is required when a development results in 100 more trips to the adjacent roadway network during peak hours. The threshold values for TIS in Victoria are based on the type and size of development (VicRoads 2006). Based on that, TIS is required for commercial buildings with a floor area more than 5000m2 GFA. The threshold values for TIS in Western Australia are in terms of the level of expected transport impact and are connected to the type and size of development (Western Australian Planning Commission 2006). According to that, TIS is necessary for development with more than 100 vehicle trips during peak hours and office area with more than 5000m^2 GFA.

The Festival Plaza tower is in Adelaide CBD, SA. The Festival Tower overlooks the River Torrens and is in the middle of the city center, behind the old Parliament House. Adelaide's city center is unique in that it is bordered on all sides by public parkland, with the high-rise office apartments known as the square mile in the center north, near the King William Street.

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Figure 1: Traffic Volume Estimates (LocationSAViewer, 2022)

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Figure 2: Roadways and intersection/s around the development

The present traffic volume on road links around the site ranges from 20,000 to 50,000 vehicles per day, as indicated in Figure 1. However, it is expected to have a significant increase in traffic in this region after the construction of Festival Plaza tower. Traffic increases and congestion risks on North Terrace and King William Road are expected, especially during peak times as Figure 2.

King William Road and North Terrace major intersection is one intersection selected for investigation and modelling. Other modelling intersections were selected within 200m radius from King William Road and North Terrace major intersection due to the limited time, scope, and resources. Only three such intersections which are expected to be impacted by this development were found within this radius. These include the two intersections in King William Road (Figure 3) and the intersection on North TCE road with the Station Road. However, the Station Road is closed due to continued construction work preventing this intersection being of use for the investigation. As such, the three major intersections identified for investigation as above are considered for modelling using SIDRA and AIMSUN software in analysing the road network performance as below Figure 3.

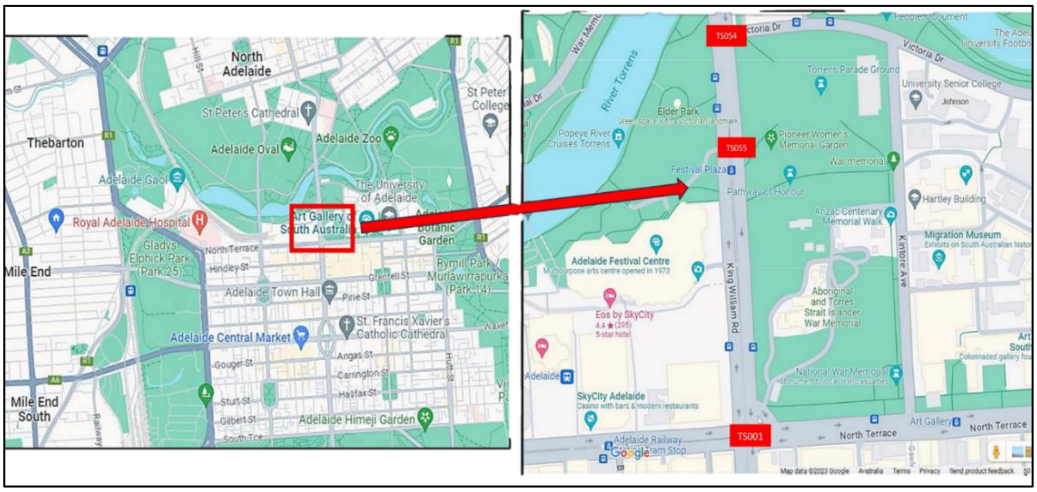

Figure 3: Background area & intersections

Festival plaza tower is a 26-story building, and 8 levels are expected to be occupied by Flinders University by 2024 while 16 floors expected to be occupied as offices by 2025. The section 2.3 of this report provides more information about this development.

1.2 Project Objective

The background study and literature review were the initial steps in this research project. The next stage was to obtain the necessary data from the Department of Infrastructure and Transport (DIT) and conduct a field study. The ITE (Institute of Transportation Engineers) Trip Generation Manuals' database was used to estimate trip generating rates. This research project's core activity is the use of SIDRA and AIMSUN as tools in modelling of existing conditions and concept designs. The concept designs were compared, and conclusions were drawn once it was developed with both SIDRA and AIMSUN. The reason for using SIDRA and AIMSUN for modelling is that SIDRA only focuses on the intersections while AIMSUN provides more details than SIDRA by simulating the road performance.

The main project aims are depicted through the flow chart in Figure 4.

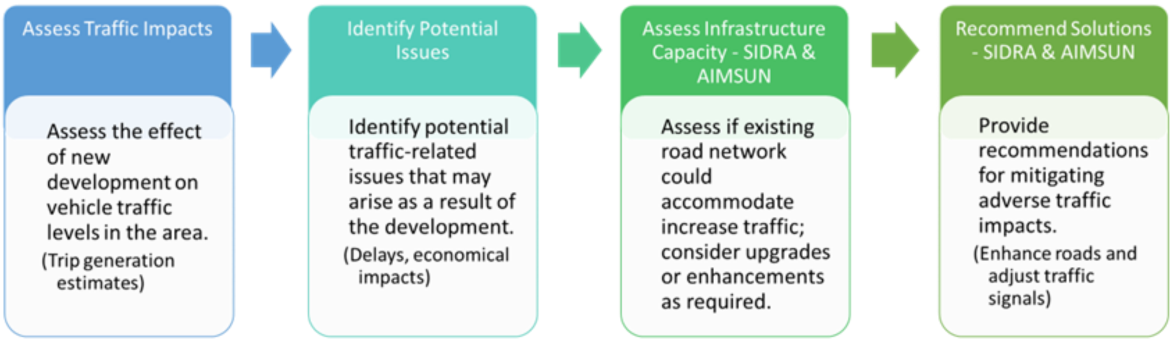

Figure 4: Aim of the research.

However, there were some limits on the accuracy of data collection during field survey. Moreover, assumptions had to be made for SIDRA and AIMSUN modelling, as well as estimations using ITE Trip Generation Manuals.

This thesis spans 6 chapters, which are further broken down into sections and sub sections. The first chapter is the introduction of this research. Chapter 2 is the literature review section which provides information about land use, transport interaction, strategically located Adelaide Festival Tower, Festival Plaza development, impact due to the development, simulation modelling, transportation assessment and modelling. Chapter 3 explains the methodology utilised to carry out modelling, using the micro-analytical and micro-simulation programs SIDRA and AIMSUN. This chapter also includes the data collection methods, modelling and calibration of existing scenario and develop other scenarios required to analysis the road performance due to the new development and ends with the assumptions and limitations of the project. Chapter 4 discusses the results and analysis including delays, total cost, CO2 emission and Level of Service (LOS). Chapter 5 is the discussion section of the thesis and Chapter 6 is the conclusion.

2 LITERATURE REVIEW

The literature review aims to highlight the importance of this thesis and justify it with providing vision of existing research about traffic impact study due and how their application in conjunction with transport modelling software contributes to the success of new developments. Many of the techniques that are available to quantify the impacts of traffic are evaluated and used for the research conducted herein.

The review was conducted in six parts. The first section of this report provides the land-use and transport interaction, with transport assessments and other similar types of developments in CBD. The second section explores the site-specific information and strategic planning in Adelaide to understand existing government plans for the site. Next section discusses background information about the festival plaza development. Forth section highlights the impacts on economy, environment, travel time, congestion and delay due to the infrastructure development. Next section provides details about modelling types and application, which reviews the available data, method of collection, limitations identified and the application of data within traffic simulation software. The final section explores transport assessments and modelling of transport associated with development, microsimulation, intersections etc.

The findings highlighted in this literature review would be beneficial to CBD since the review provides an extensive site visual and emphasizes the potential of traffic modelling. Other users conducting TISs may find the information in this review useful for their own studies.

2.1 Land-use and transport interaction

Transport systems have satisfied the needs of the densely populated urban land use that characterizes urban areas providing numerous amenities and attractions, making the connection between land use and transportation a necessity in the CBDs.

The formation of activity systems by social, cultural, and economic activities occurring at various areas in the CBDs is inevitable. There are non-routine irregular activities in sports and leisure that are influenced by lifestyle and in healthcare and education as specialized demands, whereas some routine activities like commuting and shopping are predictable. All of these operations are related to the transportation requirements for passengers' mobility as essential needs characterized by the land use.

Production activities related to manufacturing and distribution that have local, regional, or worldwide linkages that cannot function without continual mobility of freight are included in the service sector under economic necessities.

As a result, land use is expected to satisfy practically all social, cultural, and economic needs, with transportation of passengers and freight required for their functionality, implying a relationship between land use and transportation (Rodrigue, Comtois and Slack, 2020).

That urban land use and transport are closely inter-linked is common wisdom among planners and the public. That the spatial separation of human activities creates the need for travel and goods transport is the underlying principle of transport analysis and forecasting. Such relationships can be identified as the distribution of land uses over the urban area that determines the locations of human activities, the distribution of human activities in space that requires spatial interactions or trips in the transport system to overcome the distance between the locations of activities, the distribution of infrastructure in the transport system that creates opportunities for spatial interactions and can be measured as accessibility, and the distribution of accessibility in space co-determines location decisions and so results in changes of the land-use system (Wegener and Fürst, 1999).

Adelaide being a densely populated CBD of around 78% of the total population in South Australia depending heavily on automobile transportation for their numerous social and cultural needs shows the gravity of interaction between land use and transportation (Rodrigue, Comtois and Slack, 2020).

Relationships will inevitably shift as land use or transportation patterns change. This link has a scale effect since sizable infrastructure developments frequently precede and result in land-use shifts. Small-scale transportation developments, however, frequently enhance the current land use pattern (Rodrigue, Comtois and Slack, 2020).

Due to high capital costs, decisions made by individuals, organizations, and governments have a substantial impact on both land use and transportation. Main dynamics are the traffic patterns for people and goods, employment and workplaces, and population and housing as below Figure 5 (Rodrigue, Comtois and Slack, 2020).

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Figure 5: Dynamics of Urban Change(Rodrigue, Comtois and Slack, 2020)

Although it is possible to lessen the detrimental social effects in transport systems by way of enhancing the urban form, it may lead to address the crucial component of transport emissions (Andrew, M., 2021). The integrated land-use and transport planning can have a significant impact in reducing the amount of vehicle use with the change of ways of travelling expected through,

- reducing the peoples' need to travel,
- providing safe and attractive walking and cycling networks,
- providing better access to mass rapid transit,
- providing clear differentiation of freight and other strategic routes,

as against any independent planning that may lead to accommodate numerous corrections probably at high costs later on in the operation stage.

The Greater Adelaide 30-Year Plan was established in 2010 and revised in 2017 to deliver a more compact urban form and carbon neutral city, and to manage the growth within the existing urban footprint by monitoring how the city grows. This directly relates to how transportation and land use interact in optimizing costs in developing infrastructures for both land use and transportation (South Australia. Department of Planning and Local Government, 2017). Out of the key areas that were focused to strengthen in 2017 update, the following have specific relevance to Land use and Transport interaction.

- supporting Greater Adelaide's new urban form
- delivering a more connected and accessible Greater Adelaide
- supporting economic development and unlocking investment

The 2016 Transport Canberra and City Services (TCCS) Guidelines for Transport Impact Assessment (TIA) provides helpful direction for managing and comprehending transport impact assessments resulting from land-use development projects, with a location specific approach. The underline requirement to satisfy the access and transport movement, safety, and environment, right throughout in this approach can be considered as useful tips in completion of the thesis.

In July 2015, a report titled "Building a Stronger South Australia" was published by the Government of South Australia under the Integrated Transport and Land Use Plan (ITLUP) as a collaborative, extensive and visionary plan designed as a Guide comprising a bold plan for a stronger future to shape and grow the places where the community live and work in the best ways possible (Government of South Australia, 2016). It was envisioned that new ideas and bold vision would complement wise and thorough planning, which would result in benefits for,

- a greater choice of travel modes
- more efficient goods and services
- improved road safety
- less environmental impacts of the transport system
- promoting medium density mixed-use development
- opportunities for more attractive and lively suburban centers
- protecting the vital freight routes needed by export industries.

Such broad concepts would be good thoughts in the preparation of the thesis.

2.2 Strategically located Adelaide Festival Tower

Adelaide Festival Tower is designed as a mixed-use tower of gross building area of 58270 sqm with a net lettable office floor space of 40,000 sqm and gross leasable retail floor space of 330 sqm as one part of the development of the high-rise tower and a three storied Retail Pavilion of gross building area of 3734 sqm (Walker Riverside Developments, 2020).

It is a part of the development of a new Festival Plaza towards the rejuvenation of the Riverside precent. The site is located at one of the most significant public locations and situated between the Adelaide Festival Centre, Parliament House, Old Parliament House, Adelaide Casino and the Adelaide Railways Station and has frontage to King William Road to the east and a right of way to North Terrace as below

Figure 6 (Walker Riverside Developments, 2020). The Plaza is designed to integrate and link with the waterfront of the Torrens River (Walker Riverside Developments, 2020).

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Figure 6: – Festival Plaza Site (Walker Riverside Developments, 2020)

Added to the site's value are the Adelaide Festival Centre and Dunstan Playhouse, located to the north and north-west of the limits, Elder Park located further north, the Adelaide Oval located to the north of the River Torrens through the new Riverbank pedestrian footbridge, Government House to the east of the site, Old Parliament House and Parliament House in the frontages to the North Terrace, and other State Heritage places Adelaide Railway Station and Adelaide Casino are located to the west of the site. With these respectful buildings, parklands character and civic functions of busy land use, the transport requirements need specific interactive approaches (Walker Riverside Developments, 2020). In March 2022, the brand-new Public Plaza known as Public Realm was finished and inaugurated. By the end of 2023, the remaining office buildings and retail locations are expected to be finished. 40000 square meters of luxury office space will be located in the Festival Tower. Overall, the Festival Plaza reconstruction is expected to be finished in 2025. It includes the freshly opened Festival Plaza public realm, the five-level Festival Car Park, the SkyCity Adelaide casino expansion, a three-story shopping center, and Festival Tower with a 26-story, 5 Star Green Star office structure.

In May 2020, the 20-Year State Infrastructure Strategy was released as required by Infrastructure SA Act 2018, to set out independent assessment and advice related to the existing state, projected needs and challenges, as well as key priorities over the next five years with respect infrastructure. It has identified the activation of the world-class Riverbank Precinct with the development of Festival Plaza as one of the major tourism infrastructures to promote Adelaide as a destination in respect of tourism, sports, and culture sector.

It will be necessary to review the existing tram networks covering this area in this study for improvements that could be possible within the network and in possible expansions.

2.3 Festival Plaza information

The traffic impact assessment is based on the new Festival Plaza Tower development. A revitalized 5,000 square-meter city square and public realm, a business tower with 40,000 square meters of premium office space behind the old Parliament building, and a two-story precinct with cafes, restaurants, and luxury retail stores will be part of this expansive mixed-use commercial and retail development. This will entail the construction of a new parking lot with 1,600 spaces for parking.

The Festival Tower will connect the city's most popular public spaces, creating a vibrant entertainment destination. Establishing a site that will make Adelaide proud while also attracting tourists by connecting the Adelaide Oval, railway station, casino, Festival center, convention center, and Riverbank area as Figure 7 (RenewalSA., 2023).

The tower will attract local blue-chip firms, interstate, and worldwide commercial tenants with the best office space in Adelaide, contributing to the state's economic gain. It will also help to attract people to the square for amusement after work. The project began in 2019 and is scheduled to be completed in its entirety in 2025 (Figure 7). When completed, the project will include a completely renovated Station Road, Walker Corporation's new three-story retail complex, and Festival Tower, a 26-story, 5-Star Green Star office skyscraper.

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Figure 7: Festival Tower site area & Festival Plaza tower after completion (Walker-Corporation, 2023)

Nonetheless, the festival plaza tower, a 26-story skyscraper, is the primary development that is required to be included for the traffic impact analysis since it will have a significant impact on traffic. Flinders University will occupy 8 floors and offer a variety of amenities, including offices, spectacular event spaces, and flexible and collaborative formal classroom spaces, as the Festival Plaza's principal tenant in 2024. Festival Plaza Tower will have an impact on local traffic issues in the long run. A TIS must thus be prepared to mitigate the negative effects of this traffic linked with new building as well as on the neighborhood's current transportation and parking infrastructure.

In this literature review, it is important to examine the key transportation hubs and facilities serving this region since traffic impact can be sensitive to public transport. The study area is well connected via various transportation modes such as train, tram, and buses. The Adelaide rail network map and the Adelaide tram network map are highlighted in Figures 8 and 9 with Light rail covering four routes connected to Adelaide Railway Station and three Tram networks as depicted. The Adelaide bus network map surrounding the study region is highlighted in Figure 10 and assists in identifying any possible network improvements and enhancements.

However, for the TIS, only road network travel is assessed. Traffic impact studies focus on road networks because they constitute a distinct infrastructure system with the most vehicular traffic. TIS studies are designed to analyze how development affects road infrastructure, which is managed separately from the public transport modes of trains, trams, and buses. Although trains, trams, and buses are key modes expected to promote urban transportation, their usage is often lower compared to road travel, resulting in a lesser overall impact, making them less important in traffic impact studies.

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Figure 8: Adelaide rail network map (Adelaide Metro, 2022)

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Figure 9: Adelaide Tram network Map on Weekends and Adelaide Oval special event days (Adelaide Metro, 2022)

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Figure 10: Adelaide Bus Network Map (Adelaide Metro, 2022)

2.4 Impact due to the development

Signalized intersection congestion worsens as South Australia's population and infrastructure grow along with the amount of traffic through the Central Business District (CBD). To assess the efficiency of the road network, TIS assesses the potential consequences of a new development on the adjacent roadway network.

2.4.1 Economic Impacts

Extensive negative effects on the community and economy are caused by congestion, traffic delays, and unreliable travel times. Users of the transportation system are liable to waste their valuable time and become frustrated as a result of delays, especially when such delays are unexpected.

Based on how people are willing to trade up money for savings in travel time, VLC has calculated the financial worth of the cost of congestion in Adelaide in 2016 and 2031. According to estimates, the cost of road congestion will rise significantly from $4.2 million in 2016 to $7.6 million in 2031 (Figure 11) (H Smithers, 2019). Hence, road networks (road travel mode) are the focus of traffic impact studies because they represent the particular infrastructure system that receives the most vehicle traffic compared to the railways, tram lines, and bus routes.

The total daily congestion cost is affected differently by each modelled time-period. The PM peak (33.0% in 2016 and 33.7% in 2031) is when the most expenses are incurred. The AM peak follows closely behind, reaching 32.2% in 2016 and 32.5% in 2031, respectively. The hourly cost incurred, therefore, is equivalent between the AM and PM peaks in both years ($0.7 million in 2016 and $1.3 million in 2031 - Figure 12). This shows that both peak times saw comparable degrees of congestion (H Smithers, 2019). Adelaide's predicted annual cost of congestion is $1.4 billion in 2016, and it will rise to $2.6 billion in 2031.

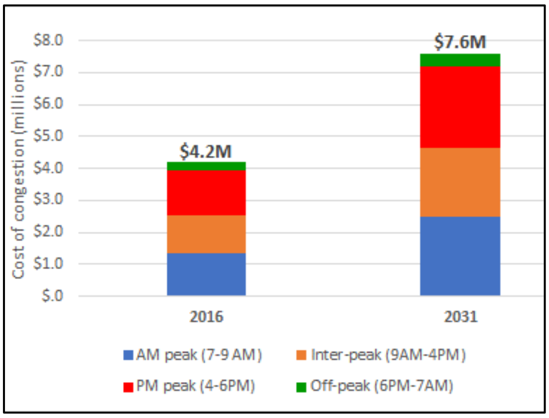


Figure 11: Adelaide Greater Capital City Statistical Area (GCCSA) average weekday cost of congestion - 2016 and 2031

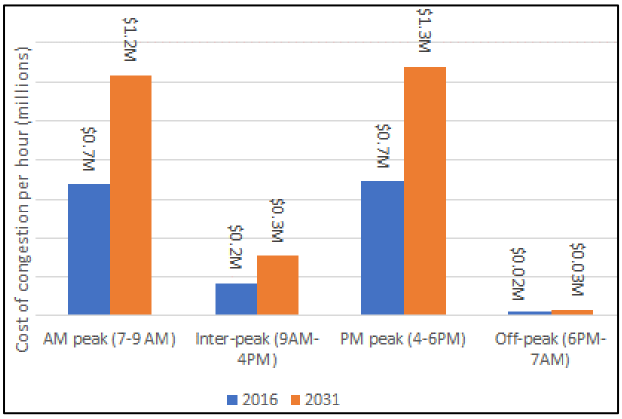


Figure 12: Adelaide GCCSA average weekday hourly cost of congestion by time-period - 2016 and 2031

2.4.2 Environmental Impact Due to Emissions by Heavy Traffic

According to the Bureau of Infrastructure, Transport, and Regional Economics (2009), when traffic is heavy, car engines run less effectively, increasing the amount of air pollutants they emit. In Australia, the transportation industry is accountable for 14% of the country's total emissions, with road travel accounting for 90% of those emissions.

95% of the emissions from cars using Melbourne's Monash Motorway were found to be Carbon Dioxide (CO_2), according to a case study (Han, Kazantzidis and Luk, 2009). Road transport accounted for 84% of the 91Mt of CO_2 equivalents (CO_2e) generated by Australia's transportation industry in 2012 (Commonwealth of Australia, 2013).

Several industries, including transportation, fugitive emissions, agriculture, and stationary energy (other than electricity), all saw an increase in emissions. Emissions from the power, industrial processes, and land use, land use change, and forestry (LULUCF) sectors, on the other hand, decreased. The Paris Agreement's 2030 target for Australia is based on emissions from the year 2005. According to preliminary projections, national emissions will be 490 Mt CO_2-e in the year before December 2022, a 0.3% decrease from the year before. National emissions on a quarterly basis are currently anticipated to be 123 Mt CO_2-e for the same period, which is a 0.1% drop over the previous quarter.

2.5 Simulation Modelling

The complexity of transportation networks nowadays makes direct experimentation impractical. Today, we rely on simulations of traffic flow to provide efficient traffic control. (Gao et al., 2020) shows that computer simulations provide us useful information about enhancing roads, managing intersections, and implementing mechanized traffic control. Traffic simulation models, which frequently employ automated methods to evaluate traffic effects, have been essential since the advancement of computer technology. Computer simulation of transportation systems includes mathematical modelling of transportation networks utilizing various computer applications to forecast, plan, and develop operational aspects of transportation frameworks (Boukerche and Wang, 2020).

Traffic simulation models, which include microscopic, macroscopic, and mesoscopic models, provide detailed insights into peak-hour traffic dynamics (San José, Pérez and Gonzalez-Barras, 2021). Although these models are primarily used in smaller study areas, they provide greater scope & detail. Computational simulation assists in strategic planning, network management, and transportation infrastructure research, as well as communication between public and private organizations. Computer modelling for traffic analysis improves network efficiency, cost-effectiveness, and security while eliminating the need for on-site traffic evaluations. ANNEX 1 provides an overview of the Standard Transport Modelling Packages (Austroads, 2020).

2.5.1 Microscopic Simulation

Microscopic simulation is a simulation method that precisely simulates the behavior of individual vehicles. The method takes into account a driver's speed, lane changes, and turning patterns as well as the characteristics of each vehicle, such as its size, weight, and rate of acceleration. Microscopic simulation can be used to examine the effects of changes to the road network or traffic flow, congestion, and safety issues. It is frequently used to model complicated road networks, including intersections and roundabouts. Microscopic simulation was utilized in studies by (Li et al., 2019) and (Mohammadian and T, 2018) to examine the effects of road/roundabout design on traffic flow and safety.

Overall, microscopic simulation is an effective method for Australian road traffic investigations. Through the use of simulation, researchers may examine how different road layouts, speed limit reductions, and traffic control tactics affect traffic flow, congestion, and safety concerns. For authorities who are contemplating various ways for enhancing road safety and lowering congestion on Australian roads, these findings have significant effects.

2.5.2 Nano-simulation

In accordance with Austroads (2009) recommendations, reliable road network modelling requires accurate and relevant data. In order to evaluate development proposals, it is critical to do a preliminary analysis and to depend on recent local trip generation surveys, as suggested in a South Australian Government consultation paper for assessing development ideas. (DPTI, 2014)

The Guide to Traffic Generating Developments (Roads and Maritime Services NSW, 2013) and Austroads recommendations are valuable resources. Furthermore, the DPTI website (DPTI, 2014) and Road Asset Management Section (DPTI, 2015) provide statistics on traffic volumes, which can be used to determine daily average traffic. Data from the traffic signalling system (SCATS) (Data.SA, 2018) can be utilised for more detailed volume counts, however interpreting these sources can be difficult. Austroads recommends using micro- and nano-simulation techniques to aid in analysis in such circumstances.

Two popular transport analysis programmes, VISSIM and SIDRA, are compared in a study that was presented at the 13th COTA International Conference of Transportation Professionals in the context of a real-world project in Xianyang City, China. According to the results, VISSIM produces output that is more accurate while SIDRA is less complicated to utilise (Tianzi, Shaochen and Hongxu, 2013). This demonstrates the benefits of modelling with SIDRA. When analysing results from a transport simulator, it is crucial to understand its limits. A number of limitations were found in an analysis of micro- and nano-simulation models from the University of Leeds (Staffan Algers and B, 1997), including imperfect representations of human behaviour, difficulties in accurately modelling real-world networks, hardware restrictions, and the need for meticulous result analysis. However, programmers have likely addressed and reduced these issues in later software versions, thanks to enhanced personal computer capabilities.

Nano simulation addresses human travel, while microsimulation focuses on vehicle transit. As per (Roads and Maritime Services NSW, 2013), microsimulation programs, including AIMSUN, now integrate nanoscopic agent-based simulation due to methodological similarities.

There are a number of limits and limitations that must be taken into account when undertaking the TIS study project. These include maintaining default SIDRA parameter values while addressing inconsistencies during validation, the limitations of student versions of SIDRA and AIMSUN affecting analytical output, restrictions due to time and resource constraints that impact model detail, and potentially unforeseen factors like weather-induced traffic variations during research or surveys.

2.6 Transport Assessments and Modelling

2.6.1 Computer Simulation as an Analytical Tool

Transport and traffic modelling are techniques that assist planners and engineers in analyzing the results of traffic initiatives (Austroads, 2020). The three basic categories of transport models are analytical models, transport planning models (Four Step Model), and simulation models. Analytical models reflect real-world occurrences using mathematical equations. The Four-Step approach is widely used in planning organizations around the world since it is straightforward to apply and solve on a computer. Simulation models (Macroscopic, Mesoscopic, Microscopic, and Nano simulation) come into play when analytical methods are impractical or time-consuming, particularly for addressing complex tasks like TIS (Austroads, 2020).

Computer-based traffic simulation is a valuable tool for studying the impact of traffic on transportation networks. It enables safe and affordable examinations throughout peak and off-peak periods. Compared to on-site or lab-based analyses of traffic flow parameters, this approach has benefits (Dia and Gondwe, 2008). Different levels of detail, including macroscopic, mesoscopic, microscopic, and nanoscopic simulations, can be observed in traffic analysis by computer simulation, particularly for highway applications (San José, Pérez and Gonzalez-Barras, 2021). These modeling methodologies offer varying levels of information and complexity, with macro being less complex and nano being the most complex despite smaller study areas. Computer simulations are used to test policy idea, evaluating operational performance, and modifying transportation networks for various modes. Computer simulations are frequently used by both public and private organizations to support decisions regarding modifications to the road network.

The process of microsimulation, which follows each individual vehicle's movements on a network of roads, is versatile however require additional resources. Microsimulation can be performed using programs like AIMSUN, PARAMICS, VISSIM, and SIDRA TRIP (Espada, Luk and Lloyd, 2010). The most popular micro-modeling programs among Australian and New Zealand Transport organizations are SIDRA and AIMSUN. However, certain organizations have reported using SIDRA and microsimulation excessively, which results in ineffective utilization of resources (Espada, Luk and Lloyd, 2010). Many traffic microsimulation platforms were developed from projects by transportation researchers and eventually evolved into commercial platforms after working with partners in the industry. Some research-based systems persist, while commercial models often provide academics with free, time-limited licenses like AIMSUN (Raju and Farah, 2021).

Using SIDRA, a study assessed the effectiveness of Perak's traffic flow, where urbanization has resulted in a developing and complex traffic system (Muhammad and Jamaludin, 2022). The study focused on intersection capacity, safety, delays, level of service, accidents, operational costs, and environmental concerns. Two roundabouts experienced rush-hour traffic jams that slowed down traffic and altered pace. The study aimed to improve traffic flow, revealing a speed improvement ranging from 20% to 57%, linked to congestion and road speed. Consistent traffic demand at both roundabouts emphasized the importance of effective traffic management.

Traffic modelling was applied to a challenging arterial road corridor with three closely spaced signalized crossings in a study on the revitalization of a regional center in Adelaide (Zhang, 2013). The approach incorporates the analytical (SIDRA), empirical (LINSIG), and micro-simulation (AIMSUN) modelling methodologies. SIDRA estimated lane flow from intersection analysis. LINSIG improved queue balancing and signal regulation to reduce travel time. AIMSUN assessed delay and dynamic queuing. Without triple the effort, this integrated strategy enhances confidence in traffic analysis and modelling (Zhang, 2013).

A study in Erbil, Iraq, used HCS2010 and SIDRA software along with a Genetic Algorithm-based optimization strategy to reduce delays at five signalized crossings. SIDRA reduced the average delay after optimization by 21%, and HCS2010 reduced it by 29%, but it remained greater than field observations. Further optimization based on SIDRA is required to achieve better performance, as the SIDRA model also indicated a shorter optimal cycle time (Omar and Hussein, 2022).

The above studies that have been conducted to investigate the effects of traffic on a specific transportation network utilizing a computer-based traffic simulation approach such as SIDRA and AIMSUN, could be given special emphasis in the project study.

2.6.2 Assessment of Transportation Network Performance Using SCATS

The most widely used method to mitigate the impact of traffic and regulating congestion is the Sydney Coordinated Adaptive Traffic System (SCATS) (Figliozzi and Monsere, 2013). It functions using inductive loop sensors on the surfaces of the roads, which automatically collect data to forecast traffic volume and flows. SCATS launched in the 1970s as an intelligent transportation system pioneered by the NSW Department of Main Roads and is typically implemented at signalised intersections to monitor all vehicles and their travel directions (Wey, 2000). Over time, its capabilities and relevance have grown, adapting to new developments.

However, Fixed time control does not accurately represent SCATS controlled operations when the controller's phases frequency is unpredictable, pedestrian volumes are unusually high, traffic flows and arrival patterns are erratic, and pedestrian volumes are low (Essa and Sayed, 2020). Fixed time signals are not recommended to be used for micro simulating SCATS-controlled adaptive traffic lights; however, they are appropriate for high-level strategic planning. SCATS techniques provide benefits in congested traffic networks, but their adoption should be evaluated with consideration of the extra effort and costs related to upgrading traffic models, particularly in microscopic simulations.

2.6.3 Assessment of concept design Using Trip generation rates

The Department of Planning, Transport, and Infrastructure (DPTI) recruited Parsons Brinckerhoff to establish vehicle trip generation rates for various land uses, which will aid in determining the traffic impacts of proposed developments (DPTI, 2014). Data was collected from a variety of sources, including the Director-General of Transport of South Australia's (1987) guidelines, the Roads and Traffic Authority's "Guide to Traffic Generating Developments" (2002), and the Institute of Transportation Engineers' "Trip Generation" (9th edition, 2012). Adelaide lacks specific benchmark trip generation rates for new developments, leading consultants to rely on potentially outdated or non-Australian data sources (DPTI, 2014). In addition, there have been substantial technical advances and an increase in environmental awareness over the past ten years, which have changed employment trends, work schedules, and modes of transportation. Trip generation rates will need to reflect these changes (DPTI, 2014). Updated rates are also required since new land uses such as transit-oriented developments (TODs), huge hardware projects, home maker centres, and others lack reliable data on trip generating potential (DPTI, 2014).

The literature on land use traffic generation is varied, with several sources being utilized to estimate trip generation rates. Based on survey data, these rates typically account for two trips (round trip) and take into consideration the busiest day of a standard week due to day-to-day and week-to-week trip rate changes in different developments (DPTI, 2014). The handbook "Policies, Guidelines, and Procedures to Traffic Generating Developments" was first published in 1984, was changed by RTA NSW into the RTA handbook to Traffic Generating Developments in October 2002, and was later updated by RMS NSW in May 2013 to include current traffic surveys. Its main objective is to offer developers and regulatory authorities a standardized traffic generation factor for use in evaluating development applications. It also includes comprehensive guidance on different areas of traffic impacts from land use developments, including parking and traffic generation.

The Institute of Transportation Engineers (ITE) in the United States published the multi-volume manual's ninth version in 2012 (Institute of Transportation Engineers, 2017). Due to its frequent updates and comprehensive coverage of land uses, it is commonly used in Australia and New Zealand and provides an overview of trip generating data for different land uses. Although, Australian and New Zealand trip rates generally align with those in the USA, there's ongoing debate about the direct applicability of US trip generation rates in these regions, as rates in Australia and New Zealand are often lower (DPTI, 2014).

The RTA Guide to Traffic Generating Developments (2002) and the ITE Trip Generation Manual are the two main resources used by traffic engineering specialists in Australia and New Zealand. South Australia, however, continues to follow the Land Use Traffic Generation Guidelines from 1987. When certain land use types are not covered by the RTA Guide or the Land Use Traffic Generation Guidelines, the ITE Trip Generation Manual is frequently referenced.

2.7 Summary of Literature Review

There are multiple components to this literature review. The first half of the chapter focuses on transport evaluations and related developments as it examines the connection between land use and transportation, especially in the CBD. The second section explores site-specific statistics and Adelaide's strategic planning to comprehend the government plans related to the site. Background information about the festival plaza's development is included in the third section. The fourth section emphasizes the negative effects of infrastructure expansion on the economy, the environment, and traffic, such as increased travel times, congestion, and delays. The advantages of traffic modelling are covered in the fifth section, along with relevant case studies. The collected data are compiled in the last stage, which also focuses on adopting the most effective traffic modelling program and assessing method in accordance with the project's goals.

From the literature and studies reviewed throughout this report, a number of conclusions can be drawn. The first major issue is traffic congestion, which has negative effects on the environment and the economy. Since the majority of traffic delays occur at important signalized crossroads along significant routes, it is evident that these locations should be the focus of research and road network enhancements.

This literature review highlights the utility of tools like SIDRA and AIMSUN for decision analysis. SIDRA will focus on intersections, providing data to the AIMSUN model, which simulates traffic movement across the study area. However, there are limitations, mainly the model's level of detail due to time and resource limitations, unexpected events, including differences in traffic due to the weather while conducting surveys. Additionally, a number of SIDRA parameters will be kept as default modelling settings. This only requires resolution if inconsistencies are found during the validation stage. Additionally, there are restrictions related to the SIDRA and AIMSUN student versions that can restrict the possibilities for analysis output. Tools like SIDRA and microsimulation software are crucial for an accurate assessment of traffic performance.

SIDRA and AIMSUN, which are used in this study, are the exclusive tools the Department of Infrastructure and Transport (DIT) in Adelaide employs. Building models of the road network is necessary for the investigation as there isn't a microsimulation model available for the study area yet which can provide a thorough analysis of all network components, including intersection operations. Based on the findings of this literature review, it could be determined that computer simulation is a useful tool that can safely and inexpensively model major road and highway networks in order to assess the effects of traffic-related incidents.

This study has several key objectives. Firstly, it aims to investigate the impact of new development, recognizing the value of understanding how such developments affect society, especially in the context of Adelaide where limited similar research exists. Secondly, the study seeks to utilize microsimulation to assess the consequences of infrastructure development on various factors including the economy, environment, travel times, congestion, and delays. The third objective is to evaluate worst-case scenarios and recommend appropriate solutions based on different locations within the project area. To achieve this, accurate assessment of the impacts of new development utilising key variables outlined in the literature and transportation-related factors will be necessary. A significant percentage of the literature review's focus was directed towards developing and investigating SIDRA and Aimsun simulation-based approaches for reducing the negative effects of new development. Last but not least, the study intends to provide feasible solutions to managing the effects of new development, with a focus on enhancing travel times, LOS improvement, and delay reduction. The network is tested with various scenarios to identify the most effective alternative measures.

This research aims to propose effective transportation strategies like new road openings and enhanced traffic lights, based on literature review. It was observed that there are significant gaps in data and performance statistics relating to traffic congestion. These flaws must be addressed objectively assess how specific measurements and bigger policies are progressing, as well as the gains they are making. This is necessary to ensure that successful congestion control initiatives are carried out. This information will be helpful for future study and development in the area of transportation engineering.

3 METHODOLOGY

A Traffic Impact Assessment assists in mitigating the negative consequences that the proposed development may have on the surrounding community. It assures that the transportation network can handle the predicted increase in traffic. Following the development of the Festival Plaza Tower, the North Terrace and King William Drive are predicted to be overcrowded. The effects of the new development in three major intersections, at peak period was assessed by analyzing delays, total cost, emission, and level of service. These intersections are remarkably close to the festival plaza development site. All the access roads are connected to the King William Road and North Terrace as below Figure 13.

Figure 13: Three Major intersections expected to be congested due to the new development.

The methodological approach of the research is presented below Figure 14.

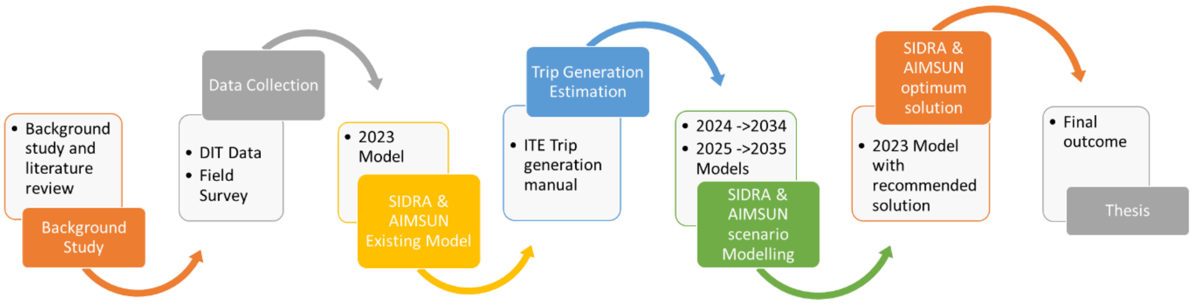


Figure 14: Research flow chart

Research work was initiated with background study and literature review. DIT data collection and Field survey was carried out as the data collection process. Site visits were carried out in order to collect data, including light and heavy vehicle counts, and queue lengths.

AIMSUN micro-simulation software and SIDRA micro-analytical evaluation tool were utilized in this project to analysis the road performance. Hence, after collecting traffic data from existing and in-field sources, and fed into software to build existing condition and analyze their performance, resulting in a report on the delay, total cost, emission, and so on before and after development. The ITE Trip

Generation Manual database (Institute of Transportation Engineers, 2017) was utilized to predict trip generation after the development of festival plaza tower. Finally, it demonstrates the potential solutions for reducing delay, emissions and cost, as well as improving overall traffic flow conditions, after modelling by SIDRA and AIMSUN software.

SIDRA is an innovative micro-analytical evaluation tool that uses lane-based traffic and vehicle drive cycle models. Professionals in traffic design, operations, and planning utilize this popular program to analyze intersection and network capacity, level of service, and performance. SIDRA is also recognized as software by the Department of Infrastructure and Transport (DIT) (Department of Infrastructure and Transport (DIT), 2023). Also, AIMSUN is an effective microsimulation tool used for traffic analysis and optimization that aids urban planners in managing transportation. Its simulation and prediction analytics enable understanding of network performance and making decisions.

This research study is assisting transportation designers as well as DIT by analyzing the impact of new development on North Terrace and King William Road, including delay, total cost, and emissions based on the development's location during peak time. The approach was used to assess the performance of North Terrace and King William Road before and after the development. The traffic impact study for the new festival plaza development was carried out, and it presented various solutions and proposals by road enhancement and adjusting traffic signals, as all feasible alternatives.

3.1 Data Collection

Data collection was performed by collecting Department of Infrastructure and Transport (DIT) data and conducting Field surveys.

3.1.1 DIT Data

DIT Data contains vital information for comprehending intersections and traffic flow. To begin, there were intersection drawings that illustrate the physical design of three specific intersections that were useful insights into the geometry and layout. Furthermore, manual turning counts data sheets (TS001 from 2012 and TS054 from 2009) were gathered, which were generated based on Turning Movement Counters (TMCs), allowing for the manual tracking of vehicle movements at these intersections. Finally, SCATS data sheets with counts and details regarding phasing operations were collected, providing a comprehensive picture of how traffic is managed and traffic flows across these intersections.

According to Tactical Adelaide Model (TAM) Guidelines weekday AM peak hour is 8:00-9:00 AM and PM peak hour is 5:00 – 6:00 PM. Then, SCATS counts were used to identify the peak period of the study area. According to the SCATS counts of intersections, AM peak period was identified as 8:00-9:00 AM and PM Peak Period was identified as 5:00- 6:00 PM. However, PM peak period is selected for this study since high number of vehicles can be identified in 5:00- 6:00 PM comparatively to AM peak period as following Figure 15.

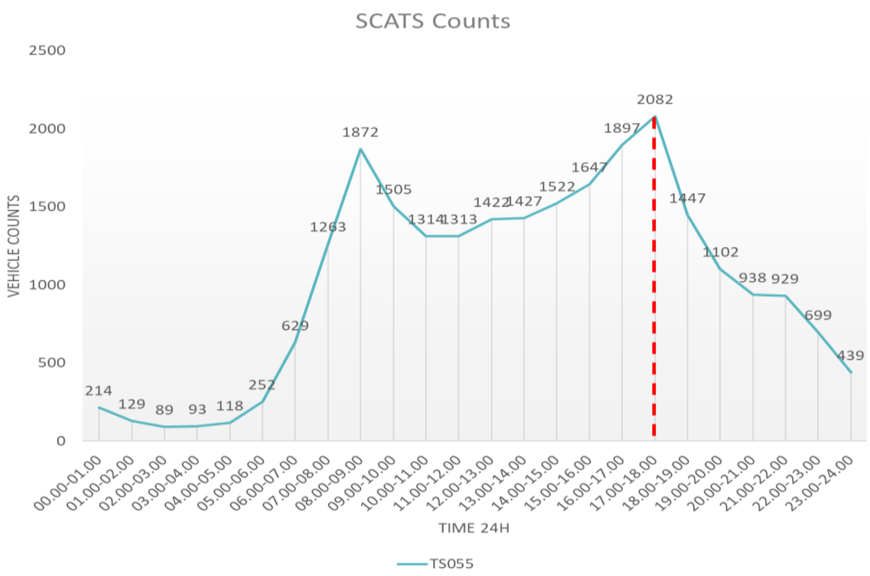


Figure 15: SCATS Counts vs. Time

3.1.2 Field Survey

The study begins with a methodical approach to data collection. The approach began with the collection of relevant information from the Department of Infrastructure and Transport (DIT), which laid the groundwork for a comprehensive field survey meant to capture real-time traffic conditions. Three major intersections were selected to analyze the road performance due to the Festival Plaza Tower development. This field survey was conducted between 5:00 PM to 6:00 PM, a purposefully chosen PM peak hour, to guarantee that the most recent and representative vehicle volume data were captured.

The field survey produced a large dataset that included a variety of essential metrics. These comprised both light and heavy vehicle volumes, which provided information about the types and quantities of vehicles travelling through the intersections. Furthermore, pedestrians were accurately recorded. Finally, vehicle queue lengths were recorded (Figure 16), which is an important indicator for calibrating the SIDRA model and usefully contributed in the analysis.

Figure 16: Queue Lengths observation

The SIDRA Intersection 9.1 User Guide was used as the guidance to record vehicle and pedestrian counts. The major tool was the SIDRA Intersection Input Data Preparation Form, which ensured that the data were accurate, standardized, and in accordance with industry best practices. Recorded data is presented in below Figure 17 and Annex 3.

Figure removed due to copyright restriction

Figure 17: Field Survey Data Form (Source: SIDRA INTERSECTION 9.1 User Guide)

The field survey method allowed for a thorough understanding of traffic dynamics and vehicle movements at the selected three intersections.

In comparison to weekends, weekdays provide a higher volume of traffic. The most effective days to perform a field survey include Tuesday, Wednesday, or Thursday because Mondays and Fridays can have unique traffic trends because they represent the beginning and end of the workweek. The three field survey days were either Tuesday, Wednesday, or Thursday. A team of two people was assigned to perform the survey by monitoring the traffic flow and taking photos of the length of the queues, offering high reliability to the findings.

The SIDRA and AIMSUN current models, which accurately reflect real-world situations, were built using the dataset gathered through this field survey as the primary input. These models, which were crucial for the research, were calibrated using observed queue lengths and traffic flow to make sure they accurately reflected the traffic circumstances in the real world.

In conclusion, it became clear that the data gathering procedure was an essential part of the study. It provided an extensive understanding of intersection geometry, trends in traffic volume, queue lengths, and many other important elements. This information was not only crucial for achieving the short-term research objectives, but it also made a substantial contribution to the creation of reliable and accurate SIDRA and AIMSUN models, improving the general reliability of the findings of the research.

3.2 Trip Generation Estimation

Trip generation rates, which are standardized values that estimate the number of trips generated by a specific land use type, is used to calculate the potential traffic impact. There will be new trips due to the festival plaza tower development. New trip generation estimations are required for SIDRA and

AIMSUN future models to evaluate the traffic impact. Trip generating rates were estimated by ITE Trip Generation Manuals (Institute of Transportation Engineers, 2017).

The average number of workday trips created by a certain land use is quantified by the trip generation rate (Annex 4). In the case of the Festival Plaza Tower, which has eight university floors and sixteen office floors, ITE trip generation manual was utilized to calculate trip generation rates based on the following parameters and assumptions (Table 1).

Table 1: ITE trip generation Manual outputs

Factors	8 University Floors	16 Office Floors
Day	Weekday	Weekday
Time	One hour between 4:00 - 6:00 PM	One hour between 4:00 - 6:00 PM
Location	Urban Area	Urban Area
Trip rates	Student trips are based on 1000 ft^2 GFA = 1.17	Employees trips are based on 1000 ft^2 GFA = 2.45
	Employees trips are based on number of employees = 0.79	
Floor area	143,520 m^2	287,040 m^2
No of employees	200	-
Assumptions	95% trips are exit trips	95% trips are exit trips

Based on extracted information from ITE Trip generation Manual, trip generation estimations were done as below Table 2.

Table 2: Trip Generation calculations

Alternative Scenario	Type	Time	Day	Location	Trip type	Rate			Total trips	Total Exit Trips (Assume 95% exit)
						X means	X value	Rate		
A1 - 2024 (After opening Flinders university - 8 Floors)	Students	PM	Weekday	Urban	Vehicle	1000 ft^2 GFA	143.52	1.17	168	160
	Employee	PM	Weekday	Urban	Vehicle	No. of Employee	200	0.79	158	150
									Total Trips 2024	310 Trips
A2 - 2025 (After opening All Offices - 16 Floors)	Employee	PM	Weekday	City core	Vehicle	1000 ft^2 GFA	287.04	2.45	703	668 Trips
									Total Trips by the end of 2025	310 + 668 = 978 Trips

Calculated trips were distributed among the lanes based on existing traffic volume ratios of each road as below Figure 18.

A few assumptions were incorporated in the trip distribution diagram created for the development in 2024 (comprising eight university floors) and 2025 (comprising 16 office floors). Due of the significant number of vehicle traffic, the PM peak period (5:00-6:00 PM) was chosen for the investigation. The majority of trips during this period were expected to involve leaving the area. Therefore, 95% of the projected trips were classified as exit trips. The eight university floors are expected to result in 310 additional exit journeys in 2024. The 16 office floors will also result in an increase of 668 additional exit trips in 2025. The total impact of this new developments will lead to 978 additional exit trips (Annex 5).

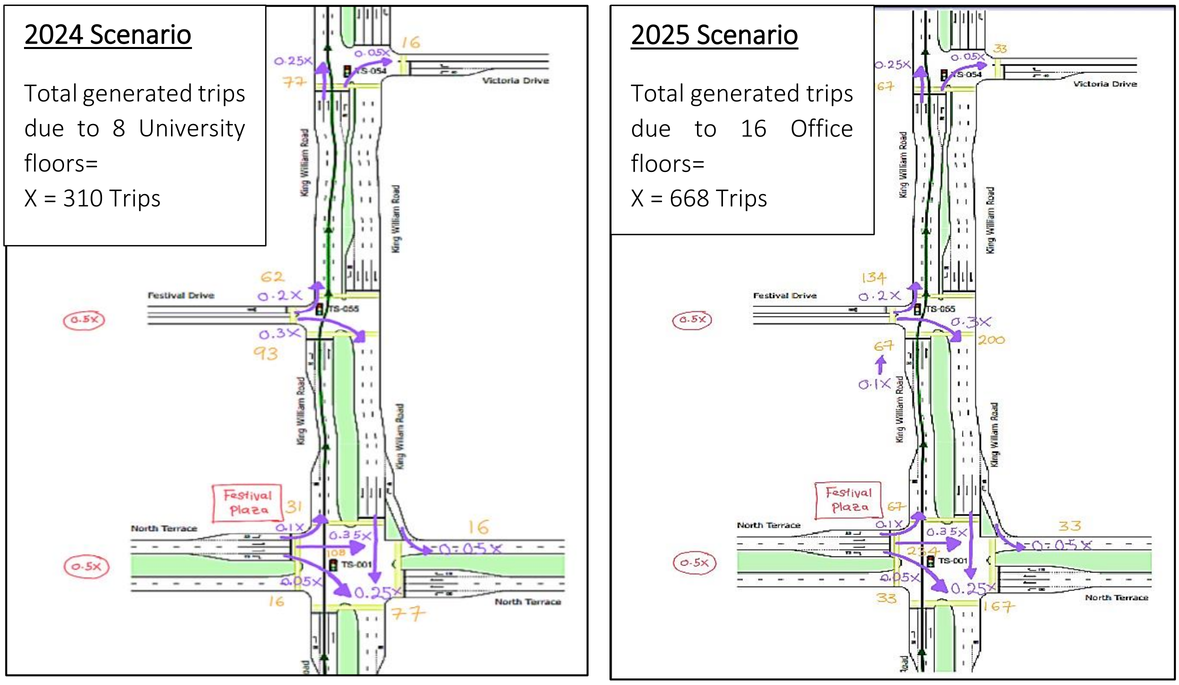


Figure 18: New Trips distribution diagram

3.3 SIDRA Modeling

SIDRA (Signalized/Unsignalized Intersection create Research Aid) is a sophisticated micro-analytical tool used to evaluate the operational performance of intersections and create different intersection concepts. Applications include signalized intersection and network timing calculations, level of service assessment, performance analysis, and intersection and network capacity assessment.

SIDRA can simulate several interconnected signalized and unsignalized intersections and allows for the lane-by-lane modelling of various user classes. For the evaluation of the level of service, a qualitative metric was used to rank operational conditions, by taking into account variables like speed, travel time, delay, traffic congestion, freedom of movement, interruptions, comfort, and convenience.

Overall, SIDRA software modelling process can be shown below Figure 19.

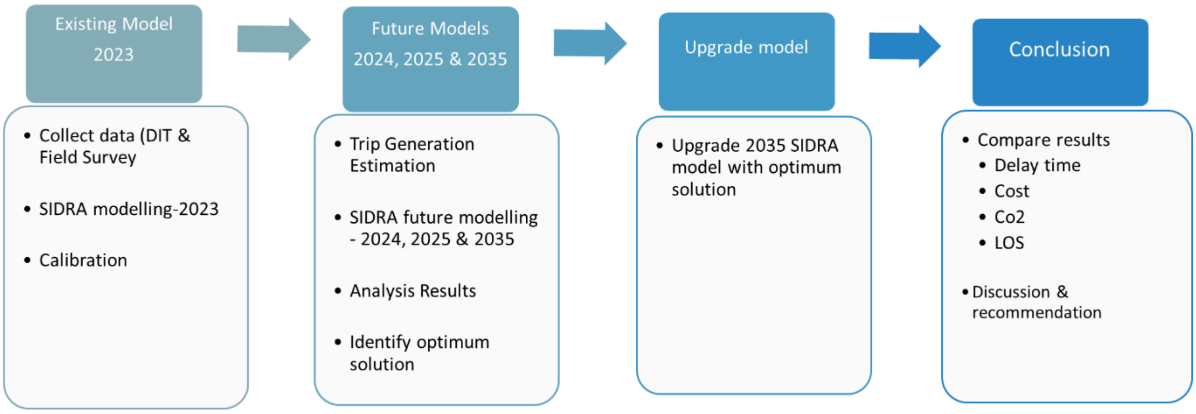


Figure 19: SIDRA Modelling Process

The SIDRA Intersection Modelling procedure involves developing models for the three intersections by feeding required inputs. Geometric and traffic data were used to develop an initial layout, which was then refined as needed. Following that, the simulation model was run through various settings to evaluate the performance of the intersections. The insights gained from this modelling were critical in identifying prospective intersection improvements and making appropriate judgements about their design and operational features.

Creating a model in SIDRA involves a series of essential steps. First, INTERSECTION DATA that include the location's site description and all existing approaches based on the data from DIT intersection drawings were fed. With this, accuracy and completeness can be achieved as it involves matching the SIDRA model geometry with the drawing specifics and on-site observations.

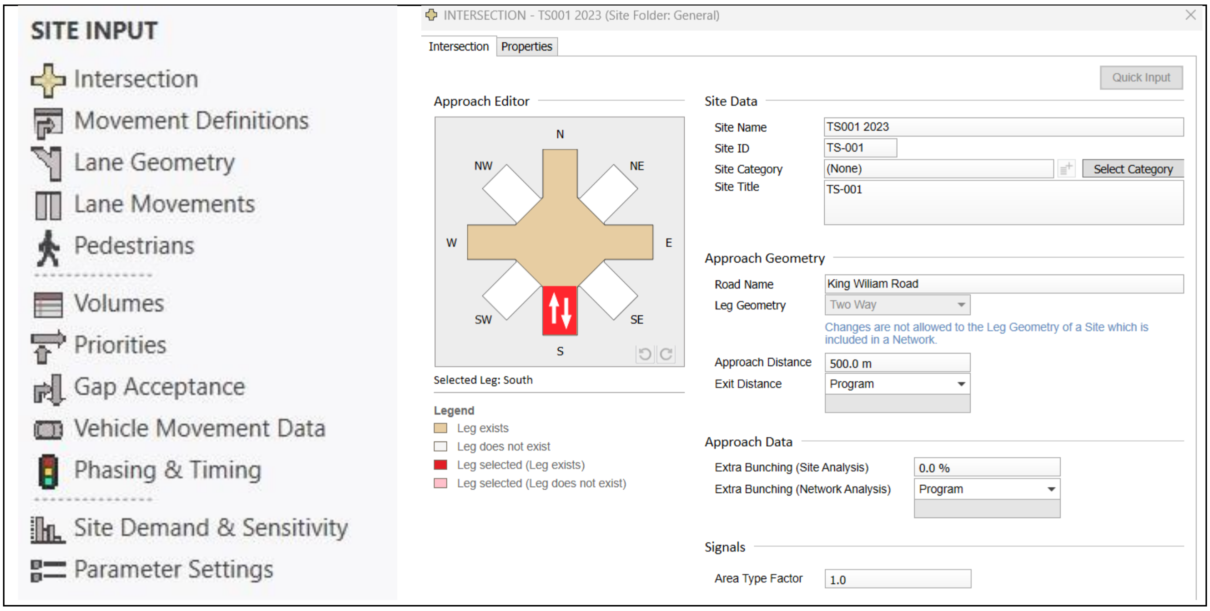


Figure 20: Intersection data

Then, MOVEMENT DEFINITIONS such as vehicle classes and approach movements were fed to the respective intersections.

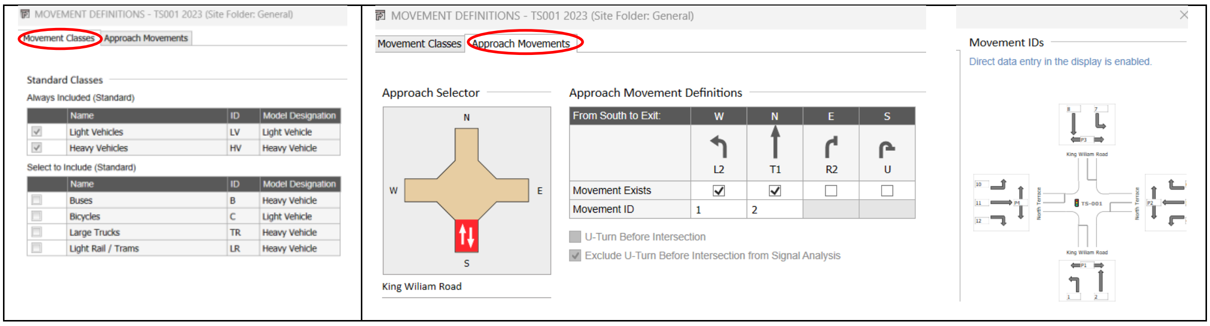


Figure 21: Movement definitions

In LANE GEOMETRY, approach and exit lanes, as well as any strip islands, were added. The key objective was to ensure that the observed intersection geometry exactly matched the current SIDRA geometry. At certain points in an intersection, it is also necessary to define the lane disciplines, directions, and possible turns.

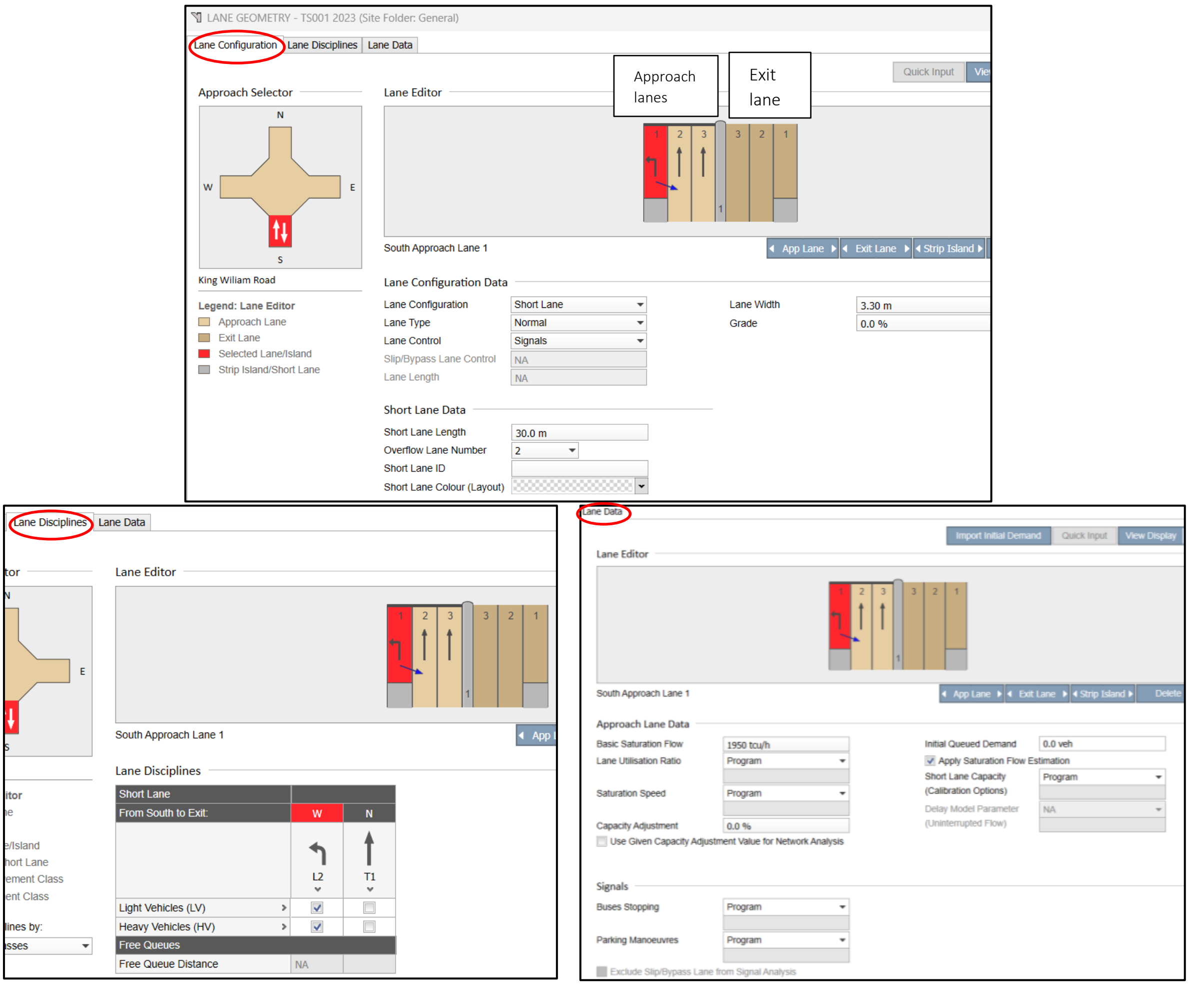


Figure 22: Lane Geometry Data

LANE MOVEMENTS step allows or prohibits movements based on intersection drawings provided by DIT and to match with current site observations.

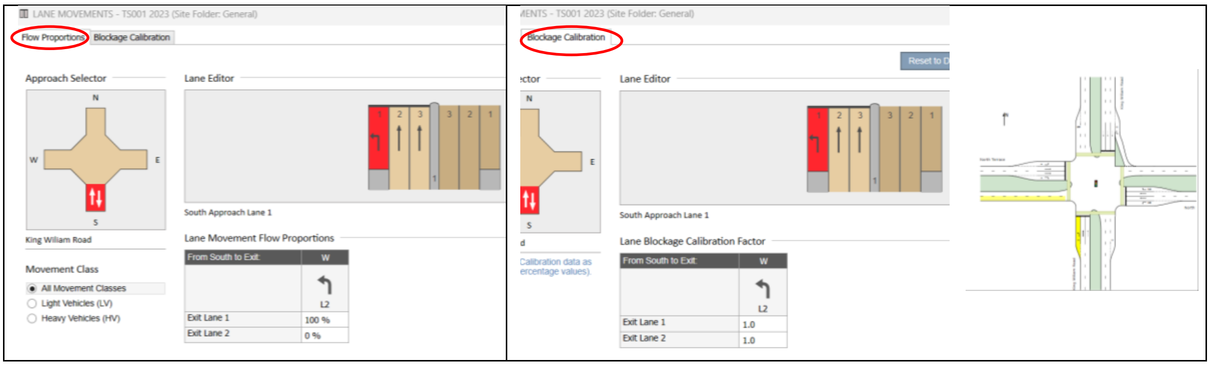


Figure 23: Lane Movements

PEDESTRIANS refer to the identification of various types of crossings and pedestrian movements, as well as the types of control present at the intersection. Field data and SIDRA default data for pedestrian movements and timing data were used for the modelling.

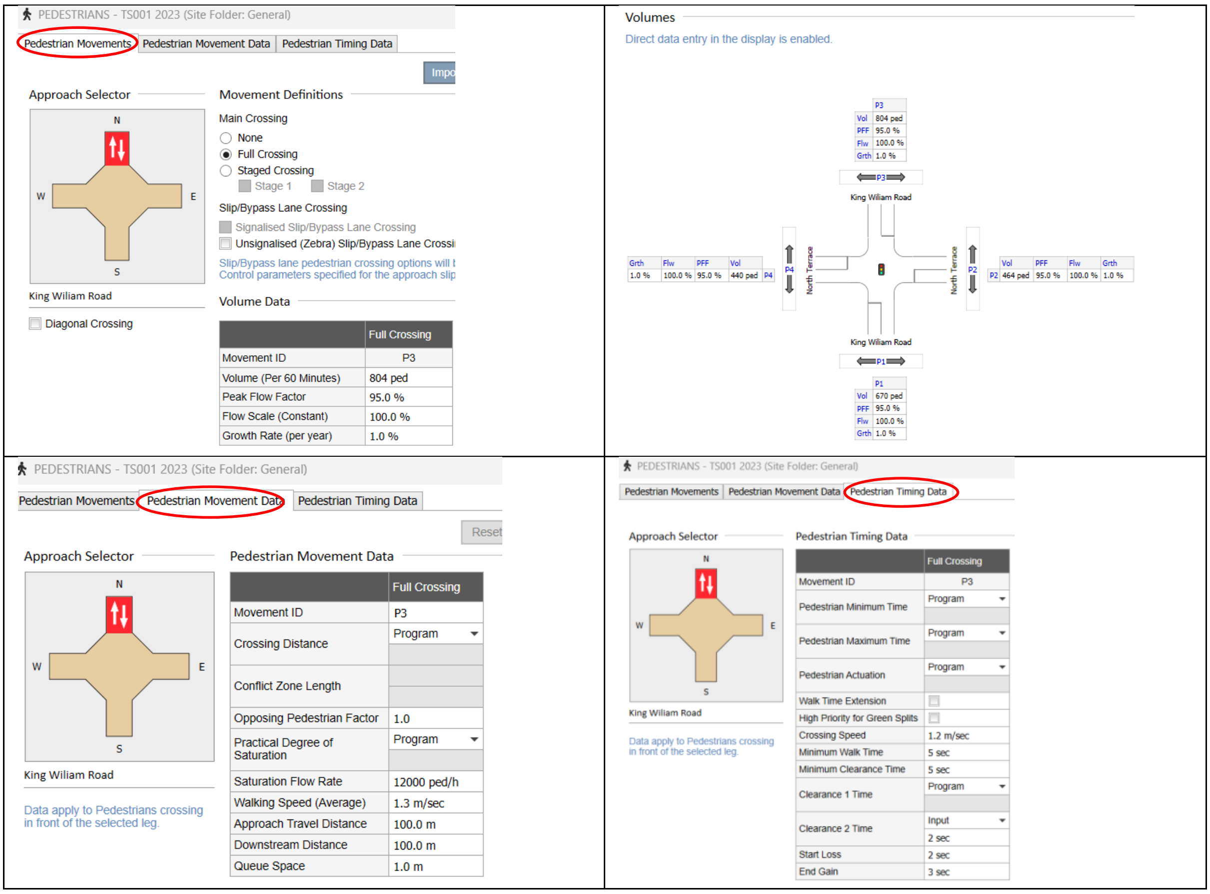


Figure 24: Pedestrians

VOLUMES step is the most critical stage in SIDRA modelling. The total number of vehicle data as input were fed based on the collected field data on different approach directions. Volume factors were remained in default setting. However, for 10-year forecast models, the growth rate was changed to 1% (D Gargett and Cosgrove, 2020).

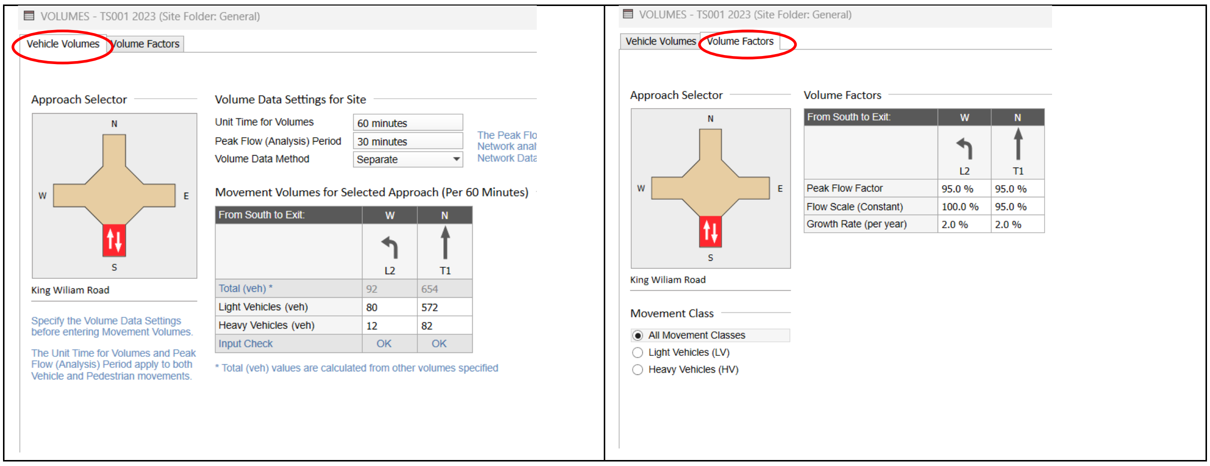


Figure 25: Volumes

PRIORITIES include the application of all movement classes and specifying any opposing movements including both vehicles and pedestrians.

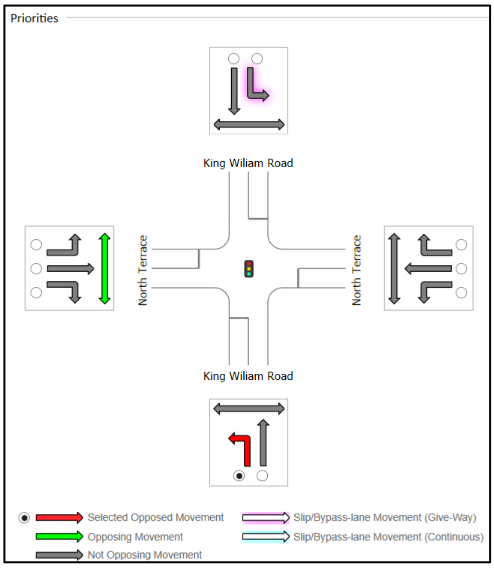


Figure 26: Priorities

GAP ACCEPTANCE requires the implementation of two-way sign control and settings compliant with SIDRA. Both parameters were chosen as default during the process.

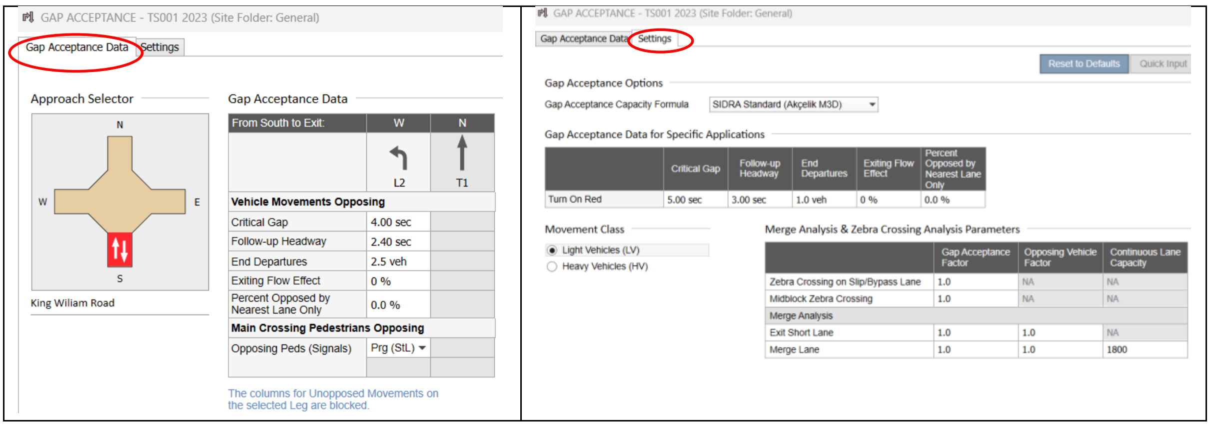


Figure 27: Gap Acceptance

VEHICLE MOVEMENT DATA includes input or preset road data, calibration, and signaling.

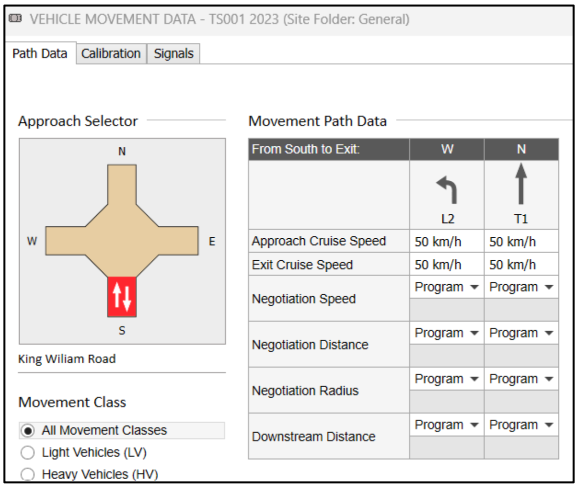


Figure 28: Vehicle Movement Data

PHASING & TIMING is considered as an important step where phasing data based on collected DIT data were fed. PM peak period was selected for the modelling based on SCATS counts. There are different types of site cycle time options in timing option tab which were used as follows,

- ✓ Existing model 2023- Selected "User-given phase times" option and specified data in "Phase & Sequence Data" tab based on collected data from DIT. User-given phase times option allows user to specify the phase time and cycle time.
- ✓ Alternative scenarios (2024,2025,2034 & 2035) – Selected "User-given cycle time" option which allows user to specify cycle time but phase time is determined by SIDRA
- ✓ Optimum Solution 2035 model – Selected "Practical Cycle Time" option which determine critical movements and calculate the phase time. Phase times and cycle time are determined by SIDRA in "Practical Cycle Time" option.

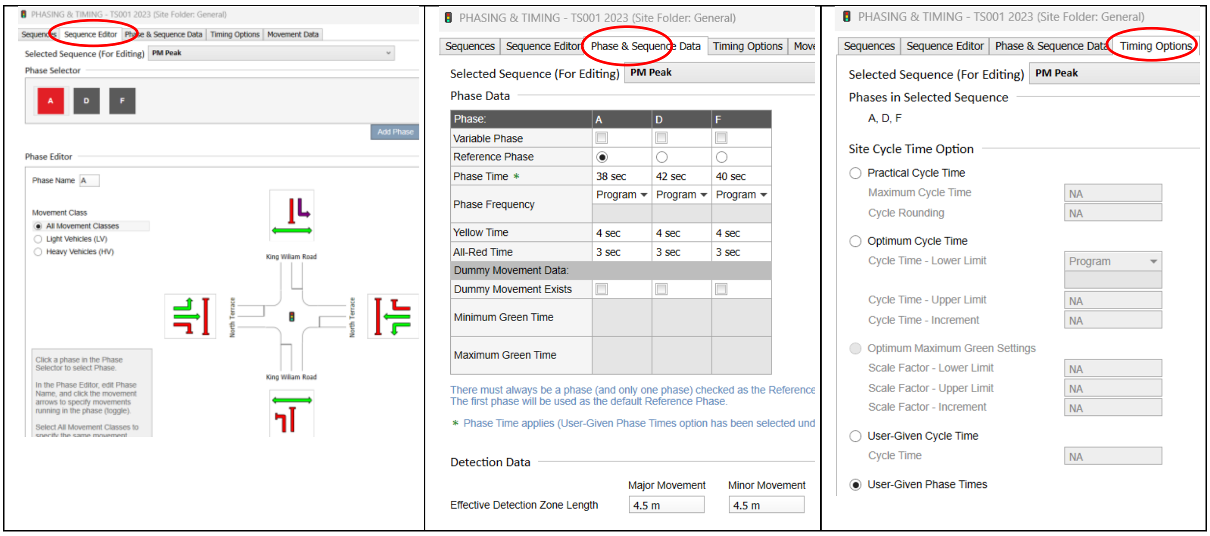


Figure 29: Phasing and Timing

DEMAND & SENSITIVITY is used to evaluate the future performance of the intersections. Demand and Sensitivity option undertook a design life study of existing and final scenarios for the next 10 years.

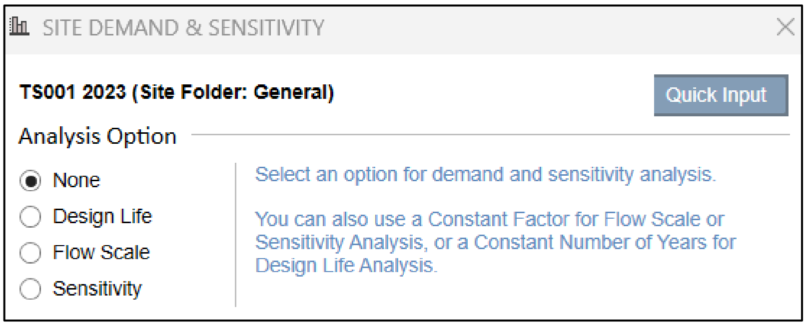


Figure 30: Demand and Sensitivity

The network modelling process in SIDRA initiated after all of the necessary parameters for the three intersections were entered. Following that, routes were added to the network, with a concentration on the northbound approach (south to north) due to the higher number of vehicular traffic in this direction compared to the south approach.

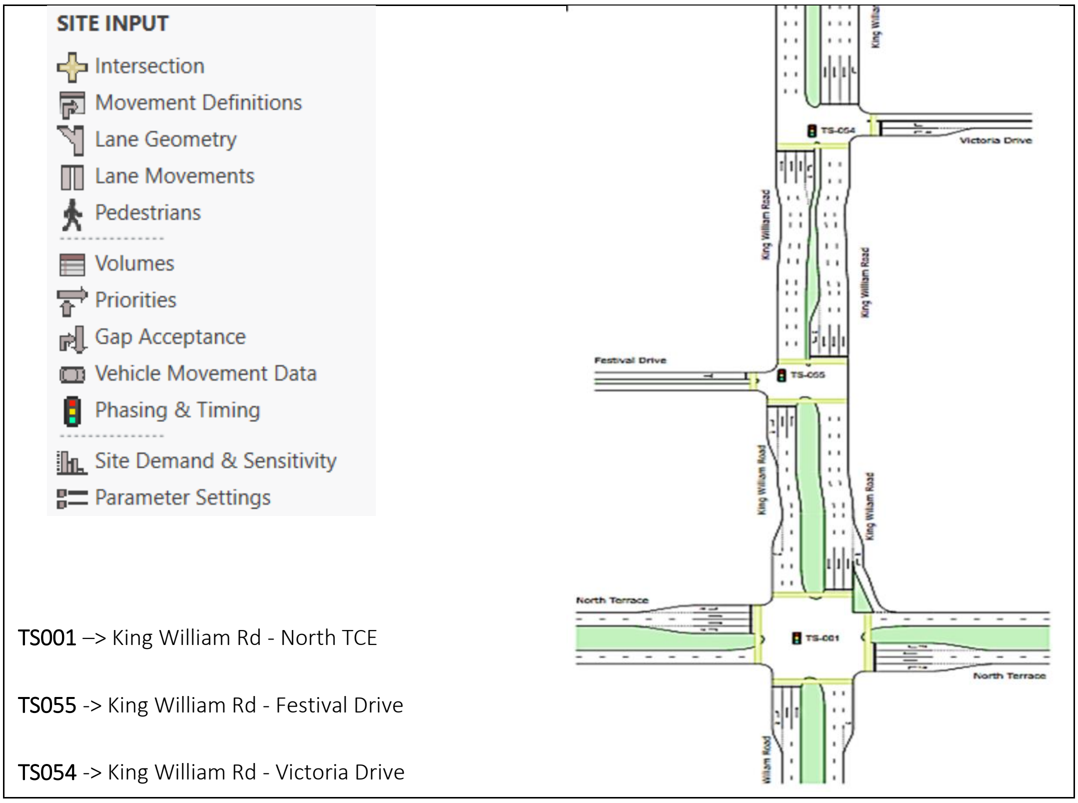
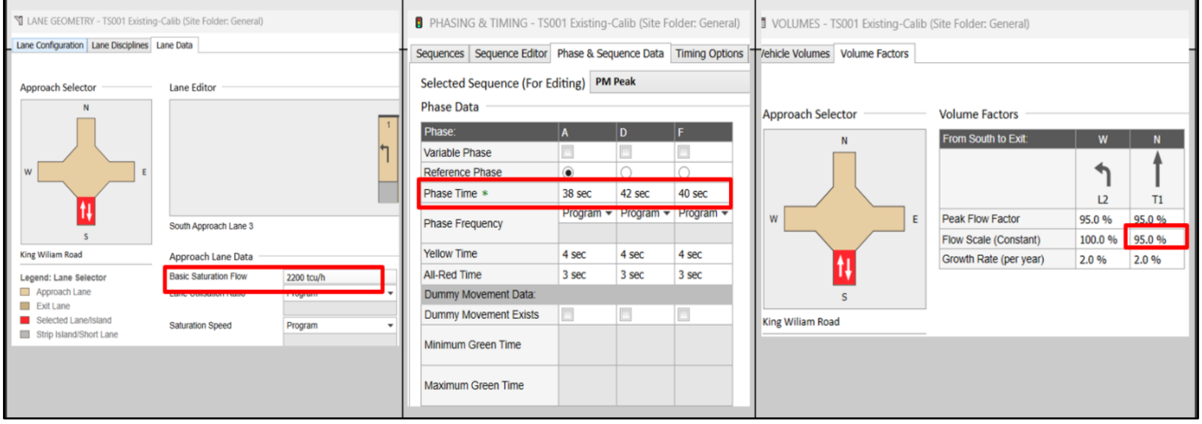


Figure 31: SIDRA Site Inputs & Existing Network

After completing the SIDRA, existing model calibration was done based on observed queue lengths as following Figure 32. Model calibration is the process of comparing model predictions with real measurements made of the system to identify a particular set of model parameters that best describe the behavior of the system.

Basic Saturation Flow	Phase Data	Volume Factor – Flow Scale



To match the observed queue length, the basic saturation flow was increased to 2200 lcu/h, which is the maximum saturation flow.	Phase time was adjusted by 1 or 2 seconds to reduce the queue lengths as observed.	Finally reduced the volume factor by 5% to get the expected queue lengths

Figure 32: SIDRA Calibration based on observed queue lengths

The calibration process concentrated on lanes 2 and 3 of King William Road's South approach. Initially, the observed queue length for these lanes was 130 meters. However, after entering the traffic volumes and related data into SIDRA, the estimated queue length was 165.1 meters.

Calibration stages were conducted to achieve a more accurate representation, with the goal of reducing the queue length from 165.1 meters to 145 meters, which equals to 10% of the observed queue length. Following these calibration changes, the queue length was successfully reduced to 139.8 meters, as shown in Figure 33.

Site: TS-001 [TS_001 Existing XC (Site Folder: General)]

Output produced by SIDRA INTERSECTION Version: 9.1.2.202

TS-001
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated Cycle Time = 120 seconds (Site User-Given Phase Times)

Lane Use and Performance

	Demand Flows [Total veh/h	HV] %	Arrival Flows [Total veh/h	HV] %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Aver. Delay sec	Level of Service	95% Back Of Queue [Veh	Dist] m
South: King William Road											
Lane 1	97	13.0	97	13.0	382	0.253	100	69.8	LOS E	4.7	36.5
Lane 2	313	12.5	313	12.5	402[1]	0.780	100	71.2	LOS E	18.0	139.4
Lane 3	375	12.5	375	12.5	481	0.780	100	46.7	LOS D	21.3	165.1
Approach	785	12.6	785	12.6		0.780		59.3	LOS E	21.3	165.1

Site: TS-001 [TS_001 Existing - C (Site Folder: General)]

Output produced by SIDRA INTERSECTION Version: 9.1.2.202

TS-001
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated Cycle Time = 120 seconds (Site User-Given Phase Times)

Lane Use and Performance

	Demand Flows [Total veh/h	HV] %	Arrival Flows [Total veh/h	HV] %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Aver. Delay sec	Level of Service	95% Back Of Queue [Veh	Dist] m
South: King William Road											
Lane 1	97	13.0	97	13.0	425	0.228	100	62.5	LOS E	4.5	35.2
Lane 2	296	12.5	296	12.5	489[1]	0.604	100	58.5	LOS E	14.8	115.1
Lane 3	358	12.5	358	12.5	593	0.604	100	39.3	LOS D	18.0	139.8
Approach	751	12.6	751	12.6		0.604		49.8	LOS D	18.0	139.8

Figure 33: SIDRA queue lengths before and after calibration

Further, South approaches of other two intersections were adjusted by changing the saturation flow to 2200 lcu/h.

To analysis the road performance the following scenarios were modelled by adjusting the existing model by SIDRA.

- 2023 existing model was forecasted for 10 years (2033).
- 2024 model was done by forecasting existing model for 1 year and allocating the calculated new trips due to 8 floors of university
- 2024 model was forecasted for 10 years (2034).
- 2025 model was done by forecasting 2024 model for 1 year and allocating the calculated new trips due to 16 floors of office spaces.
- 2025 model was forecasted for 10 years (2035).

Resulting output of above models were analyzed to recommend the optimum solution which is discussed in section 4 of the report.

3.4 AIMSUN Modelling

AIMSUN is a powerful traffic simulation tool that enables the development of complex models of traffic networks, testing of various scenarios, and analyzing of the outcomes. The detailed procedure for using the AIMSUN software to simulate various scenarios is described in this section. The model was also calibrated and validated, demonstrating its accuracy in simulating actual traffic situations.

Overall, AIMSUN software modelling process can be shown below Figure 34.

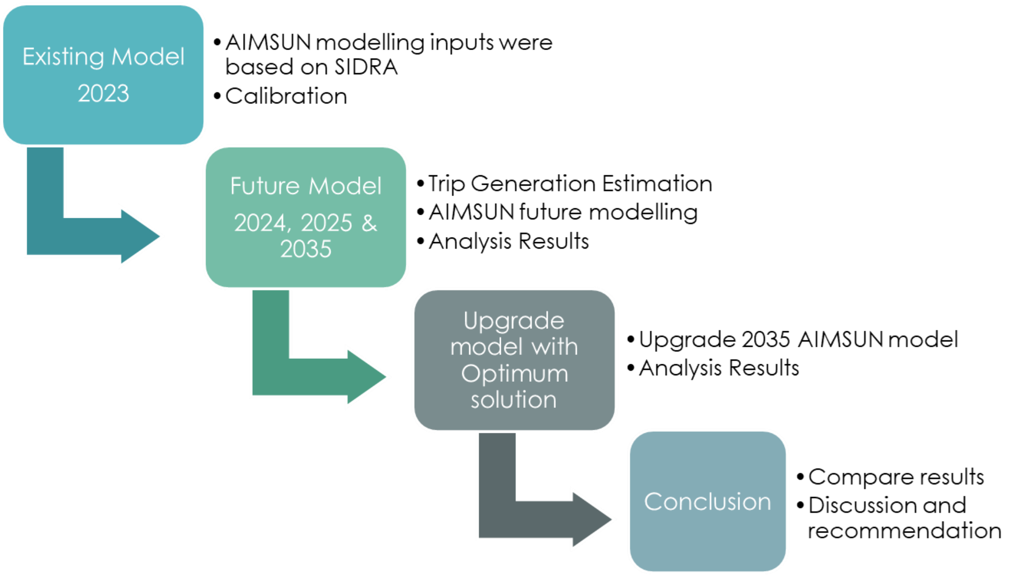


Figure 34: AIMSUN Modelling Process

The general steps to create a model in AIMSUN can be identified as follows:

The Network Geometry was first created by Importing the road network and adjusting the road geometry as in SIDRA model which includes number of lanes adjustments, intersection alignment, turning movements, lane discipline, yellow box, stop-lines and turn priorities. Then, the Traffic Demand, Control Plan and Master Control Plan were specified. Specifying of Signal Phasing was followed thereafter for the three intersections same as SIDRA Model as below Figure 35.

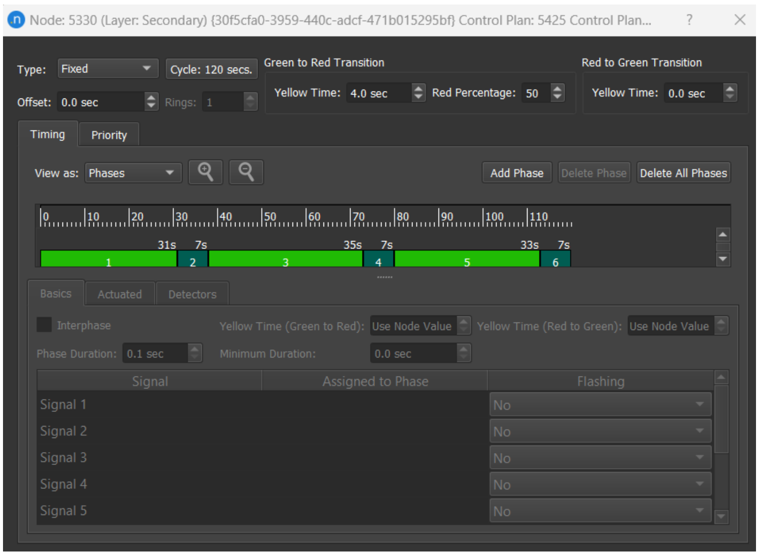


Figure 35: AIMSUN Signal Phasing

As next step Centroids were created and connected based on below Figure 36.

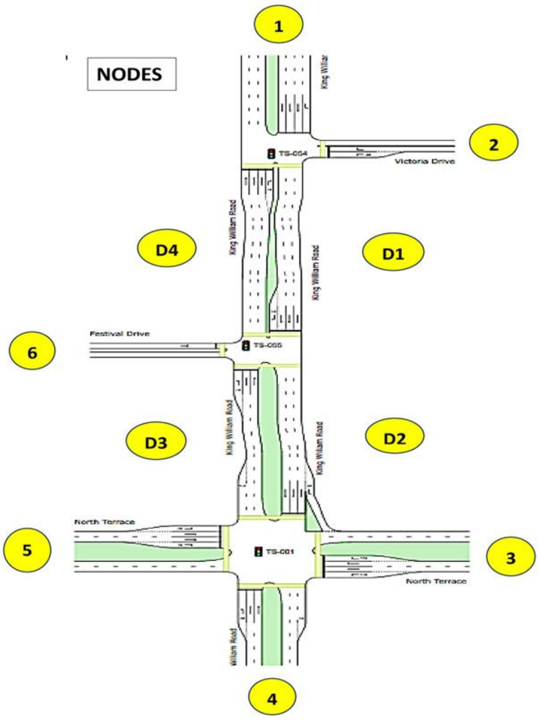


Figure 36: Nodes of the road network

Then OD Matrices were prepared. It is necessary to prepare OD-Matrices that outline travel patterns within the network in order to feed AIMSUN with the crucial data. D1, D2, D3, and D4 in this context are dummy regions created by SIDRA to synchronize the flow of vehicles at each intersection. One OD matric was made for trucks while the other was made specifically for passenger cars. The OD matrix for the 2025 model is located in the Annex 12, whereas the OD matrix for the existing (2023) model is shown in Figure 37 for reference.

Cars

	5369: 1	5405: 2	5406: 3	5407: 4	5408: 5	5409: 6	5467: D1	5470: D2	5473: D3	5476: D4	Total
5369: 1		172	90	416		50	84				812
5405: 2	256		4	4		4	4				272
5406: 3	284	10		136	604	10					1044
5407: 4	542	20			80	10					652
5408: 5	120	10	520	80		10					740
5409: 6	40	20	42	50							152
5467: D1				10							10
5470: D2											
5473: D3	32					20					52
5476: D4	230	20									250
Total	1504	252	656	696	684	104	88				3984

Heavy vehicles

	5369: 1	5405: 2	5406: 3	5407: 4	5408: 5	5409: 6	5467: D1	5470: D2	5473: D3	5476: D4	Total
5369: 1		8	5	43			34				90
5405: 2	8										8
5406: 3	22			16	44						82
5407: 4					12				82		94
5408: 5	20		28	9							57
5409: 6			1	3							4
5467: D1											
5470: D2			12	30							42
5473: D3											
5476: D4	27	12									39
Total	77	20	46	101	56		34		82		416

Figure 37: AIMSUN OD Matrix for Cars and Heavy vehicles

Then, Sub-path was created to analyze specific pathways and produce AIMSUN outcomes. These results act as useful standards, enabling comparisons with the outcomes of SIDRA.

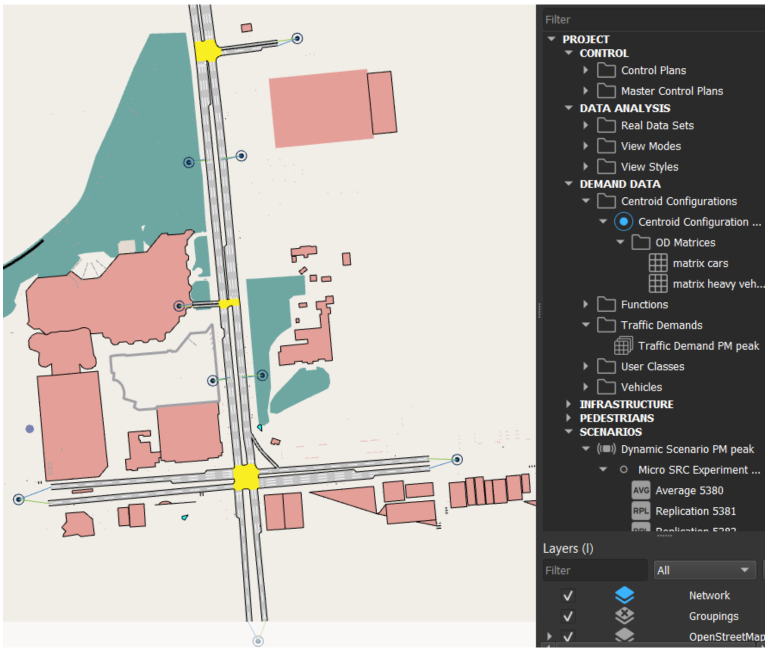


Figure 38: AIMSUN Inputs and Model

A minimum of five replications must be carried out for AIMSUN model scenarios.

A dynamic experiment in AIMSUN needs a replication. The number of replications to be performed can be defined when a replication object is added to the experiment. It was set to five in this instance. A unique random seed is used for each replication to create and reflect variation. To get the average results from a set of replications, an optional average calculation was done.

As seen in Figure 39, the consistency of the results across all replications is within a 5% margin, demonstrating the model's stability to be quite resilient.

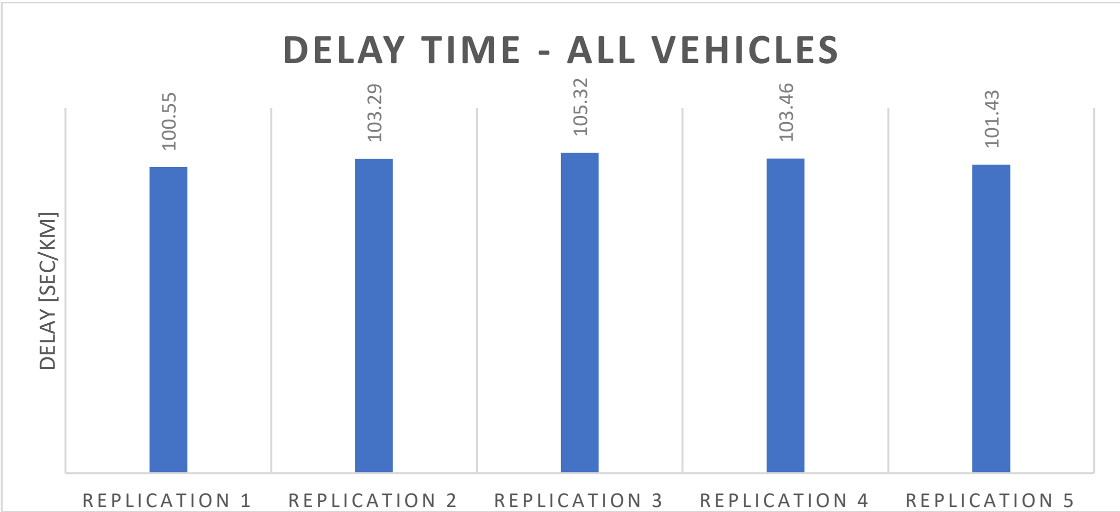
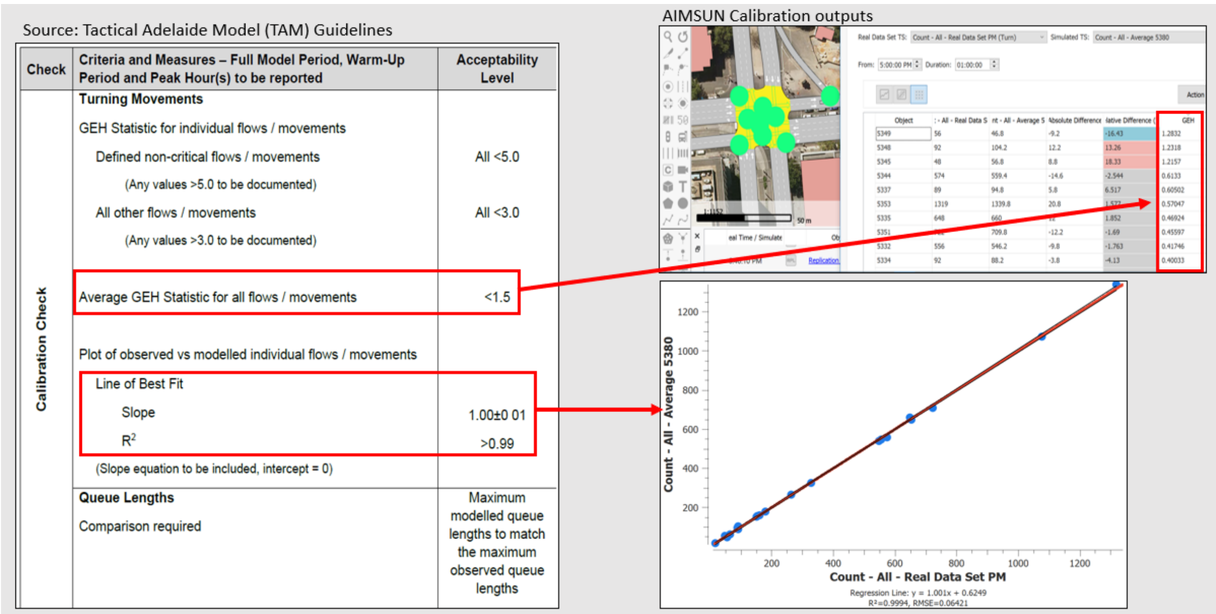


Figure 39: Delay time of five replications

After completing the AIMSUN existing model, calibration was done based on observed flow as follows. In order to obtain an accepted degree of confidence when compared to the on-street conditions, general calibration and validation activity needs an iterative process of adjusting parameters and reviewing model outcomes.



Check	Criteria and Measures – Full Model Period, Warm-Up Period and Peak Hour(s) to be reported	Acceptability Level
Calibration Check	**Turning Movements**	
	GEH Statistic for individual flows / movements	
	Defined non-critical flows / movements	All <5.0
	(Any values >5.0 to be documented)	
	All other flows / movements	All <3.0
	(Any values >3.0 to be documented)	
	Average GEH Statistic for all flows / movements	<1.5
	Plot of observed vs modelled individual flows / movements	
	Line of Best Fit	
	Slope	1.00±0 01
	R^2	>0.99
	(Slope equation to be included, intercept = 0)	
	Queue Lengths	Maximum modelled queue lengths to match the maximum observed queue lengths
	Comparison required	

Figure 40: AIMSUN Model Calibration

To analyze the road performance the following scenarios were modelled by adjusting the existing model by AIMSUN.

- 2025 model was done by increasing traffic demand volume factors of existing model by 2% (1% growth per year; 2% for 2-year forecast) and feeding the new OD matrix by allocating the calculated new trips due to the whole building development.
- 2035 model was done by increasing the traffic demand volume factor by 10% (1% growth per year; 10% for 10-year forecast).

Resulting output of above models were analyzed to recommend the optimum solution which is discussed in section 4 of the report.

3.5 AIMSUN and SIDRA model consistency.

Due to their various areas of expertise, SIDRA and AIMSUN software were both used for road performance study. While AIMSUN is a simulation program that can visualize accurate locations based on architectural markers, SIDRA focuses mostly on intersections and has the ability to optimize signals. AIMSUN, for example, can pinpoint exactly the location of the road extension ends, but SIDAR can simply specify the extension length. In addition, SIDRA considers constant queue space (7m), whereas AIMSUN considers varied queue spaces (4m, 5m, etc.) dependent on vehicle size.

As a result, SIDRA software was used to analyze individual intersections and optimize signal phasing. AIMSUN was used to simulate road network in order to analyze road performance.

Furthermore, the comparability of SIDRA and AIMSUN models was examined in order to validate both software modeling. Delay times were compared, and close vehicle delays were observed for the SIDRA and AIMSUN models, as shown in the Table 3 below. The speeds of the SIDRA network and the AIMSUN network were also compared, and they were within 10% of each other. Further, queues were observed in 2035 optimized SIDRA and AIMSUN models.

Table 3: SIDRA and AIMSUN model comparison

FACTOR	SIDRA	AIMSUN
2023 Model - Delay Time for TS001	45.3 s	43 s
2023 Model - Speed of Network	35.5 km/h	33.6 km/h
2035 optimized Model – Queue of TS001 South Approach	6 vehicles	5 vehicles

3.6 Model Assumptions and Limitations

Several constraints were discovered during the research: First, software restrictions were identified especially regarding the retention of default settings for certain SIDRA parameters, but this only needs to be resolved if inconsistencies are found during the validation stage. Furthermore, constraints were identified with the SIDRA and AIMSUN student versions, which may limit opportunities for analyzing outputs. Second, calculating assumptions, particularly in trip generation estimations, were noted. Resource and time constraints were the key restraints, affecting the model's level of detail. As a result, a sensitivity analysis was performed in order to find additional parameters influencing traffic flow on the road network. Finally, unforeseeable circumstances, such as traffic flow differences caused by harsh weather conditions, were considered as potential constraints.

4 RESULTS AND ANALYSIS

This chapter shows the findings from two distinct methods used to examine the effects of new development on the road network, namely the microsimulation AIMSUN model and SIDRA Intersection evaluation. The results from these two techniques will be utilized to estimate the effect of development in terms of many metrics, including LOS, total annual cost, emissions, and delay. The findings will be presented and reviewed in order to suggest appropriate road and signal enhancement to improve network performance.

The data output from the SIDRA and AIMSUN computer programs were analyzed by determining the delay, total cost per year, CO_2 emission, LOS and queue lengths etc. DIT recommendations for establishing acceptable values were used where possible (DIT, Traffic Modelling Guidelines: SIDRA Intersection, 2022). Field survey data and collected DIT data were utilized to model the existing conditions using software. New trips due to the developments were estimated by ITE Trip generation rates and then modelled by SIDRA and AIMSUN. Furthermore, the network was projected for the next ten years using traffic data. Resulting output of all models were analyzed to recommend the optimum solution. To improve the road performance some adjustments were carried out using the SIDRA 2035 model.

4.1 SIDRA Results analysis

The SIDRA program offers a number of performance measures that can be used to assess the operation of signalized intersections. These measurements are essential for determining intersections' effectiveness and safety. SIDRA provides indicators of performance including capacity, delay, level of service, queue length, and speed. This component of the study concentrates on the SIDRA outputs for delay and Level of Service, which are important measures of intersection performance. Additionally, total yearly costs are taken into account as an economic element, and CO2 emissions are taken into account as an environmental factor. All SIDRA results can be found in the Annex 6.

4.1.1 Optimum solution

The development has resulted in significant increases in delay time, total cost each year, and CO2 emission levels. The LOS of the TS001 intersection (King William Rd.-North TCE) in 2035 will be LOS F, indicating that road upgrade is a critical demand due to the festival plaza expansion.

Important outputs provided by SIDRA include Detailed output, Intersection Summary, Movement Summary, Lane Summary, Lane Flows, LOS Summary, Phasing Summary, Graphs and intersection performance results that can be used to analyze the performance of the road and recommend enhancements to improve the performance.

SIDRA offers a number of calculation methods to determine the Level of Service (LOS) for vehicles such as: Delay (HCM 2000), Delay & V/C (HCM 2010), Delay (RTA NSW), Degree of Saturation (SIDRA Method) and ICU Method. However, Delay (RTA NSW) is the default LOS method of SIDRA for vehicles.

Control delays of three intersections were considered individually. According to SIDRA INTERSECTION 9.1 User Guide control delay should be less than 55s which means the levels above LOS D as below Figure 41.

Delay (RTA NSW) method for Level of Service definitions based on delay only (for vehicles)

Level of Service	Control delay per vehicle in seconds (d) (*including geometric delay*)
	All intersection types
A	d ≤ 14.5
B	14.5 < d ≤ 28.5
C	28.5 < d ≤ 42.5
D	42.5 < d ≤ 55
E	55 < d ≤ 70.5
F	70.5 < d

For the RTA NSW model in SIDRA INTERSECTION, this is the default *LOS Method* for vehicles.

Figure 41: Delay method for LOS

To increase the LOS the following changes were done to the network by considering the intersections individually (Figure 42).

- Add New lanes
- Change short lane lengths
- Use “Practical cycle time” which determine critical movements and calculate the phase time

It was possible to reduce the Control delays to less than 55s by enhancing the road network and signal phasing changes as below Table 4.

Table 4: Control delay changes

Intersection / Model	Control Delay (Average) - sec		
	TS001	TS055	TS054
2023 (Existing)	45.3	16.9	28.2
2035	88.7	66.1	28.6
2035 with Optimum Solution	47.3	38.8	28.6 - Ok

As shown in Table 4, only the intersections TS001 (King William Rd - North TCE) and TS055 (King William Rd - Festival Drive) are significantly impacted by the Festival Plaza Tower development.

TS001 has a substantially high control delay among the intersections of TS001 and TS055, requiring improvements through road enhancements. As such, one lane was added in each of the four directions in TS001 intersection shown in Figure 42. North approach was added with a new lane of length only by 180m which is the distance between TS001 and TS055 intersections. Other proposed three new lanes in other directions are 300m in length at TS001 intersection. Further, in West approach 30m left turn short approach lane was extended as a full lane (300m). In South approach 50m exit short lane was extended as a full lane (300m). In the intersection TS055, South approach left turn short approach lane was extended from 20m to 100m. So, all together proposed total road length extension is about 2km.

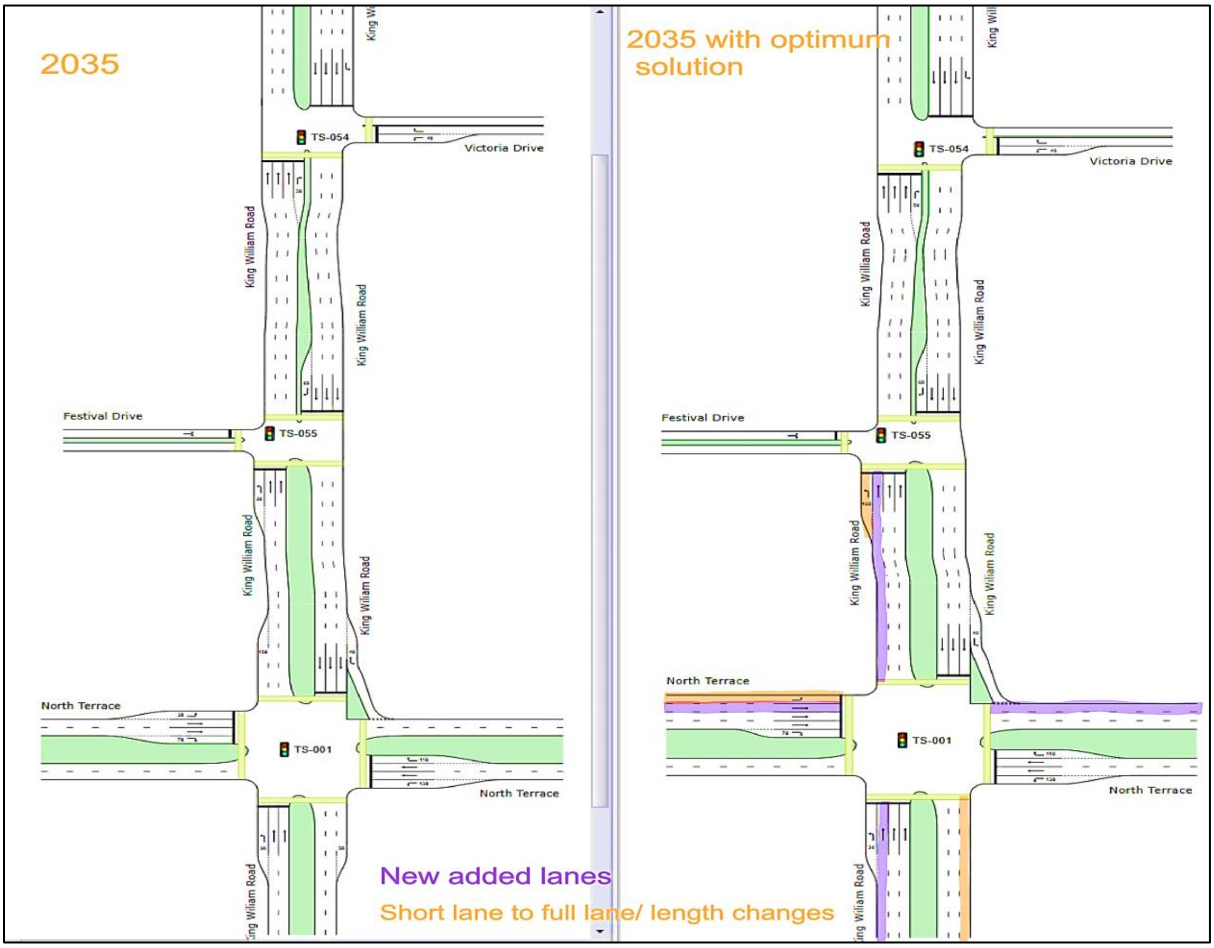


Figure 42: SIDRA Optimum Solution Changes

As a result of the SIDRA optimization of signals by selecting the "practical cycle time" option which determine critical movements and calculate the phase time as "site cycle time", new phasing times can be found as following Figure 43. As a result, network cycle time was changed from 100s from 110s.

According to Figure 43, in intersection TS001, phase time of phase D was increased from 35 seconds to 38 seconds, while phase time of phase F was increased from 30 seconds to 37 seconds. There were no modifications in phase time for phase A, which stayed at 35 seconds. In intersection TS055, phase time of phase A was decreased from 58 seconds to 34 seconds while phase C was increased from 30s to 64s. No phase time changes were identified in phase B which was 12s. At intersection TS054, the phase time of phase A was increased from 41 seconds to 43 seconds, and phase B also experienced an increase from 22 seconds to 30 seconds. No adjustments in phase time were detected for phase C, which remained constant at 37 seconds. These adjustments were determined by SIDRA based on practical cycle time.

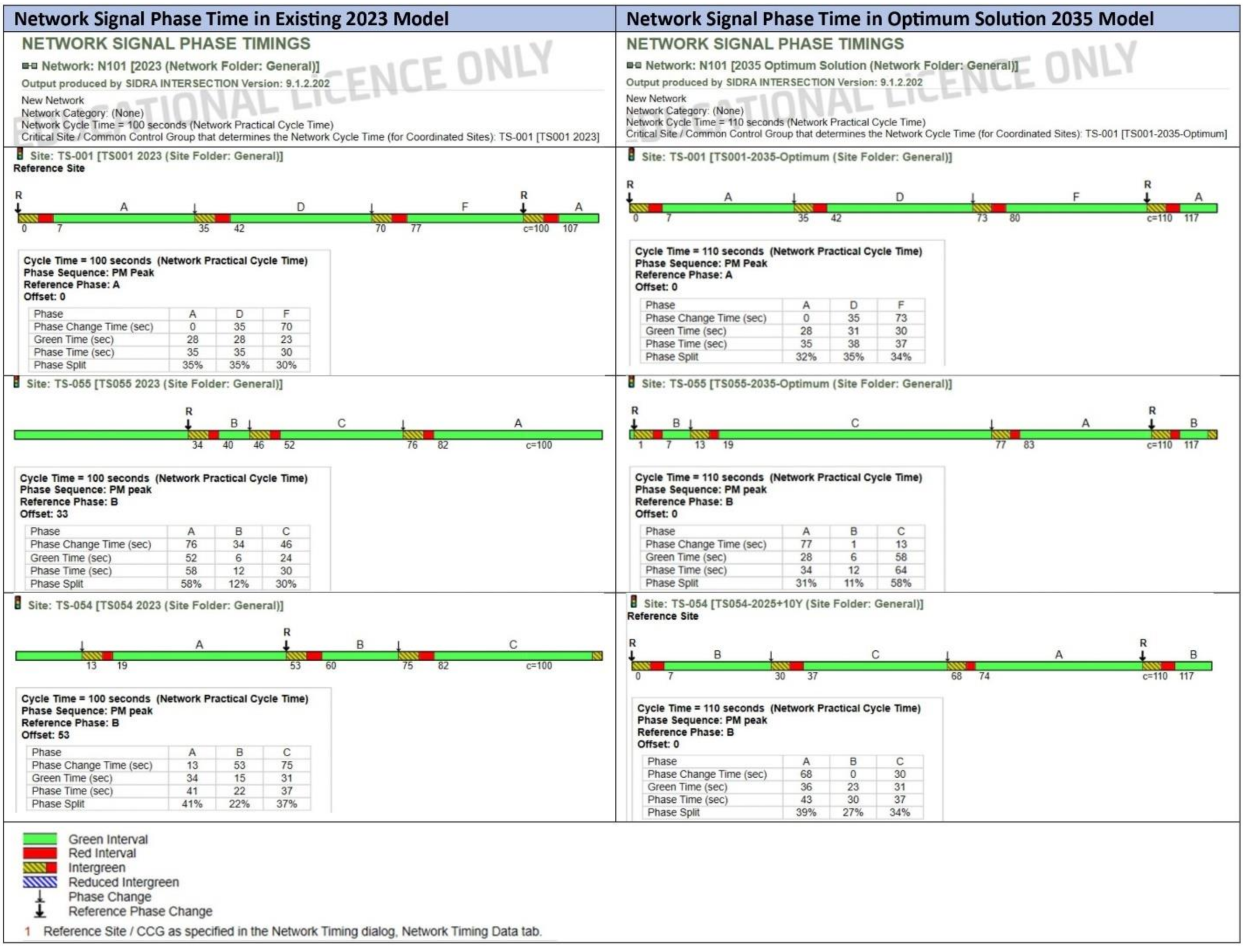


Figure 43: SIDRA Optimum cycle time

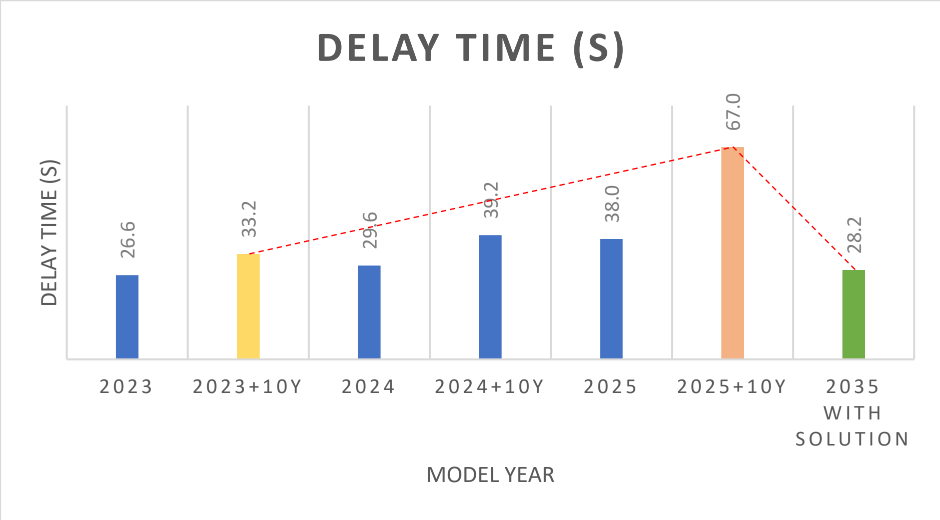
4.1.2 Delay

Delay is the additional travel time a vehicle experiences in comparison to the base travel time. As the main traffic-related outcome from SIDRA scenarios, delay time analysis was performed as per the Figure 44. As a primary output of comparing alternative scenarios, vehicle delays were utilized by SIDRA to compare the base case with the project scenarios and determine the recommended scenario.

The SIDRA software proved to be a useful tool for undertaking delay time analyses (in seconds) in the prediction of future enhancements and the corresponding changes in traffic patterns. Predicting the potential influence on traffic congestion and travel times becomes increasingly important to conduct a TIS to analyze the road performance due to the new development. SIDRA enables the ability to model several future scenarios that take into account the effects of new development projects and increased vehicle movements. With the input information about expected traffic volumes based on trip generation estimates, the software is capable of simulating and analyzing delays. This information assists in making decisions about road expansion, adjustments to signal timing, or other potential upgrades. This proactive approach ensures that the new development aligns with the goal of reducing traffic delays and managing overall transportation network efficiency, benefiting both current and future population and commuters.

SIDRA models were created for the existing condition and future models for 2024 (after opening eight floors of the building for Flinders University), 2025 (after opening the entire building with the remaining

16 office floors), and 10-year forecasting models for 2023, 2024, and 2025. Delay time of all scenarios can be compared as in the following Figure 44.



Existing Delay time – 26.6s

10Y without Festival Plaza – 33.2s

10Y with Festival Plaza – 67s

With optimum solution – 28.2s

Difference – 39s

Figure 44: Delay time vs. scenarios

As a result of the growing population, traffic delay times are getting longer every year. Figure 44, which forecasts a significant 42.9% increase in delay times by 2025 compared to the delay time in 2023, illustrates this trend. The most concerning scenario, however, occurs in 2035, when delay times increase by an outstanding 151.9% relative to the baseline.

This sudden increase is mainly due to the construction of the Festival Plaza tower. Focus must be placed on the fact that, even in the absence of the construction of tower during the next ten years, a considerable 24.8% rise in delays compared to the current scenario is expected. Therefore, it is essential to take into account changes to the signal phasing and road infrastructure.

The proposed optimum approach offers significant assurance, potentially reducing delay times by 39 seconds when compared to the anticipated delay durations for 2035. This would represent a significant 57.9% decrease in delay times, demonstrating the efficacy of this solution.

4.1.3 Level of Service

Level of service is primarily employed as a control threshold for proposed scenarios, ensuring that the scenario accurately represents a feasible concept. In project scenarios for the future design year, LOS D is the minimal need for intersections as a performance measure. However, level of service can also be utilized for demonstrating a general comparison between the base case and options.

Signalized intersection level of service (LOS) is defined as the average total vehicle delay of all movements through an intersection. Driver discomfort, irritation, and wasting travel time can all be quantified through the use of vehicle delay. Particularly, LOS criteria are expressed in terms of the average delay per vehicle over a given time frame (PM peak hour). Vehicle delay is a complicated metric that depends on a number of factors, such as signal phasing, signal cycle length, and traffic volumes in relation to intersection capacity. According to the Highway Capacity Manual, Figure 45 lists the LOS standards for signalized intersections.

Level of Service	Average Control Delay (sec/veh)	General Description (Signalized Intersections)
A	≤10	Free Flow
B	>10 - 20	Stable Flow (slight delays)
C	>20 - 35	Stable flow (acceptable delays)
D	>35 - 55	Approaching unstable flow (tolerable delay, occasionally wait through more than one signal cycle before proceeding)
E	>55 - 80	Unstable flow (intolerable delay)
F	>80	Forced flow (jammed)

Figure 45: Level of service criteria for signalized intersections

The outcomes of the SIDRA intersection investigation highlighted an upcoming issue in the network, as shown in Figure 46. The Level of Service (LOS) is predicted to reach a concerning LOS F by the year 2035, indicating a potential traffic problem during the busiest PM period. This development appears to have had less impact on the TS054 intersection. The King William Road TS001 intersection emerges as a significant obstacle with considerable control delay, which is of particular concern when compared to the intersections of TS001 and TS055.

A number of necessary road improvements were proposed in response to this oncoming problem. Firstly, the signal phasing was enhanced. As shown in Figure 46, one option was to add an additional lane in each of the four directions. Notably, the length of the additional lane for the North approach was only 180 meters, whereas the other three proposed lanes were 300 meters long, showing a significant improvement. Additionally, specific changes were made to handle lane extensions, such as expansion of the 50-meter exit short lane to a full lane in the South approach and the 30-meter left turn short approach lane in the West approach to a full lane (300m). Additionally, the left turn short approach lane for the South approach was extended from 20 meters to 100 meters at intersection TS055. Altogether this proposed road improvement is about 2km road lane extension. The Level of Service (LOS) was raised to a more manageable LOS D through proposed improvements to the road network and signal, effectively minimizing the issues associated with traffic congestion.

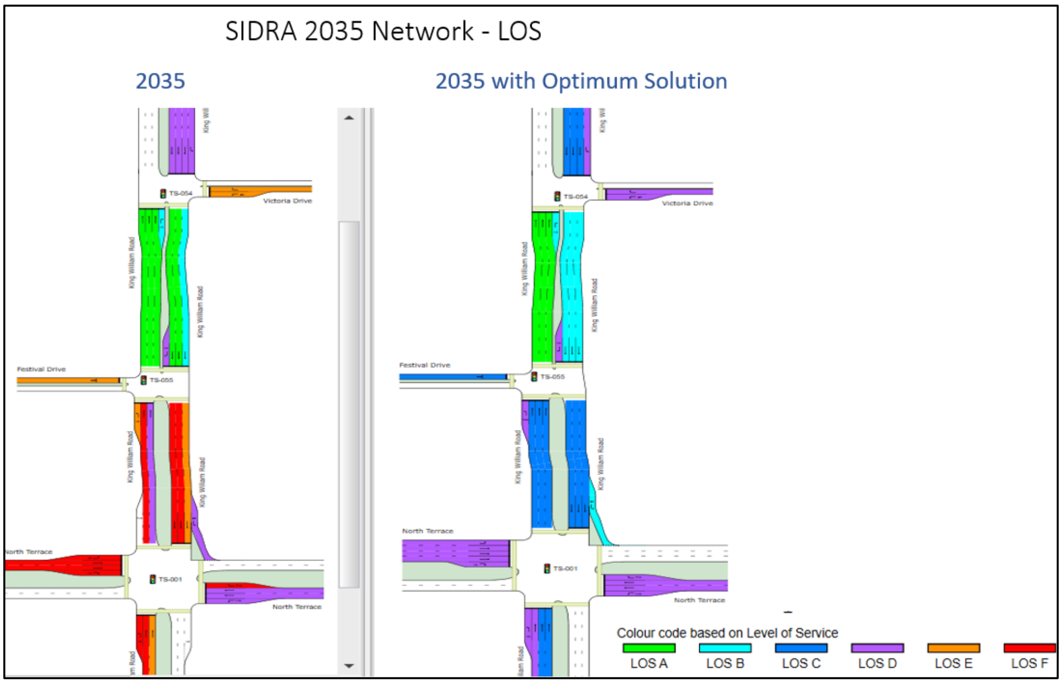
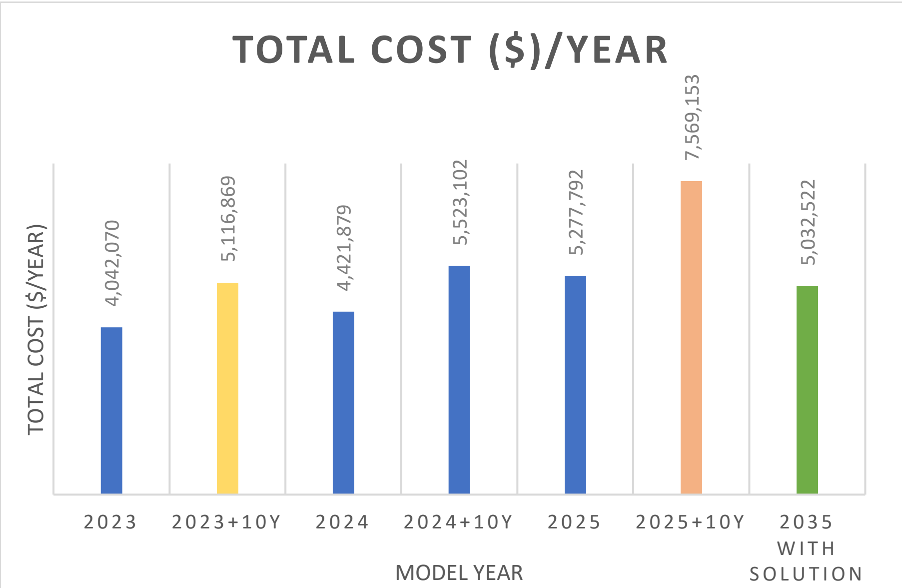


Figure 46: Level of service of 2035 SIDRA model before and after optimum solution

4.1.4 Total Cost per Year

Total cost per year was analyzed as a primary output related to economy from SIDRA scenarios. The SIDRA software is essential for estimating total expenditures, including vehicle operating costs (fuel cost per liter) and time cost (dollars per hour), across a range of future scenarios influenced by the new development. SIDRA facilitates to predict and analyze overall expenses over time, allowing users to assess the financial and time-related impact of new development. The software aids in identifying potential problem areas by accepting data for many years and circumstances. This analysis is crucial for making decisions that are in line with the objective of reducing commuters' travel time and vehicle operating expenses. The ultimate goal of this strategy is to calculate the overall cost savings based on the suggested road and signal improvements.



Existing Total Cost – 4M

10Y without Festival Plaza – 5.1M

10Y with Festival Plaza – 7.5M

With optimum solution – 5M

Difference – 2.5M

Figure 47: Total cost per year vs. scenarios

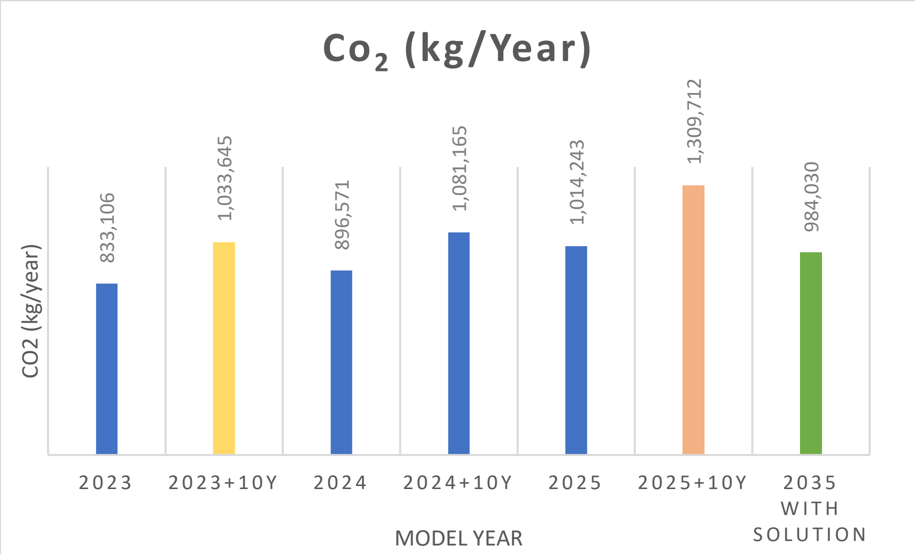
The increase in traffic causes the overall annual expenditure to keep rising every year. This trend is illustrated in Figure 47, which forecasts a significant 30.5% increase in yearly total costs by 2025 in comparison to the 2023 figures. The most concerning scenario, however, takes place in 2035, when annual total costs are predicted to rise by an outstanding 87.3% above the base year.

This large increase is primarily attributable to the construction of the Festival Plaza tower. It is important to emphasize that, even without the building of the Festival Plaza tower during the next ten years, still a significant 47.9% increase in annual total costs compared to the existing scenario is expected. Because of this, it is essential to take into account upgrading in signal phasing and road infrastructure.

When compared to the estimated yearly total expenses for 2035, the proposed optimal solution shows significant assurance, potentially saving $2.5 million per year. This would represent a significant 33.5% reduction in annual total costs, demonstrating the effectiveness of this proposed solution.

4.1.5 Emission

Road network delays and traffic congestion contribute to a number of environmental issues. Increased fuel consumption and the emission of hazardous pollutants as a result of new development have a negative impact on mobility and safety (Chou et al., 2010). The occurrences of releasing gases such as carbon dioxide are harmful to human health and also contribute to environmental contamination. Therefore, it is essential to quantify these emissions in order to evaluate how well the suggested solutions perform to lessen their impact. The amount of CO2 emissions for every scenario were taken into consideration in the study by SIDRA presented in Figure 48.



Existing Co2 level – 0.8M

10Y without Festival Plaza – 1M

10Y with Festival Plaza – 1.3M

With optimum solution – 1M

Difference – 0.3M

Figure 48: Co2 emission (kg/year) vs. scenarios

The trend of CO2 emissions, although not considered as unexpected, is alarmingly and continually increasing with each passing year. Figure 48 shows how CO2 emissions are anticipated to increase by 21.7% by 2025 compared to 2023 values. The worst-case scenario, however, is the year 2035, when CO2 levels will have increased by an outstanding 57% above the baseline year. The reason for the drastic increment is the Festival Plaza tower development. It is important to note that a significant 24% increase in CO2 emissions relative to the current situation could be expected even without the construction of the Festival Plaza tower in the next ten years. Therefore, road and signal phasing enhancements are required. When compared to expected emission levels for 2035, proposed optimum solution has the potential to reduce CO2 emissions by 0.3 million kilograms year, which would represent a considerable 24.9% reduction.

4.2 AIMSUN Results Analysis

The AIMSUN data were utilized to visually analyze vehicle flow and queue lengths, allowing for better understanding of how the road network operates. AIMSUN can also be used to determine the exact finish point of an extended route. AIMSUN's extensive visual information, which includes details about the layout of buildings and roads, enables accurate identification of these vital features of the road network.

The road network is experiencing a noticeable improvement, as shown in Figure 49 below, particularly near the TS001 interstation after introducing the optimum solution.

TS001 intersection before Road and Signal enhancement in 2035	TS001 intersection after Road and Signal enhancement in 2035
	

Figure 49: AIMSUN Simulation of TS001 intersection before and after optimum solution in 2035

A considerable enhancement was made at intersection TS055 by increasing the short-left turn approach lane's length from 20 to 100 meters. It becomes clear from observations from the Optimum 2035 AIMSUN model that this proposed road extension will terminate right before the Parliament building as Figure 50.

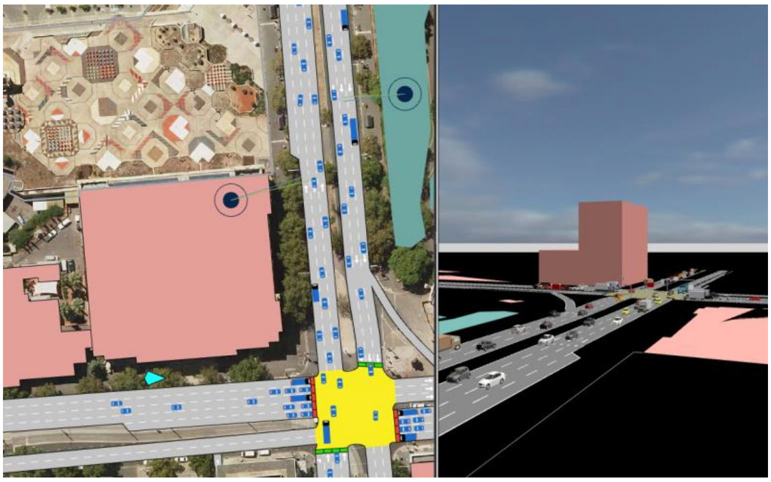


Figure 50: Road extension observation from AIMSUN model

In the context of AIMSUN, it can provide an estimate of the highest virtual queue that can be observed within the road network. The optimum model for 2035 estimated the maximum queue to be 11 vehicles, as shown in Figure 51.

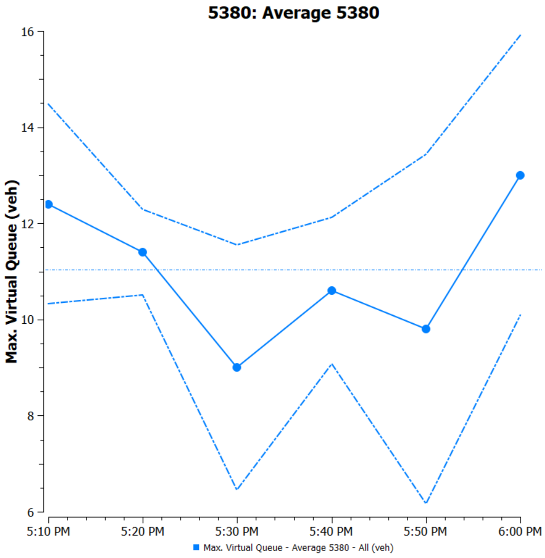


Figure 51: Maximum virtual queue (vehicle) of AIMSUN 2035 optimum model

AIMSUN offers the ability to construct sub-paths, which are described as a set of consecutive sections within the model of varied lengths and locations. This software can produce detailed statistics for these sub-paths, such as travel time, flow, counts, and delays. The sub-path was established in King William Road that operates from the south to the north (Northbound). It's important to note that the results for this specific sub-path have slightly higher values than the total network results. All AIMSUN results can be found in the Annex 7 to 11.

Finally, Queues (vehicles) were observed in both SIDRA and AIMSUN 2035 optimum model as below Figure 52. It shows that queue storage ratio is less than 0.6 which use to evaluate the network performance. Queue storage ratio is ratio of the average back of queue to the available queue storage distance.

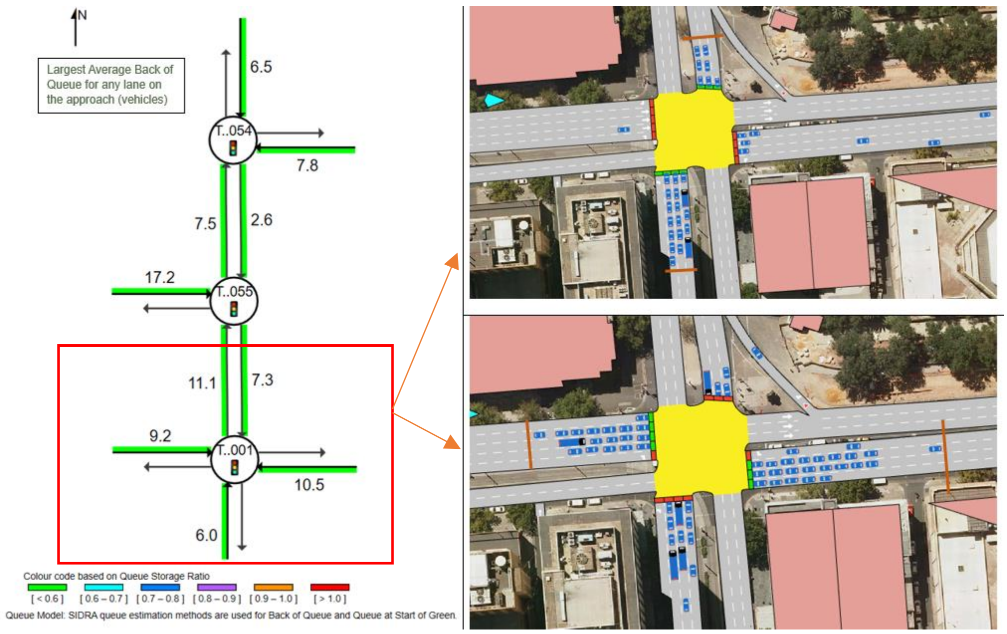


Figure 52: SIDRA and AIMSUN 2035 optimum model Queue (vehicles)observation

When observing the TS001 intersection, similar queues—that is, the number of waiting vehicles—were observed in both SIDRA and AIMSUN. SIDRA noted 6 vehicles at the South approach, compared to 5 vehicles seen by AIMSUN. Similar estimates were made by SIDRA and AIMSUN for the West and East approaches, while AIMSUN simulated 7 or 9 vehicles. The number of vehicles for the North approach, however, varied slightly between SIDRA and AIMSUN, with SIDRA representing 7 and AIMSUN displaying only 3.

4.3 Feasibility of the recommended solution

Calculating the feasibility of a new road lane addition, extension and signal enhancement is a complex process that involves multiple disciplines, including civil engineering, economics, and environmental studies. Additionally, legal and regulatory requirements may vary by location, so it's crucial to consult with local authorities and experts in the field.

However, the economic feasibility of the proposed solution can be done by conducting a simple cost analysis as in Table 5 below. Road construction project rates were based on research report published by Commonwealth of Australia on "Road Construction Cost and Infrastructure Procurement Benchmarking: 2017 update" (Department of Infrastructure, Regional Development and Cities, 2018). Further, signal phase adjustment cost was assumed based on intelligent transportation systems joint program office official website (Intelligent Transportation Systems Joint Program Office, 2007).

The proposed recommendation consists of an addition of a total road length of 2 km in providing new lanes and extensions to existing short lanes. Main Road enhancement cost can be divided into construction cost, project management cost, design and investigation cost and property acquisition cost. Construction cost consists of materials, labor and equipment required for road construction. There will be land acquisition process since this road improvement is consisting of adding new lane in intersection TS001 in each four directions. Also, road enhancement work Includes the cost of design work and engineering services. Further, signal phase adjustment cost was also considered for this calculation.

Table 5: Cost estimation for proposed road and signal enhancement

Cost Factor	Total Cost
– Construction cost	$7,452,000.00
– Project management cost	$1,188,000.00
– Design and Investigation cost	$756,000.00
– Property acquisition cost	$1,404,000.00
Total cost for road development of 2Km	$10,800,000.00
Signal phase adjustment cost	$15,000.00
Total road development cost	**$10,815,000.00**

However, this proposed road and signal enhancement can be assessed based on the expected benefits of adding a new lane, such as reduced congestion, improved traffic flow, and economic development. Then these benefits can be compared with the project's estimated costs.

The optimal solution results in annual savings of $2.5 million according to the SIDRA output, implying that the project's initial investment cost can be repaid within a span of just 5 years.

4.4 Sensitivity analysis

Sensitivity analysis is important to identify other factors that affect the traffic in road network. Conducting a sensitivity analysis is vital when examining the traffic impact of a new building development since it provides an important approach to understanding the other elements that can influence road traffic conditions. This knowledge enables decision-makers to make accurate choices, manage risks, and create sustainable, efficient, and safe urban settings. There will be a new, unpredictable parking generation as a result of this development, but the impact will be less since parking will be available in the festival plaza tower. Additionally, the nearby train station and other forms of public transportation will have a low impact on the road traffic flow. Sensitivity analysis can be found in Table 6.

Table 6: Sensitivity analysis

Factor		Impact level	Impact
Location and land use zone	Urban area	High	More likely to have a substantial traffic impact
Building purpose and peak hours	Commercial building	High	Commercial building may generate traffic throughout the day
Building size	Large building 26-levels	High	Larger building generates more traffic
Parking availability	Yes -1600 spaces	Low	Less impact on traffic since parking will be available in the festival plaza tower
Public transport (PT)	Near train and tram service	Moderate	Buildings near transit hubs may generate less traffic as employees opt for PT As more people choose PT over personal vehicles for commuting, it can lead to a reduction in the number of cars on the road during peak hours. This can result in decreased traffic congestion, shorter travel times, and improved traffic flow. Increased PT passengers may reduce the demand for parking in congested urban areas, freeing up space that can be used for other purposes or reducing the need for extensive parking facilities.
Special events and holidays	Occasionally, events happening in CBD area	Moderate – short term	Special events can significantly impact traffic for a short time period

Weather conditions	Low weather impact in the CBD area	Low – short term	Bad weather may worsen traffic condition for a short time period
Land value increase	CBD area	Low	Less impact on traffic

5 DISCUSSION

This research project seeks to conduct a traffic impact study (TIS), as a document that evaluates the possible effects of a new development, on the nearby roadway network and to look into the effectiveness of the road network. This research analyses its effects at signalized intersections and pedestrian crossings on drivers, pedestrians, the economy, and the environment.

SIDRA and AIMSUN Modeling take into account the current situation in 2023, the launch of Flinders University at Festival Plaza in 2024, the completion of the redevelopment in 2025, and the forecast models for the next ten years.

The investigation on the traffic impact of the new Festival Plaza Tower expansion offers potential fixes and recommendations. Finally, the optimal solution for 2035 was recommended by enhancing the road network and traffic signals to optimize transport strategy.

However, a number of assumptions were used for assessing trip generation rates and modelling using SIDRA and AIMSUN software, which could have an impact on the recommendations' reliability.

The development of 26-storey Festival Plaza tower is expected to result in 978 additional trips by the time it is finished at the end of 2025, which highlights a critical concern about the effect it will have on traffic condition. The intersections of TS001 and TS055 are likely to experience significant challenges from this increase in traffic demand, necessitating the use of a viable strategy to prevent congestion and delays.

Road improvement and signal phasing adjustments were recommended as appropriate solutions to these problems. With these actions, the Level of Service (LOS) at these intersections was improved. It is necessary to lessen the negative effects of the additional traffic brought on by the construction by boosting intersection efficiency and streamlining traffic flow. In order to reduce the negative consequences of the increasing traffic brought on by the development, traffic flow was optimized and intersection effectiveness was improved.

The possibility of meeting acceptable levels in the key aspects of concern through the suggested ideal solution is extremely encouraging. By putting this approach into practice, an outstanding 25% reduction in overall CO_2 emissions, a significant 58% reduction in delay times, and a 34% decrease in total expenses can be expected. The objectives of enhancing urban mobility and sustainability are all supported by these advances, which also promise to reduce costs and improve the environment.

The ultimate objective is to make sure that the transportation infrastructure continues to be reliable, functional, and environmentally friendly, meeting the needs of expanding community while minimizing negative environmental effects and preserving cost effectiveness.

6 CONCLUSIONS

There is an imminent challenge on the signalized intersections to maintain their smooth service when the population and infrastructure of South Australia continue to keep growing, leading the Central Business District (CBD) to experience its worst traffic congestions. This study intends to examine the effects of the Festival Plaza Tower, a major new construction in Adelaide's central business district, on both signalized intersections and pedestrian crossings. Through an extensive traffic impact study (TIS), the implications on drivers, pedestrians, the economy, and the environment were analyzed.

The research approach consists of many crucial phases that are intended to help the researcher fully comprehend the traffic dynamics in the studied area. In order to understand the current traffic circumstances, a thorough examination of the existing road network was done. The current volume of vehicles in the study region was assessed, which is essential for accurately modelling its current status. This was done by cross-referencing data from the Department of Infrastructure and Transport (DIT) with on-site observations.

The next stage was to determine how the new construction will affect the amount of traffic in the region studied. In order to understand how the development would affect traffic flow quantitatively, trip generation estimates are essential. ITE Trip Generation Manuals were used for the trip generation estimations. Two sophisticated computer techniques called SIDRA and AIMSUN were utilized to evaluate the overall effects of these adjustments. These computer programs play a key role in assessing the infrastructure's capacity and traffic flow, offering crucial insights on the performance of the road system. The AIMSUN model, which provides a thorough simulation of traffic performance throughout the research region, incorporates SIDRA's outputs, which are specifically focused on intersection analysis, into its model without any issues.

SIDRA and AIMSUN software were used to model intersections and the nearby road network for the peak time period, including 2023 (the existing model), 2024 (after Flinders at Festival Plaza opened), 2025 (after the completion of the redevelopment), future scenarios (10 years in the future), and a model with an optimal solution.

Data gathering, model creation using SIDRA and AIMSUN, model calibration and validation, and recommending of a development for an ideal solution are all included in this work by conducting a TIS to assess the potential effects of the new Festival Plaza Tower development on the local road network, the economy, and the environment. In a nutshell the goal of this research is to make optimum recommendations to reduce the harmful effects of traffic and improve road performance. These suggestions are centered on improving the road network and traffic signal settings, which will improve traffic efficiency and the general wellbeing of the neighborhood.

7 FUTURE WORK

The objective of this study is to conduct a traffic impact study to assess the potential effects of the new Festival Plaza Tower development on the local road network, the economy, and the environment. The information gathered from this study will be a useful tool for upcoming development projects and for more research in the area of transportation engineering.

The findings from this study will be valuable in developing more accurate and complex traffic models, which may include machine learning and artificial intelligence to anticipate traffic patterns based on a broader range of characteristics. And these findings can examine how agent-based modelling can be used to replicate individual driver behavior in reaction to new developments, route improvements, or traffic control tactics.

In addition, future research is recommended investigate at the long-term implications of traffic changes imposed by developments, including how they affect local value, economic growth, and quality of life based on this research's findings.

Also, to mitigate the effects of traffic, it is useful to analyze the potential advantages of combining smart transportation technology like autonomous vehicles, traffic management systems, and ride-sharing services. And examining on how IoT devices and data analytics can be used to manage traffic and enhance urban mobility would be useful for future studies.

Further, detailed sensitivity analysis can be carried out in order to identify complex factors that affect the traffic increase in road network.

8 REFERENCE

1. Adelaide Metro (2022). Network maps. [online] Adelaide Metro. Available at: https://www.adelaidemetro.com.au/plan-a-trip/network-maps.

2. Andrew, M. (2021). Transport challenges - how integration of land use and planning can lead to carbon neutrality | Beca. [online] www.beca.com. Available at: https://www.beca.com/ignite-your-thinking/ignite-your-thinking/march-2021/transport-challenges-how-integration-of-land-use#:~:text=Role%20of%20integrated%20land%20use%20and%20transport%20planning%3A&text=reduces%20peoples [Accessed 2023].

3. Austroads (2020). Austroads Building Transport Modelling Management and Capability in Australasian Road and Transport Agencies. Sydney, New South Wales: Austroads Limited.

4. Boukerche, A. and Wang, J. (2020). Machine Learning-based traffic prediction models for Intelligent Transportation Systems. Computer Networks, 181, p.107530. doi: https://doi.org/10.1016/j.comnet.2020.107530.

5. Commonwealth of Australia (2013). 2013 Commonwealth of Australia Numbered Acts. [online] classic.austlii.edu.au. Available at: http://classic.austlii.edu.au/au/legis/cth/num_act/2013/ [Accessed 2023].

6. Cuena, J., Hernández, J. and Molina, M. (1995). Knowledge-based models for adaptive traffic management systems. Transportation Research Part C: Emerging Technologies, 3(5), pp.311–337. doi: https://doi.org/10.1016/0968-090x(95)00013-9.

7. D Gargett and Cosgrove, D. (2020). Predicting traffic growth in Australian cities. Transport Research Forum, 27. Bureau of Transport and Regional Economics, Canberra.

8. Department of Infrastructure and Transport (DIT) (2023). Traffic Modelling Guidelines: SIDRA Intersection VERSION 2.2 PUBLISHED AUGUST 2023. [online] Available at: https://www.dit.sa.gov.au/__data/assets/pdf_file/0009/365895/Traffic-Modelling-Guidelines_-SIDRA-Intersection-Version-2_2-August-2023.PDF.

9. Department of Infrastructure, Regional Development and Cities (2018). Road Construction Cost and Infrastructure Procurement Benchmarking: 2017 update. Department of Infrastructure, Regional Development and Cities Canberra, Australia: Commonwealth of Australia, p.43.

10. Department of Planning, Transport and Infrastructure (2015). ANNUAL REPORT 2014–15. South Australia: Government of South Australia, p.233.

11. Dia, H. and Gondwe, W. (2008). Evaluation of incident impacts on integrated motorway and arterial networks using traffic simulation. Transport Research Forum, 1, pp.563–575.

12. DPTI (2014). Trip generation rates for assessment of development proposals. Adelaide: Department of Planning, Transport and Infrastructure.

13. Espada, I., Luk, J. and Lloyd, B. (2010). Guidelines for Selecting Techniques for the Modelling of Network Operations. Melbourne: ARRB Conference.

14. Essa, M. and Sayed, T. (2020). Self-learning adaptive traffic signal control for real-time safety optimization. Accident Analysis & Prevention, 146, p.105713. doi: https://doi.org/10.1016/j.aap.2020.105713.

15. Figliozzi, M.A. and Monsere, C. (2013). Evaluation of the Performance of the Sydney Coordinated Adaptive Traffic System (SCATS) on Powell Boulevard in Portland. Portland State University: Civil and Environmental Engineering Faculty, p.85. OTREC -RR-13-07. Transportation Research and Education Center (TREC). https://dx.doi.org/10.15760/trec.104.

16. Gao, K., Huang, S., Xie, J., Xiong, N.N. and Du, R. (2020). A Review of Research on Intersection Control Based on Connected Vehicles and Data-Driven Intelligent Approaches. Electronics, 9(6), p.885. doi: https://doi.org/10.3390/electronics9060885.

17. Google Maps. (2023). Google Maps. [online] Available at: https://www.google.com/maps.

18. Government of South Australia (2016). The Integrated Transport & Land Use Plan (ITLUP). Adelaide: Government of South Australia.

19. Government of South Australia (2022). Location SA Viewer. [online] Sa.gov.au. Available at: https://location.sa.gov.au/viewer/.

20. H Smithers (2019). Transport Modelling Report for Adelaide. Veitch Lister Consulting Pty Ltd, p.116.

21. Han, Kazantzidis, G. and Luk, J. (2009). Freeway traffic flow under congested conditions. Austroads, Sydney, N.S.W.

22. InfrastructureSA (2020). 20-Year Strategy. Adelaide. InfrastructureSA.

23. Institute Of Transportation Engineers (2017). Trip generation manual, 10th Edition. Washington, Dc: Institute of Transportation Engineers.

24. Intelligent Transportation Systems Joint Program Office (2007). From The National Traffic Signal Report Card: costs to update signal timing is $3,000 per intersection. | ITS Deployment Evaluation. [online] www.itskrs.its.dot.gov. Available at: https://www.itskrs.its.dot.gov/its/benecost.nsf/ID/215f723db93d293c8525725f00786fd8.

25. Li, Z., Yu, H., Wang, W. and Liu, Y. (2019). Investigation of the impacts of roundabout design on traffic flow and safety using microscopic simulation. Journal of Traffic and Transportation Engineering (English Edition), 6(2), 142-154.

26. Mohammadian and T, A. (2018). Microscopic simulation investigation of the impacts of different traffic control strategies on traffic flow and congestion. Journal of Advanced Transportation.

27. Muhammad, S. and Jamaludin, S. (2022). Evaluating the Performance of Traffic Flow using SIDRA for Roundabouts in Ipoh, Perak. ResearchGate. [online] doi: https://doi.org/10.17576/jkukm-2022-34(3)-09.

28. Omar, D.H. and Hussein, S.K. (2022). Optimization of Delay at Isolated Signalized Intersection Using HCS2010 and SIDRA Intersection 8 Software: a Case Study. International Review of Civil Engineering, 13(6). doi: https://doi.org/10.15866/irece.v13i6.21407.

29. Punzo and S, V. (2019). Impacts of speed limit reductions on traffic flow and safety: A microscopic simulation approach. Transportation Research Part C: Emerging Technologies. 107, 96-114.

30. Raju, N. and Farah, H. (2021). Evolution of Traffic Microsimulation and Its Use for Modeling Connected and Automated Vehicles. Journal of Advanced Transportation, 2021, pp.1–29. doi: https://doi.org/10.1155/2021/2444363.

31. RenewalSA (2020). STRATEGIC PLAN 2020-23. Adelaide: RenewalSA.

32. RenewalSA., R.C. (2023). Festival Plaza. [online] Renewal SA. Available at: https://renewalsa.sa.gov.au/projects/festival-plaza/ scheme=AGLSTERMS. AglsAgent; corporateName=Renewal SA; address=Level 9 West.

33. Roads and Maritime Services NSW (2013). Guide to Traffic Generating Developments.

34. Rodrigue, J.-P., Comtois, C. and Slack, B. (2020). The Geography of Transport Systems, Fifth Edition. Version No. 5.0 ed. Routledge, p.467.

35. San José, R., Pérez, J.L. and Gonzalez-Barras, R.M. (2021). Assessment of mesoscale and microscale simulations of a NO2 episode supported by traffic modelling at microscopic level. Science of The Total Environment, 752, p.141992. doi: https://doi.org/10.1016/j.scitotenv.2020.141992.

36. South Australia. Department Of Planning and Local Government (2017). The 30-year plan for Greater Adelaide: a volume of the South Australian Planning Strategy. Adelaide: Department Of Planning and Local Government.

37. Staffan Algers and B, E. (1997). Review of Micro-Simulation Models. SMARTEST Project Deliverable.

38. Tianzi, C., Shaochen, J. and Hongxu, Y. (2013). Comparative Study of VISSIM and SIDRA on Signalized Intersection. Procedia - Social and Behavioral Sciences, 96, pp.2004–2010. doi: https://doi.org/10.1016/j.sbspro.2013.08.226.

39. Vehlken, S. (2020). Traffic life: temporal dynamics and regulatory dimensions in agent-based transport simulations. Mobilities, 15(5), pp.725–739. doi: https://doi.org/10.1080/17450101.2020.1806509.

40. Walker corporation (2023). One Festival Tower – Bringing together the best of Adelaide. [online] www.onefestivaltower.com.au. Available at: https://www.onefestivaltower.com.au/.

41. Walker-Corporation (2023). Festival Tower – Walker Corporation. [online] www.walkercorp.com.au. Available at: https://www.walkercorp.com.au/commercial/festival-tower/.

42. Walker Riverside Developments (2020). SCAP Agenda Item 2.2.2. Adelaide. State Commission Assessment Panel.

43. Wegener, M. and Fürst, F. (1999). Land-Use Transport Interaction. Integration of Transport and Land Use Planning.

44. Wey, W.-M. (2000). Model formulation and solution algorithm of traffic signal control in an urban network. Computers, Environment and Urban Systems, 24(4), pp.355–378. doi: https://doi.org/10.1016/s0198-9715(00)00002-8.

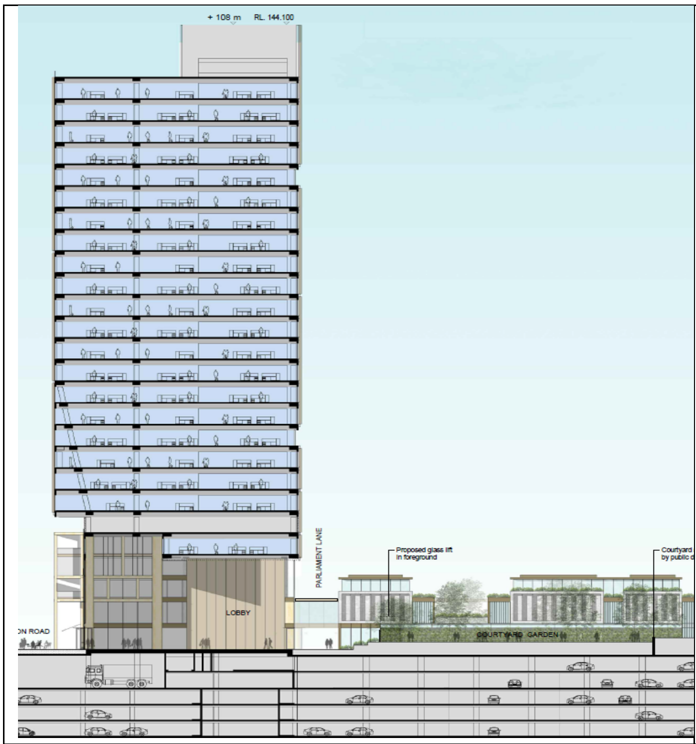
45. Zhang, K. (2013). An integrated approach to traffic modelling: linking SIDRA, LINSIG and AIMSUN. Transport Research Forum.

9 APPENDICES

Annex 1: Standard Transport Modelling Packages - Modelling Categories (Austroads, 2020)

Model Level	Sub-category	Other Terminology	Key Model Features	Example software packages
Strategic Model	Macroscopic, Demand, Multimodal, Highway Assignment	Macroscopic analytical model	Estimation of trips between origins and destinations at specific time periods. Estimation of mode choice and route choice. Estimation of link, route, area and network travel statistics.	Aimsun Cube Voyager EMME OmniTRNAS QRS II STRADA TRACKS TransCAD PTV Visum
Simulation Models	Mesoscopic models	Macrosimulation model, Operational model, Traffic Flow model	Simplified simulation of individual vehicles by the propagation of flow in discrete time intervals along a sequence of links. Static and Dynamic traffic assignment.	Aimsun Cube Avenue Dynameq OmniTRANS SATURN PTV Visum/Vissim
	Microscopic models	Microsimulation model, Operational model, Traffic model	Detailed simulation of individual vehicles and their interactions with each other. Static and Dynamic traffic assignment.	Aimsun Commuter CORSIM Cube Dynasim Paramics SUMO SYNCHRO PTV Vissim
Intersection Models	Intersection models	Microscopic model, Analytical model, Empirical model, Corridor model, Signal Optimization model	Simplistic calculation of intersection performance and operation. Static traffic assignment.	LinSig SCATES SIDRA TRANSYT TRANSYT-7F PTV Vistro

Annex 2: Festival Plaza tower area schedule



Area Schedule

DA TOWER CONFIGURATION
TRANSFER FLOOR L15

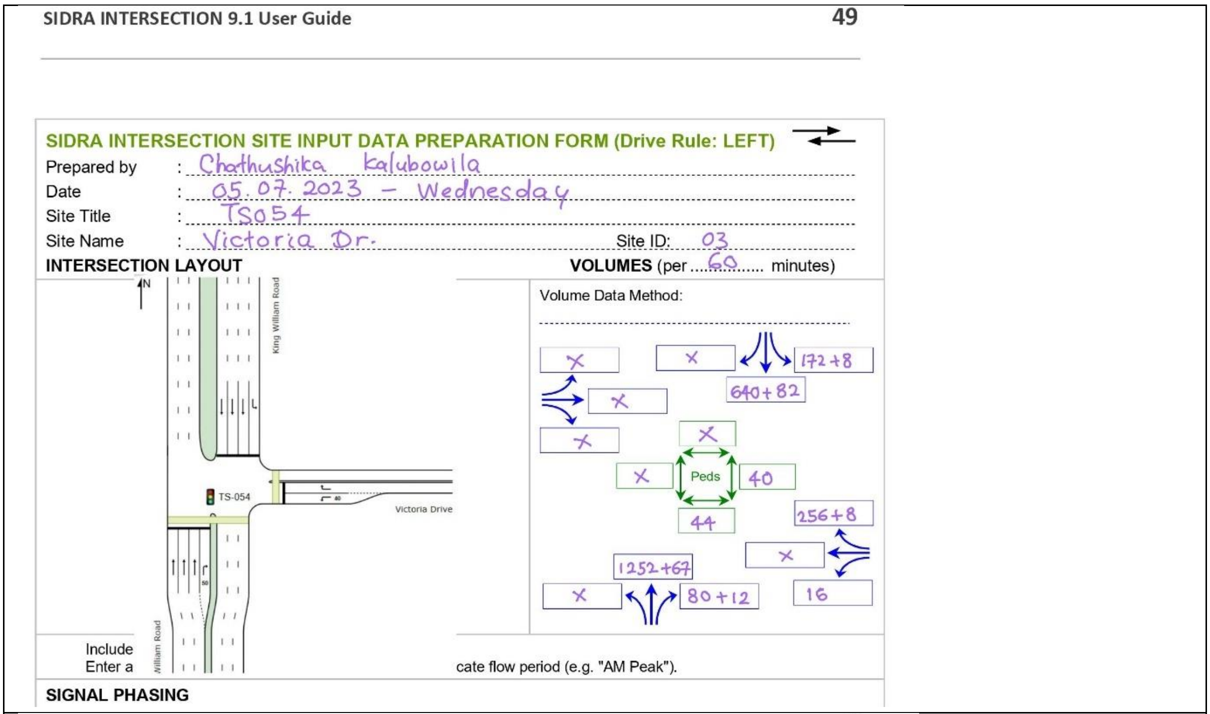
FLOOR	FLR HT	RL	USE	LIFTS	PLANT	GBA	BFA	OFFICE NLA
Roof		**144.100**						
Level 26	9000	135.100	Plant			2,211		
Level 25	3750	131.350	Office			2,211	2,252	1,931
Level 24	3750	127.600	Office			2,211	2,252	1,931
Level 23	3750	123.850	Office			2,211	2,252	1,931
Level 22	3750	120.100	Office			2,211	2,252	1,931
Level 21	3750	116.350	Office / Terrace W			2,211	1,902	1,814
Level 20	3750	112.600	Office	HIGH RISE		2,211	2,252	1,931
Level 19	3750	108.850	Office			2,211	2,252	1,931
Level 18	3750	105.100	Office			2,211	2,252	1,931
Level 17	3750	101.350	Office / LR MR			2,211	2,252	1,759
Level 16	3750	97.600	Office / LR Overrun			2,211	2,142	1,814
Level 15	3750	93.850	Office / Transfer			2,211	2,197	1,814
Level 14	3750	90.100	Office			2,211	2,197	1,814
Level 13	3750	86.350	Office			2,211	2,197	1,814
Level 12	3750	82.600	Office			2,211	2,197	1,814
Level 11	3750	78.850	Office	LOW RISE		2,211	2,197	1,814
Level 10	3750	75.100	Office			2,211	2,197	1,814
Level 9	3750	71.350	Office / Terrace E			2,211	2,197	1,798
Level 8	3750	67.600	Office / Podium Overrun			2,211	2,172	1,604
Level 7	3750	63.850	Office / Terrace S			2,115	1,762	1,580
Level 6	3750	60.100	Office	PODIUM		2,115	1,868	1,580
Level 5	3750	56.350	Office			2,115	1,868	1,580
TOWER TOTAL					-	**48,354**	**45,109**	**37,930**
Level 4	3750	52.600	Plant			2,005	-	-
Level 3	3750	48.850	Office / Plant			2,029	1,015	900
Level 2	3750	45.100	Office / Plant	PODIUM		2,068	1,002	900
Level 1	4500	40.600	Foyer / Retail / Plant			1,944	470	270
Ground	**4500**	**36.100**	**Foyer / Retail**			1,807	1,373	
PODIUM TOTAL					-	**9,853**	**3,860**	**2,070**
TOTAL	**108 m**	**144.100**				**58,207**	**48,969**	**40,000**

2. DESCRIPTION OF PROPOSAL

Application details are contained in the ATTACHMENTS.

	Approved	Proposed
Land Use Description	Demolition works and the construction of a car park over 5 basement levels a 27 level office tower (including ground level retail two levels of plant rooms); and a retail building of up to three levels	Unchanged
Building Height	108m Finished Floor Level (144.1m AHD)	Unchanged
Floor Area (total) • **Office Area** • **Retail**	• NLA 40,000m² commercial • Retail - Mixed use tower GBA (Gross Building Area) 1224m² • Retail pavilion – GBA 2355m² (total GBA 3579m²)	• NLA 40,000m² commercial • Retail - Mixed use tower 330m² • Retail pavilion – GBA 2735m² (total GBA 3065m²)
Site Access	All vehicular access from Festival Drive (V2)	No change
Car Parking	1646	No change
Bicycle Parking	356 – Located within B5, rather than being dispersed throughout the car park (V3).	No change

Annex 3: Feilds survey data collection forms for 3 intersections



SIDRA INTERSECTION 9.1 User Guide 49

SIDRA INTERSECTION SITE INPUT DATA PREPARATION FORM (Drive Rule: LEFT)

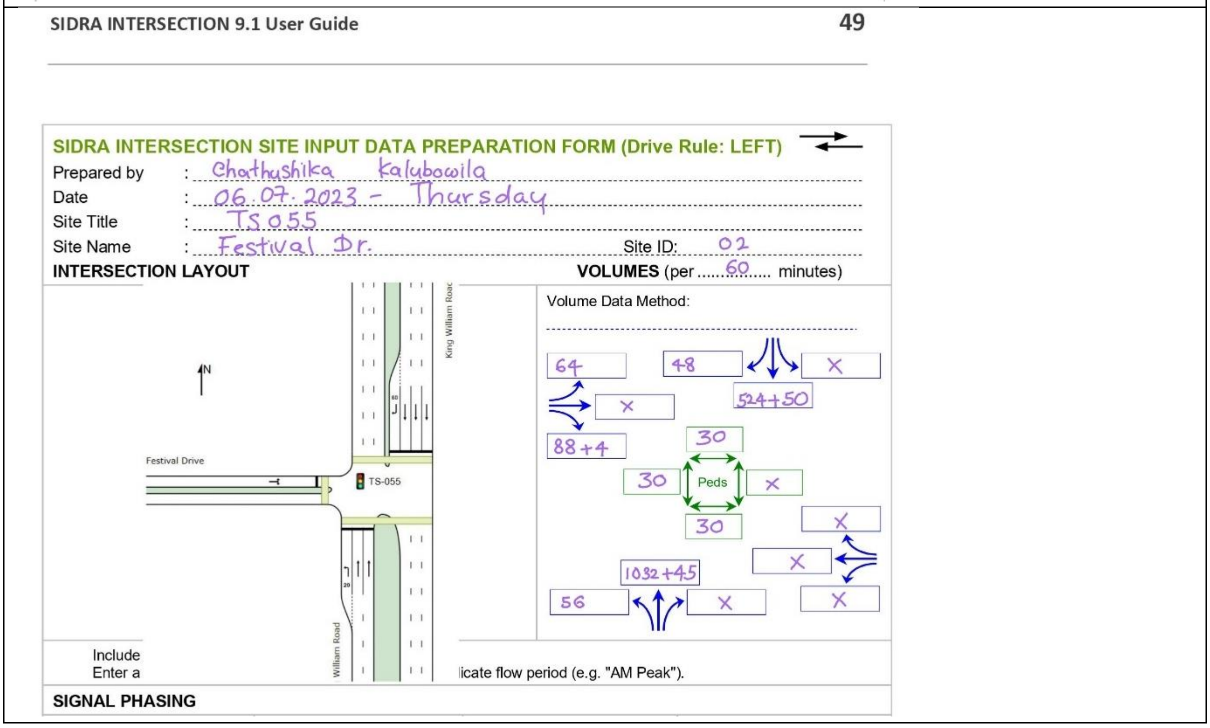
Prepared by : Chathushika Kalubowila
Date : 05.07.2023 – Wednesday
Site Title : TS054
Site Name : Victoria Dr. Site ID: 03

INTERSECTION LAYOUT **VOLUMES** (per 60 minutes)

Volume Data Method:

Include ... Enter a ... cate flow period (e.g. "AM Peak").

SIGNAL PHASING



SIDRA INTERSECTION 9.1 User Guide 49

SIDRA INTERSECTION SITE INPUT DATA PREPARATION FORM (Drive Rule: LEFT)

Prepared by : Chathushika Kalubowila
Date : 06.07.2023 – Thursday
Site Title : TS055
Site Name : Festival Dr. Site ID: 02

INTERSECTION LAYOUT **VOLUMES** (per 60 minutes)

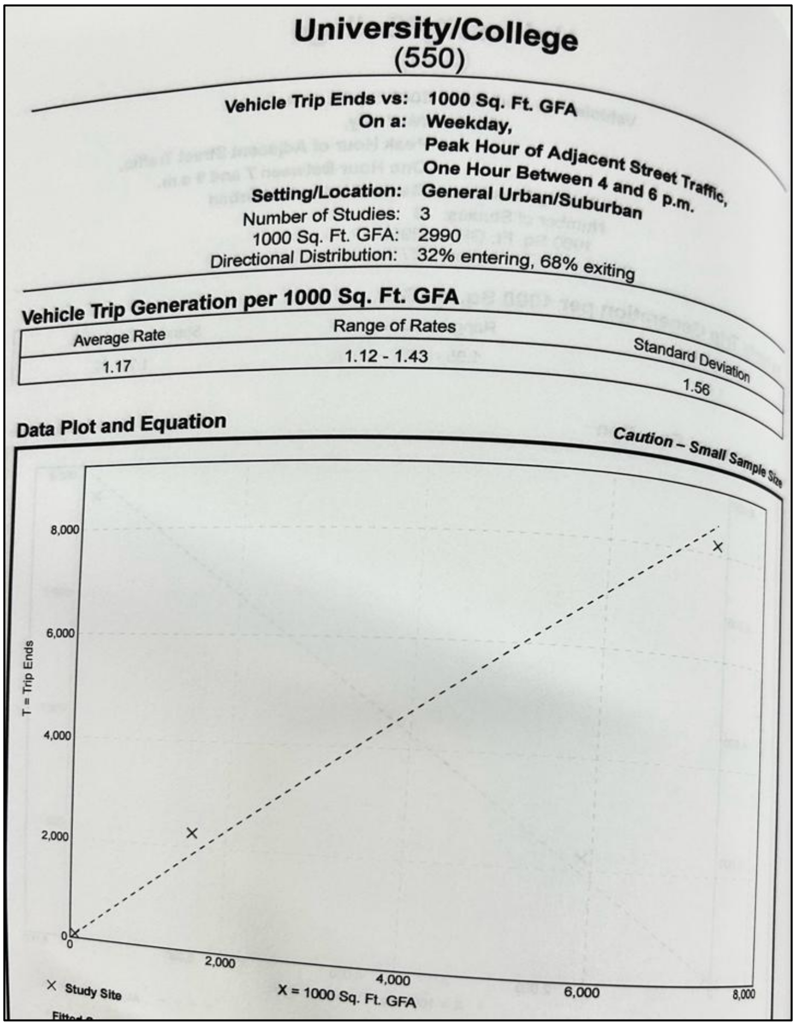
Volume Data Method:

Include ... Enter a ... icate flow period (e.g. "AM Peak").

SIGNAL PHASING

INSTITUTIONAL			
520	Elementary School	1,000 SF GFA	1.37
522	Middle School / Junior High School	1,000 SF GFA	1.19
530	High School	1,000 SF GFA	0.97
534	Private School (K-8)	Students	0.26
536	Private School (K-12)	Students	0.17
537	Charter Elemantary School	Students	0.14
538	School District Office	1,000 SF GFA	2.04
540	Junior / Community College	1,000 SF GFA	1.86
550	University/College	1,000 SF GFA	1.17

OFFICE					
710	General Office Building	1,000 SF GFA	➔	1.15	0.87
712	Small Office Building	1,000 SF GFA	2.45		
714	Corporate Headquarters Building	1,000 SF GFA	0.60		
715	Single Tenant Office Building	1,000 SF GFA	1.74*		



University/College
(550)

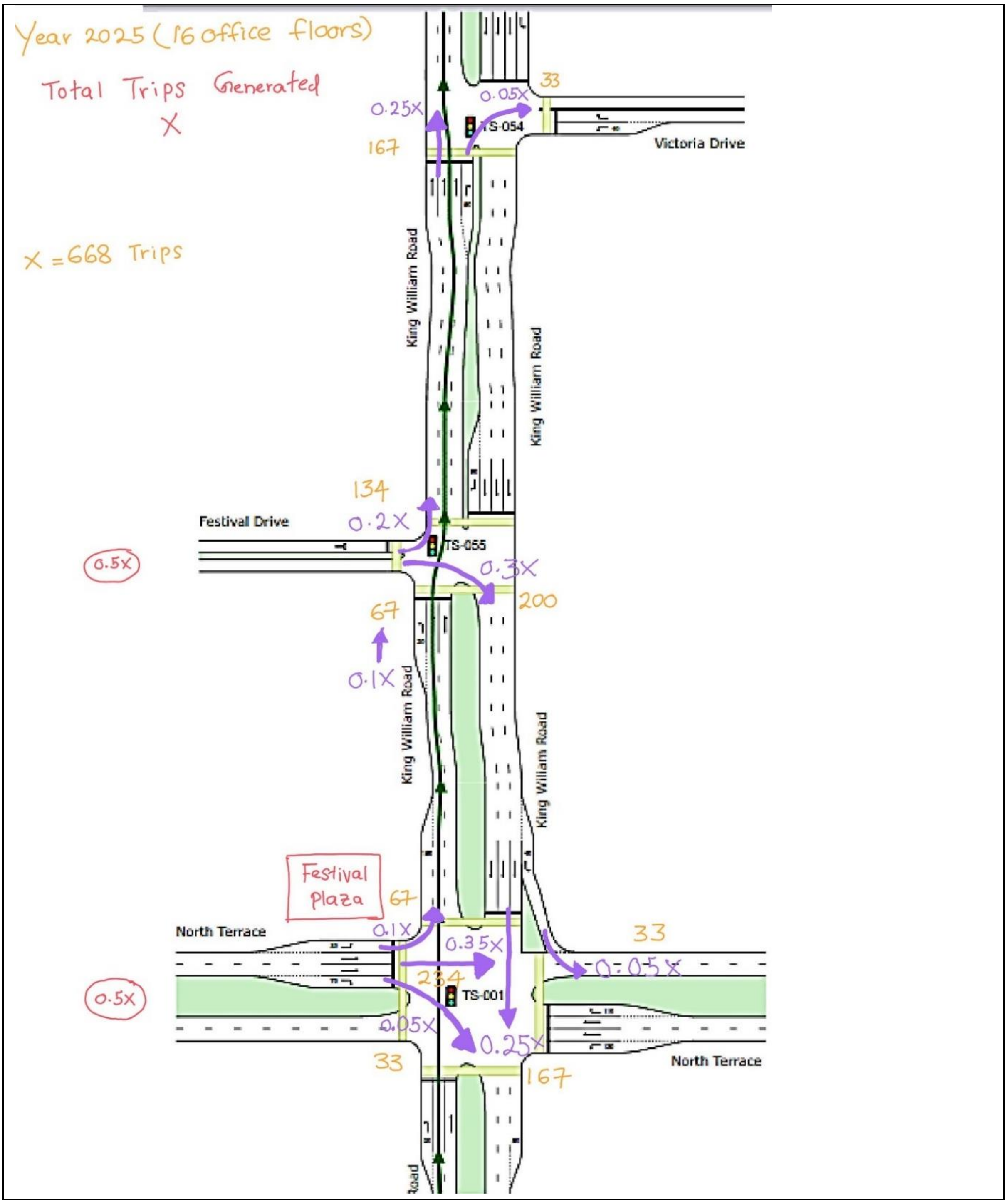
Vehicle Trip Ends vs: 1000 Sq. Ft. GFA
On a: Weekday,
Peak Hour of Adjacent Street Traffic,
One Hour Between 4 and 6 p.m.
Setting/Location: General Urban/Suburban
Number of Studies: 3
1000 Sq. Ft. GFA: 2990
Directional Distribution: 32% entering, 68% exiting

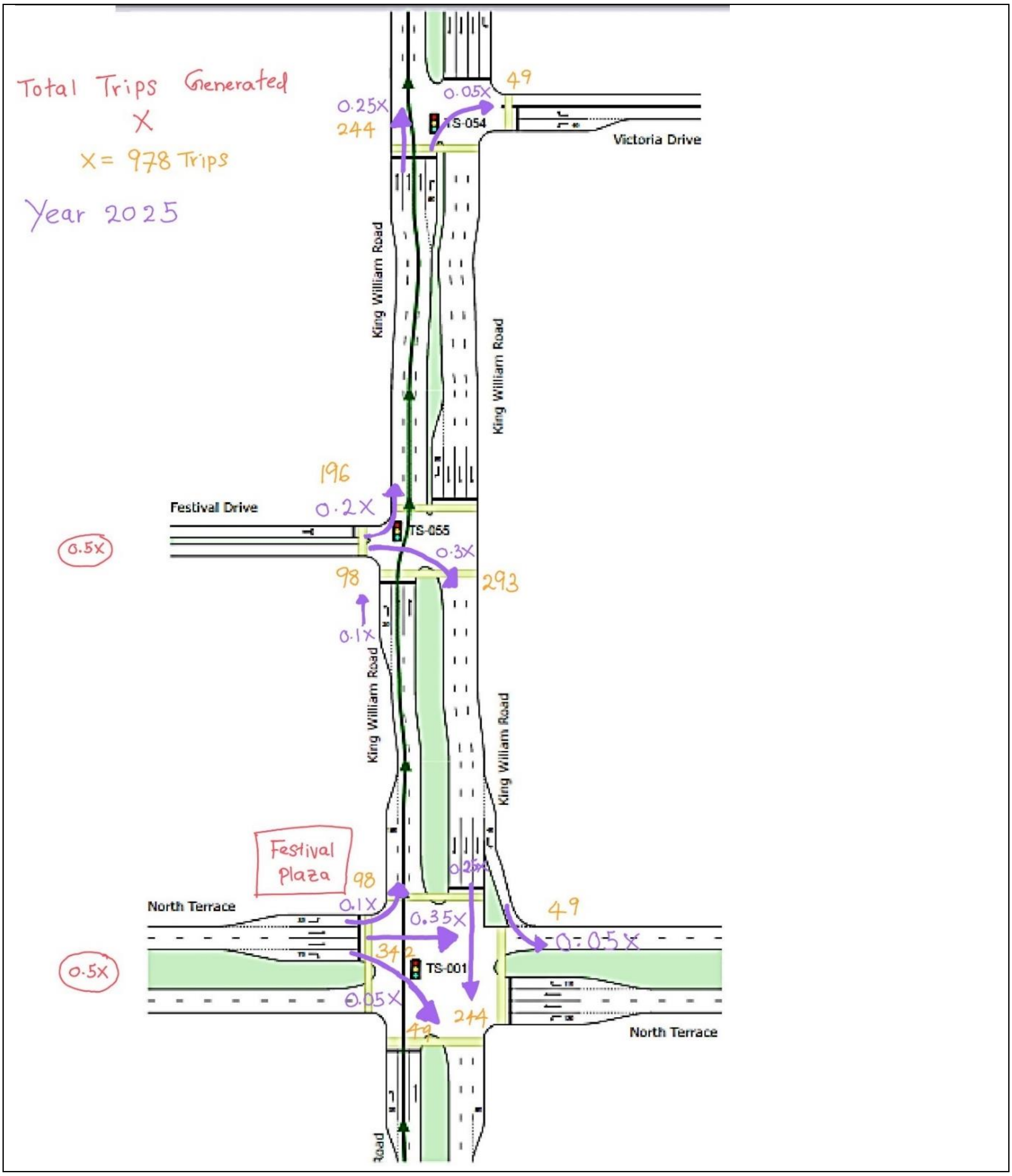
Vehicle Trip Generation per 1000 Sq. Ft. GFA

Average Rate	Range of Rates	Standard Deviation
1.17	1.12 - 1.43	1.56

Data Plot and Equation *Caution – Small Sample Size*

Annex 5: Trip generation distribution diagram





Total Trips Generated
X
X = 978 Trips
Year 2025
0.25X
244
0.05X
49
TS-054
Victoria Drive
King William Road
King William Road
196
0.2X
Festival Drive
TS-055
0.5X
0.3X
98
293
0.1X
King William Road
King William Road
Festival Plaza
98
0.1X
0.25X
North Terrace
49
0.35X
0.05X
342
TS-001
0.5X
0.05X
244
49
North Terrace
Road

Annex 6: SIDRA Northbound Network outputs of 2035 Optimum model

NETWORK SUMMARY

Network: N101 [2035 Optimum Solution (Network Folder: General)]

Output produced by SIDRA INTERSECTION Version: 9.1.2.202

New Network
Network Category: (None)
Network Cycle Time = 110 seconds (Network Practical Cycle Time)
Critical Site / Common Control Group that determines the Network Cycle Time (for Coordinated Sites): TS-001 [TS001-2035-Optimum]

Network Performance - Hourly Values

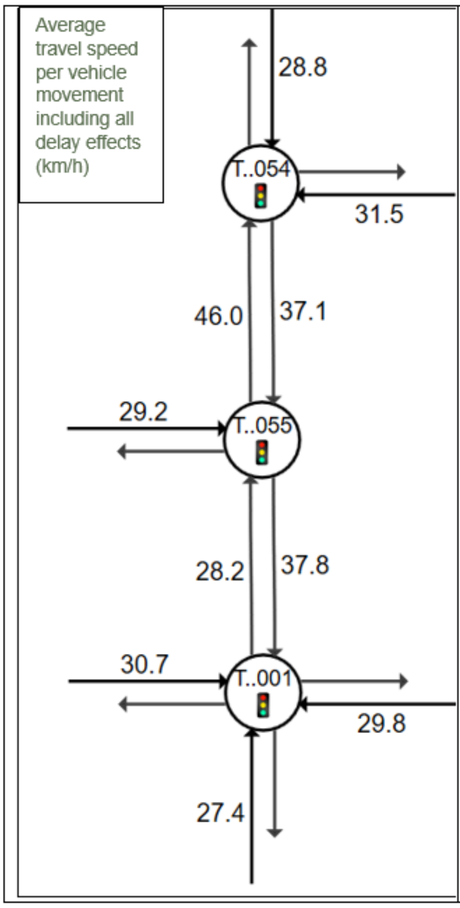
Performance Measure	Vehicles:	All MCs	Pedestrians	Persons
Network Level of Service (LOS)		LOS D		
Speed Efficiency		0.67		
Travel Time Index		6.35		
Congestion Coefficient		1.49		
Travel Speed (Average)	km/h	33.6	3.5 km/h	23.1 km/h
Travel Distance (Total)	veh-km/h	7931.0	537.3 ped-km/h	10054.5 pers-km/h
Travel Time (Total)	veh-h/h	236.1	152.5 ped-h/h	435.8 pers-h/h
Desired Speed	km/h	50.0		
Demand Flows (Total for all Sites)	veh/h	9961	2686 ped/h	14639 pers/h
Arrival Flows (Total for all Sites)	veh/h	9961	2686 ped/h	14639 pers/h
Demand Flows (Entry Total)	veh/h	5215		
Midblock Inflows (Total)	veh/h	399		
Midblock Outflows (Total)	veh/h	-159		
Percent Heavy Vehicles (Demand)	%	6.3		
Percent Heavy Vehicles (Arrival)	%	6.3		
Degree of Saturation		0.738		
Control Delay (Total)	veh-h/h	78.13	37.67 ped-h/h	131.43 pers-h/h
Control Delay (Average)	sec	28.2	50.5 sec	39.6 sec
Control Delay (Worst Lane by MC)	sec	51.0		
Control Delay (Worst Movement by MC)	sec	51.0	51.0 sec	51.0 sec
Geometric Delay (Average)	sec	1.2		
Stop-Line Delay (Average)	sec	27.0		
Ave. Que Storage Ratio (Worst Lane)		0.24		
Effective Stops (Total)	veh/h	6599	2608 ped/h	10526 pers/h
Effective Stop Rate		0.66	0.97	0.88
Proportion Queued		0.75	0.97	0.79
Performance Index		538.2	167.0	705.1
Cost (Total) *	$/h	10484.42	4391.04 $/h	14875.46 $/h
Fuel Consumption (Total)	L/h	861.3		
Fuel Economy	L/100km	10.9		
Carbon Dioxide (Total)	kg/h	2050.1		
Hydrocarbons (Total)	kg/h	0.170		
Carbon Monoxide (Total)	kg/h	1.74		
NOx (Total)	kg/h	4.530		

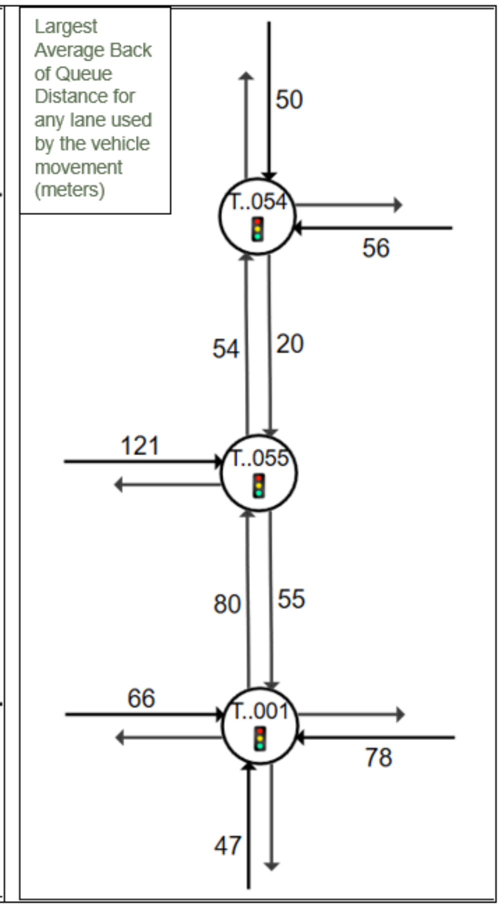
Network Model Variability Index (Average value of largest changes in Lane Degrees of Saturation or Queue Storage Ratios from the third to the last Network Iterations): 0.0 %
Number of Iterations: 5 (Maximum: 30)
Largest change in Lane Degrees of Saturation or Queue Storage Ratios for the last three Network Iterations: 0.0% 0.0% 0.0%
Network Level of Service (LOS) Method: SIDRA Speed Efficiency.
Software Setup used: Standard Left.
Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

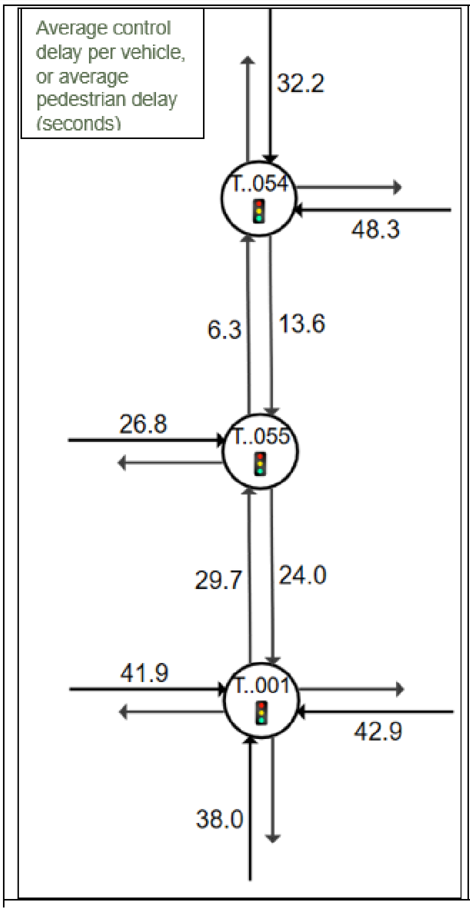
Network Performance - Annual Values

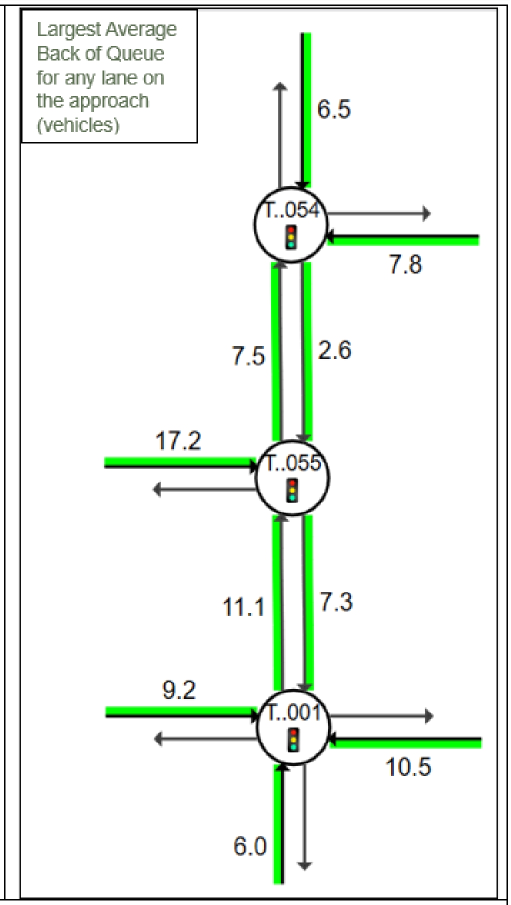
Performance Measure	Vehicles:	All MCs	Pedestrians	Persons
Demand Flows (Total for all Sites)	veh/y	4,781,103	1,289,432 ped/y	7,026,756 pers/y
Delay (Total)	veh-h/y	37,503	18,080 ped-h/y	63,084 pers-h/y
Effective Stops (Total)	veh/y	3,167,398	1,251,699 ped/y	5,052,578 pers/y
Travel Distance (Total)	veh-km/y	3,806,878	257,886 ped-km/y	4,826,140 pers-km/y
Travel Time (Total)	veh-h/y	113,319	73,184 ped-h/y	209,167 pers-h/y
Cost (Total)	$/y	5,032,522	2,107,700 $/y	7,140,222 $/y
Fuel Consumption (Total)	L/y	413,408		
Carbon Dioxide (Total)	kg/y	984,030		
Hydrocarbons (Total)	kg/y	82		
Carbon Monoxide (Total)	kg/y	836		
NOx (Total)	kg/y	2,175		

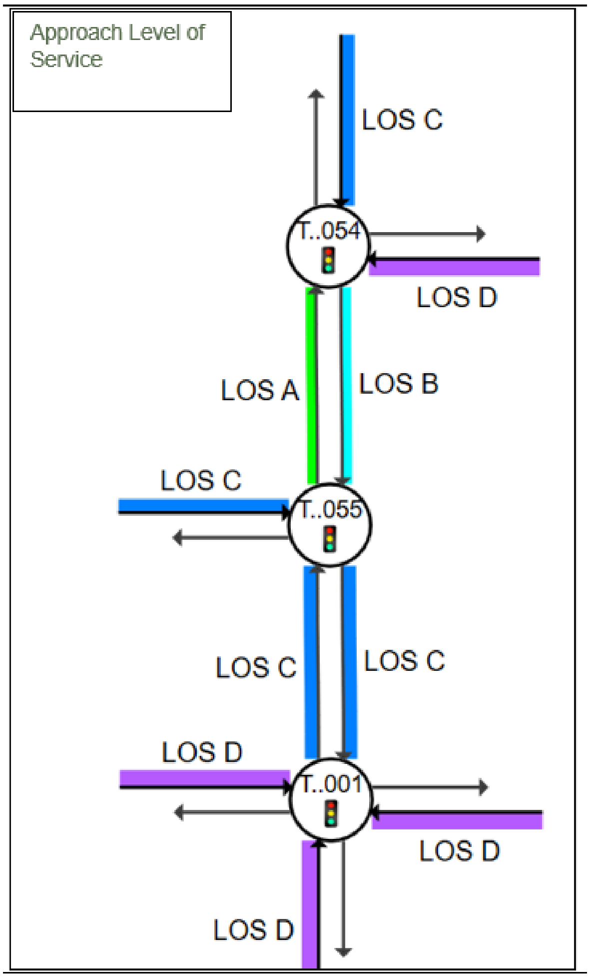
1 Hours per Year: 480 (Network)


Average travel speed per vehicle movement including all delay effects (km/h)
28.8
T..054
31.5
46.0
37.1
29.2
T..055
28.2
37.8
30.7
T..001
29.8
27.4


Largest Average Back of Queue Distance for any lane used by the vehicle movement (meters)
50
T..054
56
54
20
121
T..055
80
55
66
T..001
78
47


Average control delay per vehicle, or average pedestrian delay (seconds)
32.2
T..054
48.3
6.3
13.6
26.8
T..055
29.7
24.0
41.9
T..001
42.9
38.0


Largest Average Back of Queue for any lane on the approach (vehicles)
6.5
T..054
7.8
7.5
2.6
17.2
T..055
11.1
7.3
9.2
T..001
10.5
6.0

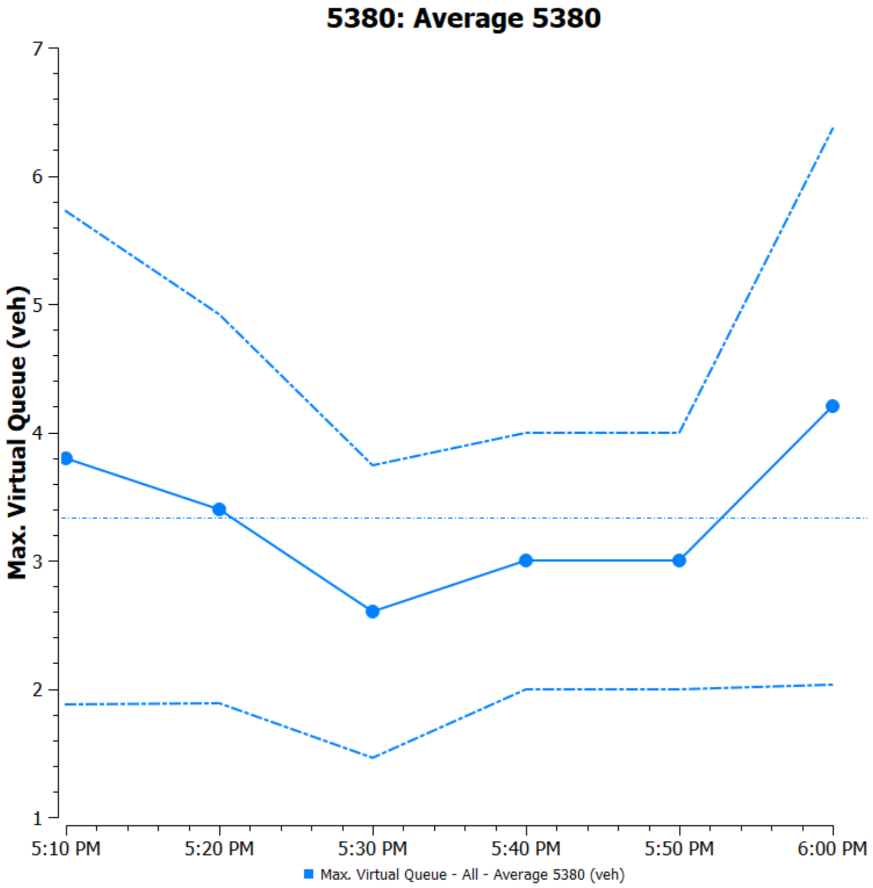


Approach Level of Service
LOS C
T..054
LOS D
LOS A
LOS B
LOS C
T..055
LOS C
LOS C
LOS D
T..001
LOS D
LOS D

Annex 7: AIMSUN outputs of 2023 existing Model

Time Series	Value	Standard Deviation	Units
Delay Time - All	102.83	1.61	sec/km
Delay Time - Car	100.94	1.43	sec/km
Delay Time - Truck	121.81	4.53	sec/km
Density - All	13.39	0.46	veh/km
Density - Car	12.25	0.38	veh/km
Density - Truck	1.14	0.11	veh/km
Flow - All	4410	137.3	veh/h
Flow - Car	4010.4	123.1	veh/h
Flow - Truck	399.6	22.63	veh/h
Harmonic Speed - All	21.25	0.21	km/h
Harmonic Speed - Car	21.53	0.19	km/h
Harmonic Speed - Truck	18.87	0.45	km/h
Input Count - All	4414.8	143.21	veh
Input Count - Car	4018	128.09	veh
Input Count - Truck	396.8	22.17	veh
Input Flow - All	4414.8	143.21	veh/h
Input Flow - Car	4018	128.09	veh/h
Input Flow - Truck	396.8	22.17	veh/h
Max. Virtual Queue - All	5.8	1.3	veh
Max. Virtual Queue - Car	5.8	1.3	veh
Max. Virtual Queue - Truck	1.2	0.45	veh
Mean Queue - All	50.5	1.83	veh
Mean Queue - Car	46.15	1.44	veh
Mean Queue - Truck	4.35	0.48	veh
Mean Virtual Queue - All	0.22	0.04	veh
Mean Virtual Queue - Car	0.2	0.04	veh
Mean Virtual Queue - Truck	0.01	0.01	veh
Missed Turns - All	0.6	0.89	
Missed Turns - Car	0.6	0.89	
Missed Turns - Truck	0	0	
Number of Lane Changes - All	543.32	19.76	#/km
Number of Lane Changes - Car	509.8	17.44	#/km
Number of Lane Changes - Truck	33.52	2.74	#/km
Number of Stops - All	0.13	0	#/veh/km
Number of Stops - Car	0.13	0	#/veh/km
Number of Stops - Truck	0.13	0.01	#/veh/km
Speed - All	27.1	0.23	km/h
Speed - Car	27.33	0.21	km/h
Speed - Truck	24.75	0.88	km/h
Stop Time - All	89.62	1.54	sec/km
Stop Time - Car	88.24	1.36	sec/km

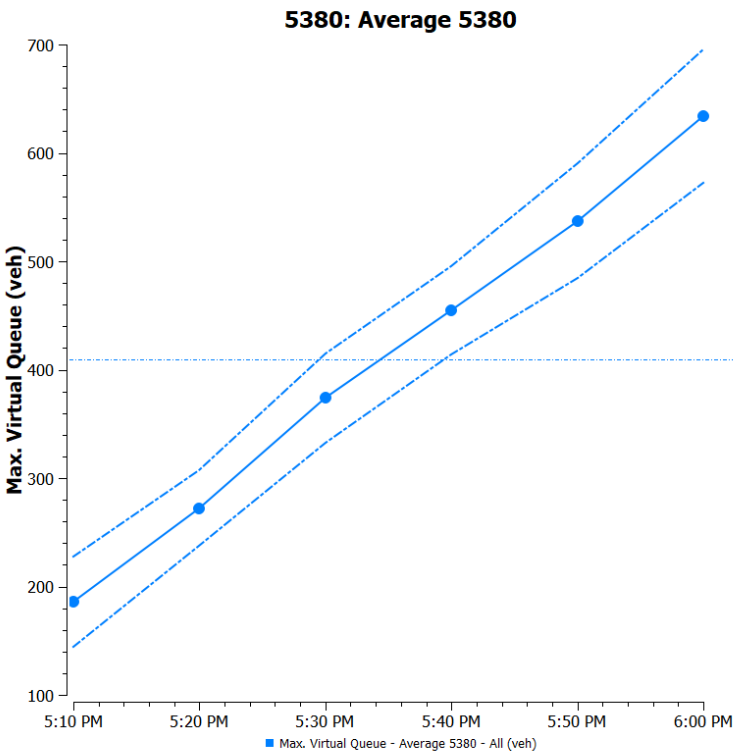
Stop Time - Truck	103.46	4.45	sec/km
Total Distance Traveled - All	2223.19	71.97	km
Total Distance Traveled - Car	2055.01	65.98	km
Total Distance Traveled - Truck	168.18	11.76	km
Total Distance Traveled (Vehicles Inside) - All	29.68	3.7	km
Total Distance Traveled (Vehicles Inside) - Car	27.83	3.77	km
Total Distance Traveled (Vehicles Inside) - Truck	1.85	0.7	km
Total Number of Lane Changes - All	4075.4	148.21	
Total Number of Lane Changes - Car	3824	130.8	
Total Number of Lane Changes - Truck	251.4	20.55	
Total Number of Stops - All	4413.2	174.41	
Total Number of Stops - Car	4037.8	143.33	
Total Number of Stops - Truck	375.4	36.42	
Total Travel Time - All	100.44	3.5	h
Total Travel Time - Car	91.73	2.94	h
Total Travel Time - Truck	8.7	0.8	h
Total Travel Time (Vehicles Inside) - All	2.26	0.44	h
Total Travel Time (Vehicles Inside) - Car	2.02	0.4	h
Total Travel Time (Vehicles Inside) - Truck	0.24	0.13	h
Total Travel Time (Waiting Out) - All	0	0	h
Total Travel Time (Waiting Out) - Car	0	0	h
Total Travel Time (Waiting Out) - Truck	0	0	h
Travel Time - All	169.38	1.63	sec/km
Travel Time - Car	167.24	1.44	sec/km
Travel Time - Truck	190.78	4.53	sec/km
Vehicles Inside - All	113.6	8.44	veh
Vehicles Inside - Car	104.2	8.44	veh
Vehicles Inside - Truck	9.4	1.14	veh
Vehicles Lost Inside - All	0.2	0.45	veh
Vehicles Lost Inside - Car	0.2	0.45	veh
Vehicles Lost Inside - Truck	0	0	veh
Vehicles Lost Outside - All	0.4	0.55	veh
Vehicles Lost Outside - Car	0.4	0.55	veh
Vehicles Lost Outside - Truck	0	0	veh
Vehicles Outside - All	4410	137.3	veh
Vehicles Outside - Car	4010.4	123.1	veh
Vehicles Outside - Truck	399.6	22.63	veh
Vehicles Waiting to Enter - All	0.2	0.45	veh
Vehicles Waiting to Enter - Car	0.2	0.45	veh
Vehicles Waiting to Enter - Truck	0	0	veh
Waiting Time in Virtual Queue - All	0.19	0.03	sec
Waiting Time in Virtual Queue - Car	0.2	0.03	sec
Waiting Time in Virtual Queue - Truck	0.12	0.04	sec

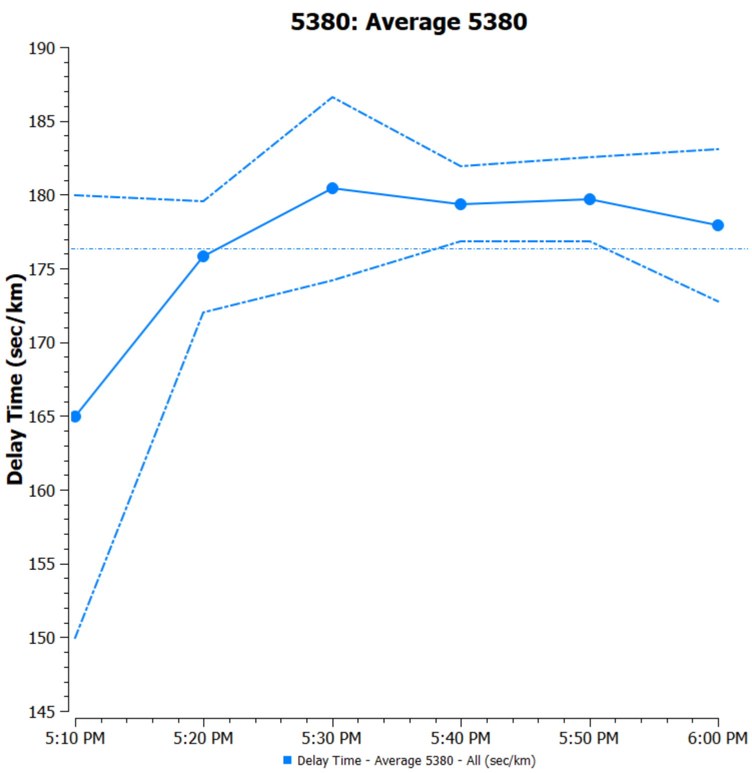

5380: Average 5380
Max. Virtual Queue (veh)
7
6
5
4
3
2
1
5:10 PM
5:20 PM
5:30 PM
5:40 PM
5:50 PM
6:00 PM
Max. Virtual Queue - All - Average 5380 (veh)

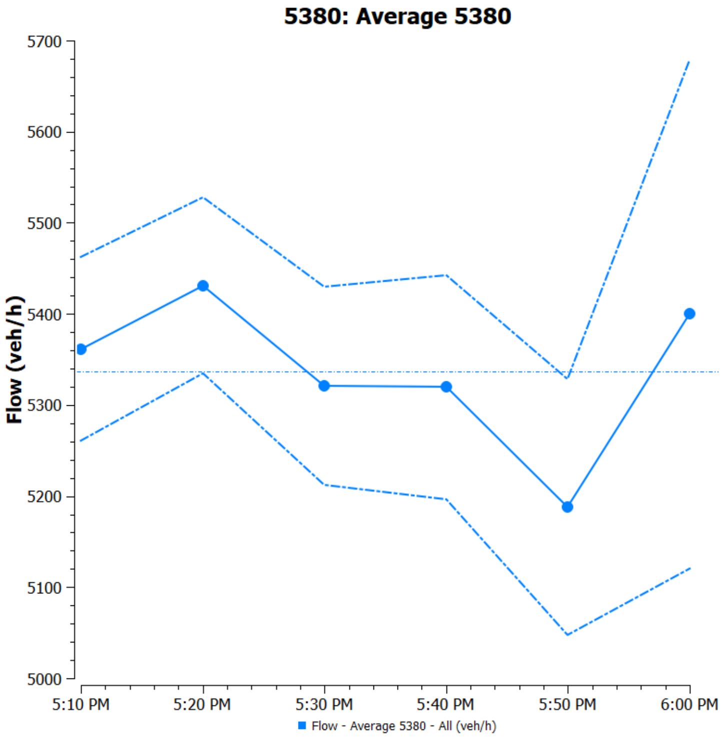
Annex 8: AIMSUN outputs of 2035 model before optimum solution

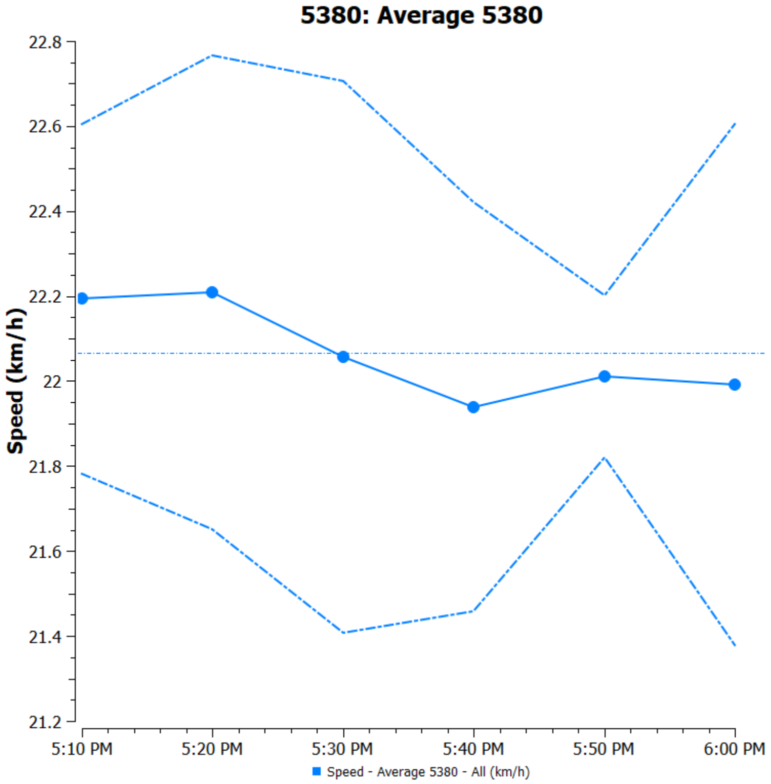
Time Series	Value	Standard Deviation	Units
Delay Time - All	176.33	2.87	sec/km
Delay Time - Car	177.38	2.92	sec/km
Delay Time - Truck	163.96	3.2	sec/km
Density - All	22.98	0.43	veh/km
Density - Car	21.46	0.38	veh/km
Density - Truck	1.52	0.12	veh/km
Flow - All	5336.8	31.26	veh/h
Flow - Car	4917.6	23.13	veh/h
Flow - Truck	419.2	26.31	veh/h
Harmonic Speed - All	14.83	0.18	km/h
Harmonic Speed - Car	14.78	0.18	km/h
Harmonic Speed - Truck	15.46	0.21	km/h
Input Count - All	5333.2	45.23	veh
Input Count - Car	4909.6	28.25	veh
Input Count - Truck	423.6	24.73	veh
Input Flow - All	5333.2	45.23	veh/h
Input Flow - Car	4909.6	28.25	veh/h
Input Flow - Truck	423.6	24.73	veh/h
Max. Virtual Queue - All	634	61.84	veh
Max. Virtual Queue - Car	622.4	61.66	veh
Max. Virtual Queue - Truck	15	3.54	veh
Mean Queue - All	106.06	2.34	veh
Mean Queue - Car	99.33	2.15	veh
Mean Queue - Truck	6.73	0.58	veh
Mean Virtual Queue - All	357.57	37.31	veh
Mean Virtual Queue - Car	351.36	36.62	veh
Mean Virtual Queue - Truck	6.21	1.68	veh
Missed Turns - All	2	1.22	
Missed Turns - Car	2	1.22	
Missed Turns - Truck	0	0	
Number of Lane Changes - All	663.33	7.99	#/km
Number of Lane Changes - Car	629.82	8.09	#/km
Number of Lane Changes - Truck	33.52	1.85	#/km
Number of Stops - All	0.18	0	#/veh/km
Number of Stops - Car	0.18	0	#/veh/km
Number of Stops - Truck	0.15	0	#/veh/km
Speed - All	22.07	0.17	km/h
Speed - Car	22.09	0.18	km/h
Speed - Truck	21.77	0.31	km/h
Stop Time - All	154.74	2.45	sec/km
Stop Time - Car	155.94	2.47	sec/km

Stop Time - Truck	140.78	3.26	sec/km
Total Distance Traveled - All	2674.87	30.75	km
Total Distance Traveled - Car	2502.63	32.85	km
Total Distance Traveled - Truck	172.24	13.25	km
Total Distance Traveled (Vehicles Inside) - All	39.47	7.98	km
Total Distance Traveled (Vehicles Inside) - Car	35.21	7.33	km
Total Distance Traveled (Vehicles Inside) - Truck	4.26	0.77	km
Total Number of Lane Changes - All	4975.6	59.95	
Total Number of Lane Changes - Car	4724.2	60.68	
Total Number of Lane Changes - Truck	251.4	13.9	
Total Number of Stops - All	7140.4	114.19	
Total Number of Stops - Car	6671.2	106.4	
Total Number of Stops - Truck	469.2	32.52	
Total Travel Time - All	172.07	3.58	h
Total Travel Time - Car	160.78	3.15	h
Total Travel Time - Truck	11.29	0.97	h
Total Travel Time (Vehicles Inside) - All	24.21	3.72	h
Total Travel Time (Vehicles Inside) - Car	22.77	3.9	h
Total Travel Time (Vehicles Inside) - Truck	1.43	0.51	h
Total Travel Time (Waiting Out) - All	142.34	15.34	h
Total Travel Time (Waiting Out) - Car	140.69	15.43	h
Total Travel Time (Waiting Out) - Truck	1.65	0.38	h
Travel Time - All	242.8	2.88	sec/km
Travel Time - Car	243.64	2.93	sec/km
Travel Time - Truck	232.91	3.22	sec/km
Vehicles Inside - All	171.4	25.11	veh
Vehicles Inside - Car	154.4	24.86	veh
Vehicles Inside - Truck	17	2.35	veh
Vehicles Lost Inside - All	0	0	veh
Vehicles Lost Inside - Car	0	0	veh
Vehicles Lost Inside - Truck	0	0	veh
Vehicles Lost Outside - All	2	1.22	veh
Vehicles Lost Outside - Car	2	1.22	veh
Vehicles Lost Outside - Truck	0	0	veh
Vehicles Outside - All	5336.8	31.26	veh
Vehicles Outside - Car	4917.6	23.13	veh
Vehicles Outside - Truck	419.2	26.31	veh
Vehicles Waiting to Enter - All	629.8	61.57	veh
Vehicles Waiting to Enter - Car	618	61.32	veh
Vehicles Waiting to Enter - Truck	11.8	2.59	veh
Waiting Time in Virtual Queue - All	218.67	17.72	sec
Waiting Time in Virtual Queue - Car	231.81	18.59	sec
Waiting Time in Virtual Queue - Truck	51.65	12.57	sec


5380: Average 5380
Max. Virtual Queue (veh)
700
600
500
400
300
200
100
5:10 PM
5:20 PM
5:30 PM
5:40 PM
5:50 PM
6:00 PM
Max. Virtual Queue - Average 5380 - All (veh)


5380: Average 5380
Delay Time (sec/km)
190
185
180
175
170
165
160
155
150
145
5:10 PM
5:20 PM
5:30 PM
5:40 PM
5:50 PM
6:00 PM
Delay Time - Average 5380 - All (sec/km)

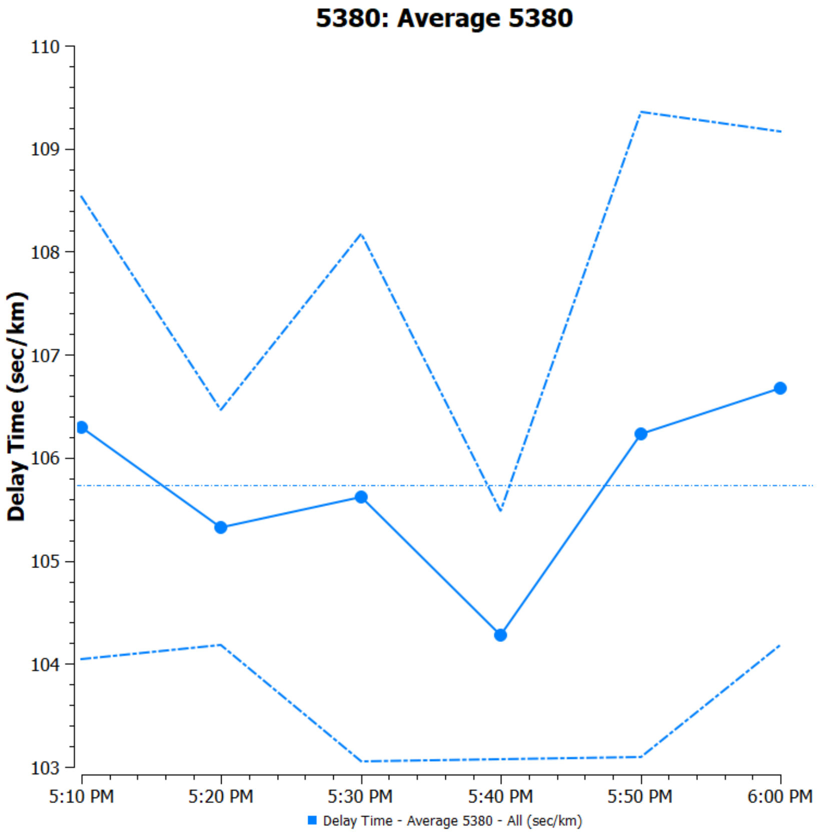

5380: Average 5380
Flow (veh/h)
5700
5600
5500
5400
5300
5200
5100
5000
5:10 PM
5:20 PM
5:30 PM
5:40 PM
5:50 PM
6:00 PM
Flow - Average 5380 - All (veh/h)


5380: Average 5380
Speed (km/h)
22.8
22.6
22.4
22.2
22
21.8
21.6
21.4
21.2
5:10 PM
5:20 PM
5:30 PM
5:40 PM
5:50 PM
6:00 PM
Speed - Average 5380 - All (km/h)

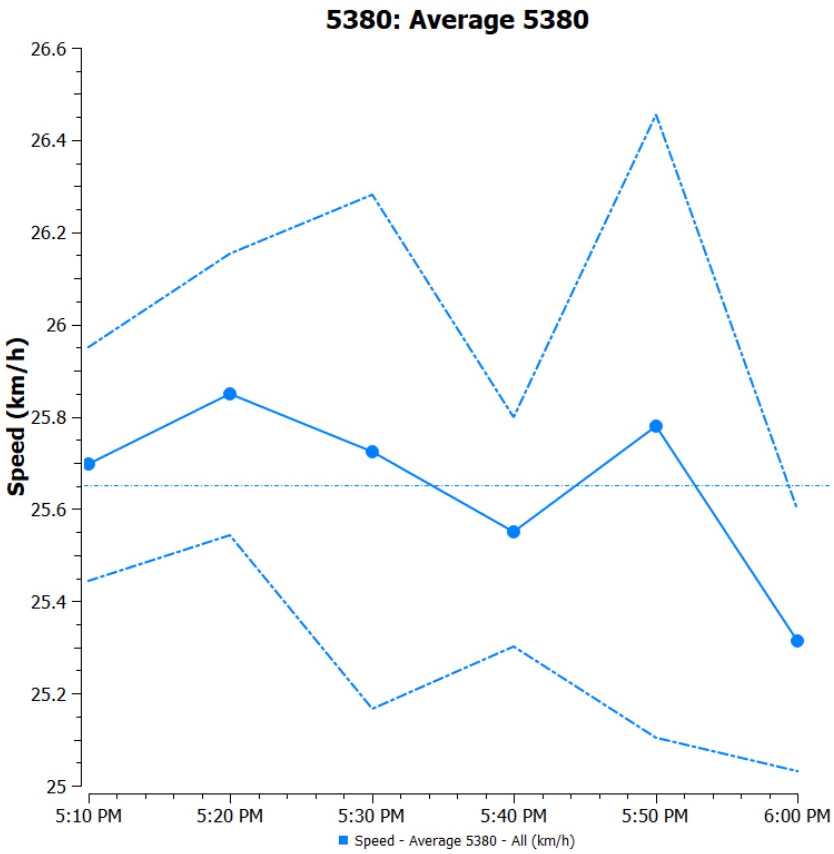
Annex 9: AIMSUN Outputs of 2035 Optimum model

Time Series	Value	Standard Deviation	Units
Delay Time - All	105.74	0.61	sec/km
Delay Time - Car	104.41	0.63	sec/km
Delay Time - Truck	122.55	3.94	sec/km
Density - All	16.3	0.32	veh/km
Density - Car	15.21	0.32	veh/km
Density - Truck	1.09	0.07	veh/km
Flow - All	5907.2	70.41	veh/h
Flow - Car	5475	74	veh/h
Flow - Truck	432.2	28.35	veh/h
Harmonic Speed - All	20.9	0.07	km/h
Harmonic Speed - Car	21.09	0.08	km/h
Harmonic Speed - Truck	18.8	0.38	km/h
Input Count - All	5866.8	73.49	veh
Input Count - Car	5432.8	72.39	veh
Input Count - Truck	434	26.09	veh
Input Flow - All	5866.8	73.49	veh/h
Input Flow - Car	5432.8	72.39	veh/h
Input Flow - Truck	434	26.09	veh/h
Max. Virtual Queue - All	14.6	1.82	veh
Max. Virtual Queue - Car	14.6	1.82	veh
Max. Virtual Queue - Truck	1.8	0.45	veh
Mean Queue - All	71.48	1.48	veh
Mean Queue - Car	66.65	1.47	veh
Mean Queue - Truck	4.83	0.32	veh
Mean Virtual Queue - All	2.23	0.2	veh
Mean Virtual Queue - Car	2.2	0.19	veh
Mean Virtual Queue - Truck	0.02	0.02	veh
Missed Turns - All	1.2	1.3	
Missed Turns - Car	1.2	1.3	
Missed Turns - Truck	0	0	
Number of Lane Changes - All	550.42	21.27	#/km
Number of Lane Changes - Car	528.97	20.62	#/km
Number of Lane Changes - Truck	21.45	1.56	#/km
Number of Stops - All	0.13	0	#/veh/km
Number of Stops - Car	0.13	0	#/veh/km
Number of Stops - Truck	0.11	0	#/veh/km
Speed - All	25.65	0.12	km/h
Speed - Car	25.73	0.1	km/h
Speed - Truck	24.67	0.55	km/h
Stop Time - All	91.07	0.4	sec/km
Stop Time - Car	90.04	0.43	sec/km

Stop Time - Truck	104.04	3.72	sec/km
Total Distance Traveled - All	2932.26	46.42	km
Total Distance Traveled - Car	2755.46	49.33	km
Total Distance Traveled - Truck	176.8	13.98	km
Total Distance Traveled (Vehicles Inside) - All	26.24	4.56	km
Total Distance Traveled (Vehicles Inside) - Car	24.19	4.06	km
Total Distance Traveled (Vehicles Inside) - Truck	2.05	0.62	km
Total Number of Lane Changes - All	4655.4	179.89	
Total Number of Lane Changes - Car	4474	174.38	
Total Number of Lane Changes - Truck	181.4	13.2	
Total Number of Stops - All	6354.2	147.67	
Total Number of Stops - Car	5944.4	144.92	
Total Number of Stops - Truck	409.8	27.92	
Total Travel Time - All	138.82	2.71	h
Total Travel Time - Car	129.61	2.73	h
Total Travel Time - Truck	9.22	0.66	h
Total Travel Time (Vehicles Inside) - All	2.14	0.72	h
Total Travel Time (Vehicles Inside) - Car	1.8	0.3	h
Total Travel Time (Vehicles Inside) - Truck	0.35	0.48	h
Total Travel Time (Waiting Out) - All	0.02	0.01	h
Total Travel Time (Waiting Out) - Car	0.02	0.01	h
Total Travel Time (Waiting Out) - Truck	0	0	h
Travel Time - All	172.23	0.61	sec/km
Travel Time - Car	170.71	0.65	sec/km
Travel Time - Truck	191.48	3.92	sec/km
Vehicles Inside - All	122.4	17.7	veh
Vehicles Inside - Car	112	15.57	veh
Vehicles Inside - Truck	10.4	3.78	veh
Vehicles Lost Inside - All	0	0	veh
Vehicles Lost Inside - Car	0	0	veh
Vehicles Lost Inside - Truck	0	0	veh
Vehicles Lost Outside - All	1.2	1.3	veh
Vehicles Lost Outside - Car	1.2	1.3	veh
Vehicles Lost Outside - Truck	0	0	veh
Vehicles Outside - All	5907.2	70.41	veh
Vehicles Outside - Car	5475	74	veh
Vehicles Outside - Truck	432.2	28.35	veh
Vehicles Waiting to Enter - All	4.2	2.05	veh
Vehicles Waiting to Enter - Car	4.2	2.05	veh
Vehicles Waiting to Enter - Truck	0	0	veh
Waiting Time in Virtual Queue - All	1.38	0.11	sec
Waiting Time in Virtual Queue - Car	1.47	0.12	sec
Waiting Time in Virtual Queue - Truck	0.21	0.1	sec

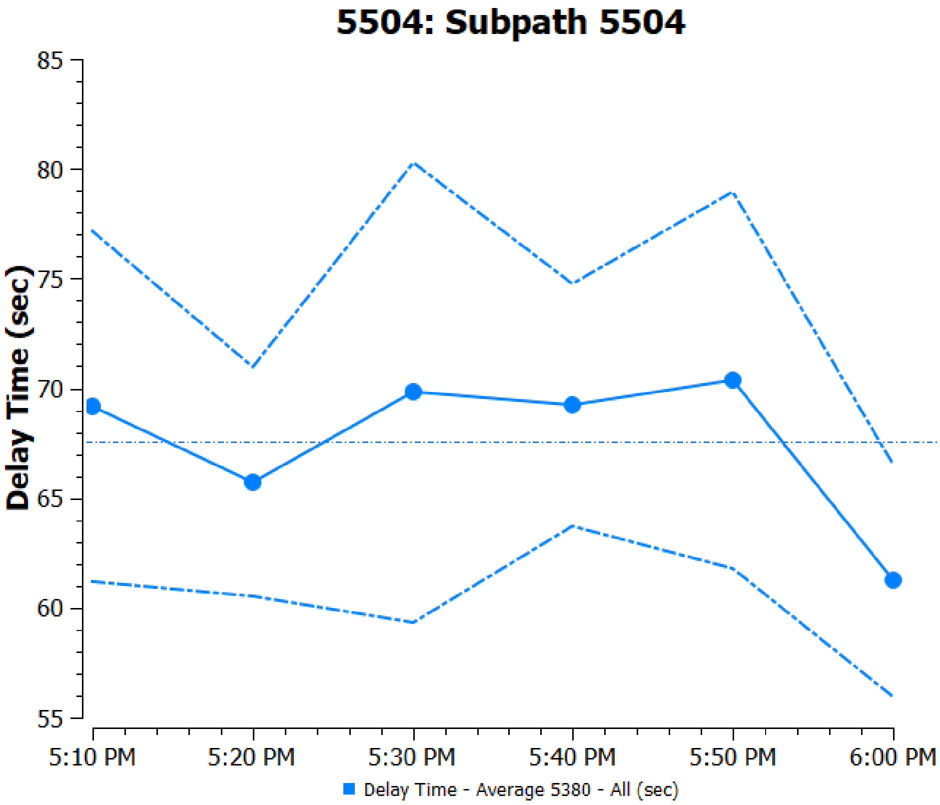


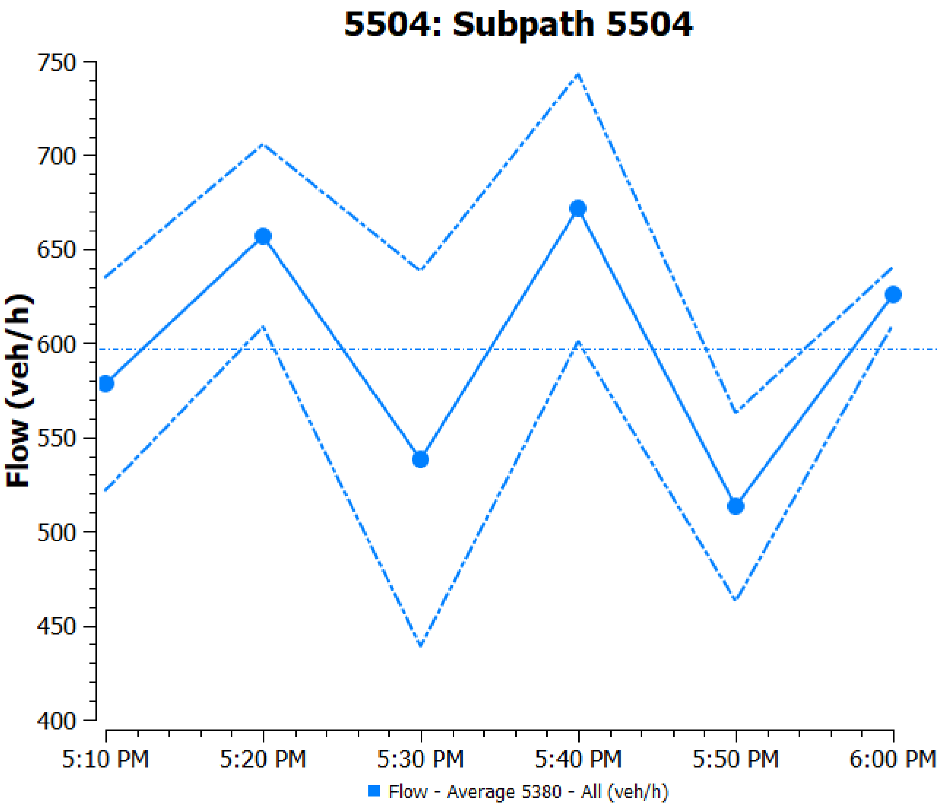
5380: Average 5380
Delay Time (sec/km)
110
109
108
107
106
105
104
103
5:10 PM
5:20 PM
5:30 PM
5:40 PM
5:50 PM
6:00 PM
Delay Time - Average 5380 - All (sec/km)

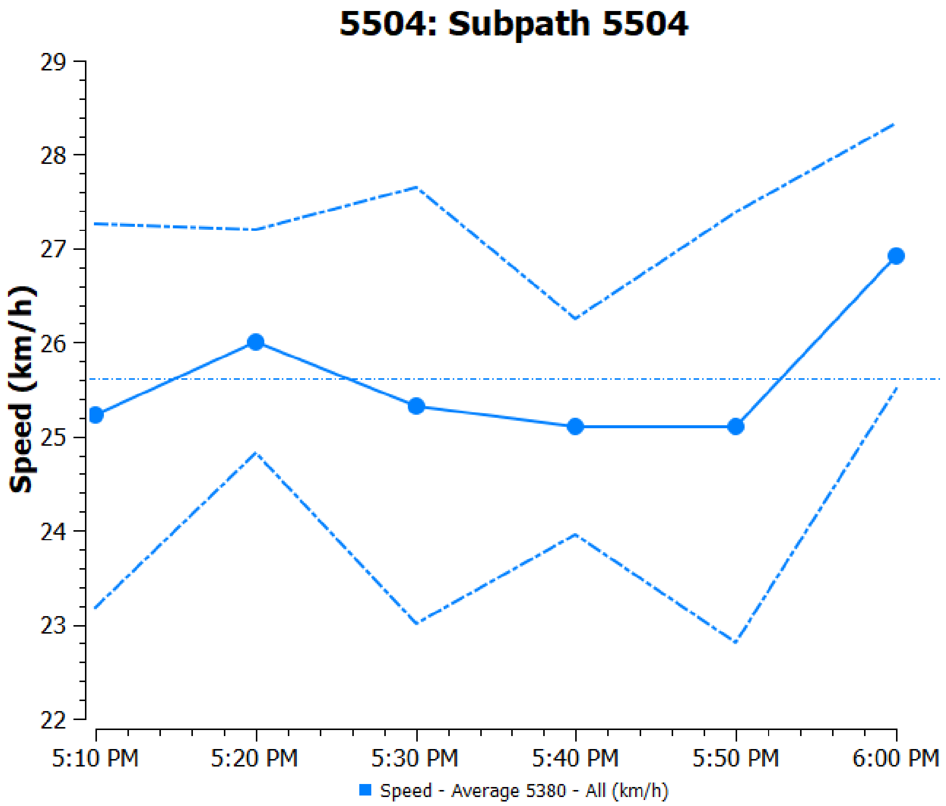


5380: Average 5380
Speed (km/h)
26.6
26.4
26.2
26
25.8
25.6
25.4
25.2
25
5:10 PM
5:20 PM
5:30 PM
5:40 PM
5:50 PM
6:00 PM
Speed - Average 5380 - All (km/h)

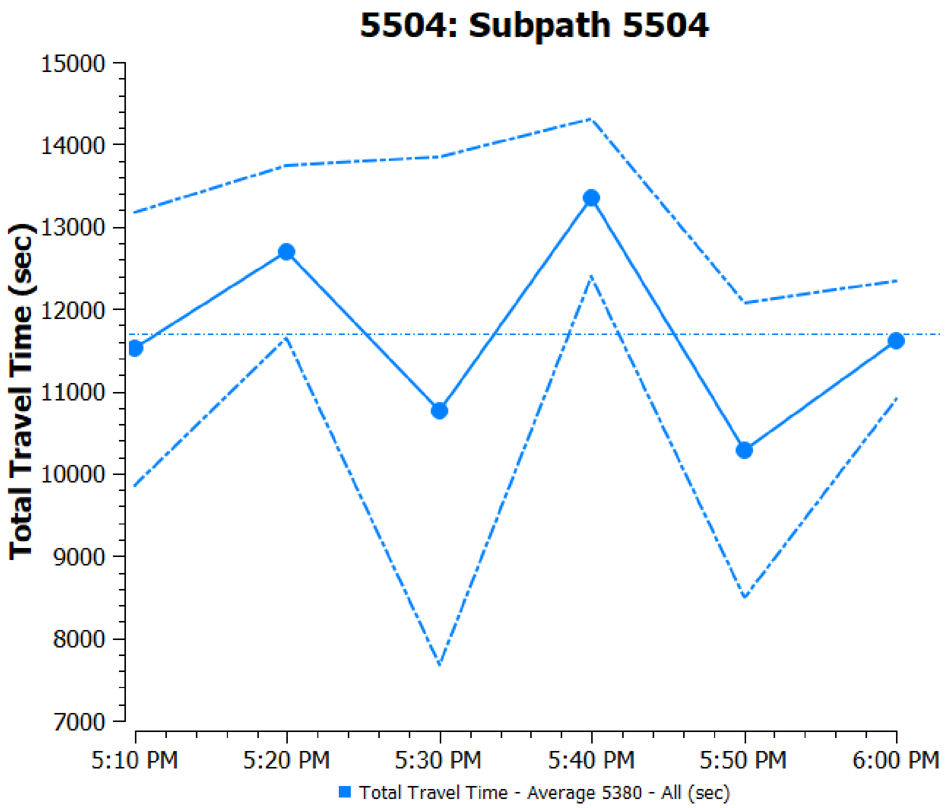
Annex 10: AIMSUN Northbound Sub-path Outputs of 2035 Optimum model



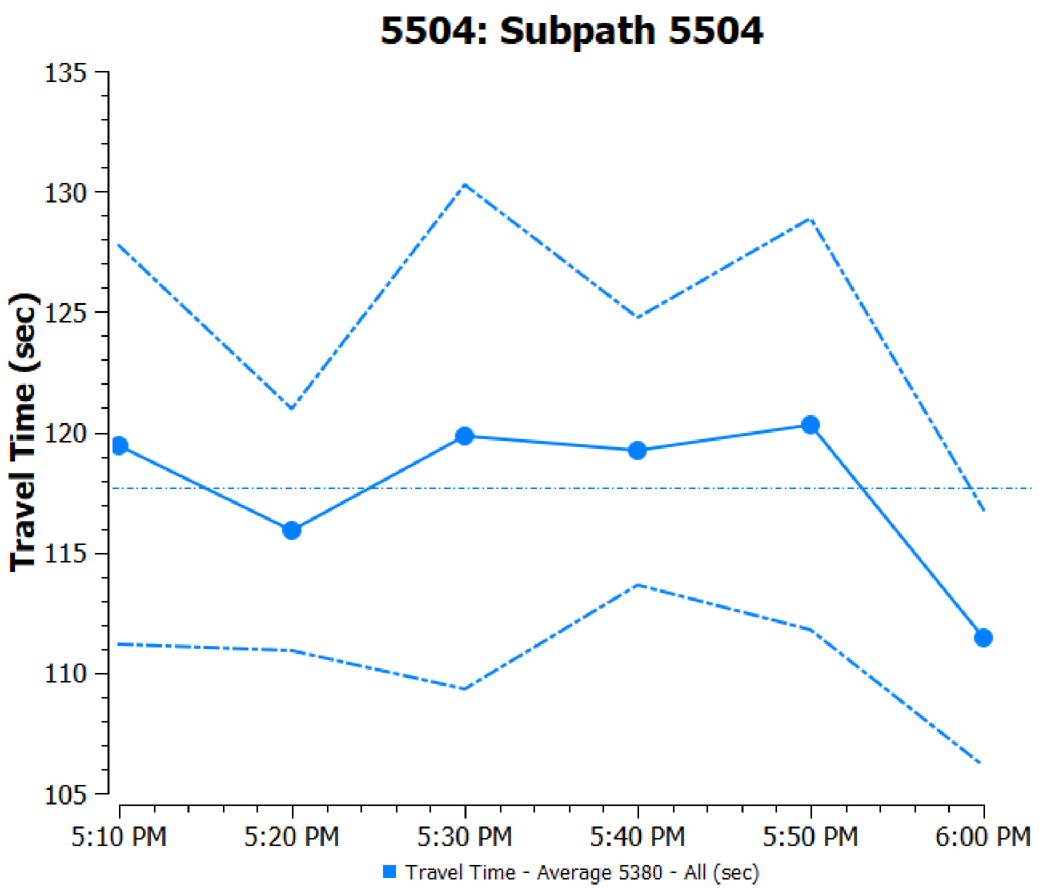




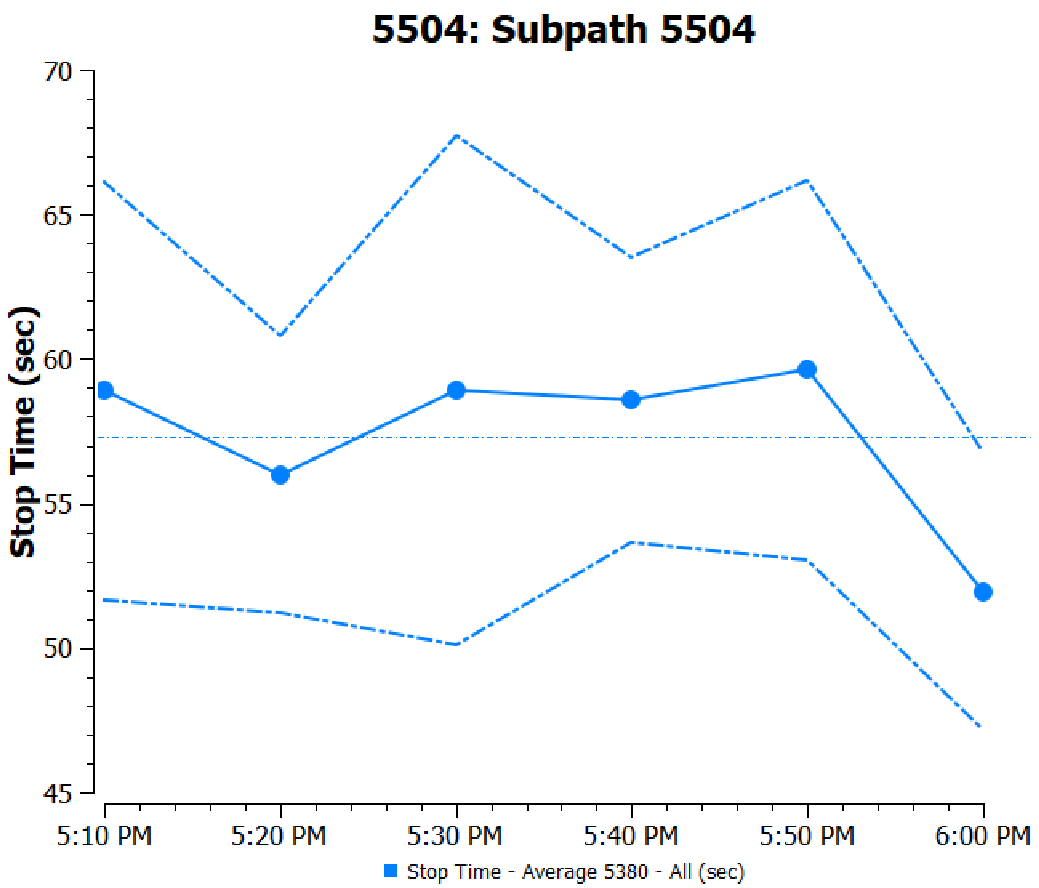
5504: Subpath 5504
Speed (km/h)
29
28
27
26
25
24
23
22
5:10 PM
5:20 PM
5:30 PM
5:40 PM
5:50 PM
6:00 PM
Speed - Average 5380 - All (km/h)



5504: Subpath 5504
Total Travel Time (sec)
15000
14000
13000
12000
11000
10000
9000
8000
7000
5:10 PM
5:20 PM
5:30 PM
5:40 PM
5:50 PM
6:00 PM
Total Travel Time - Average 5380 - All (sec)

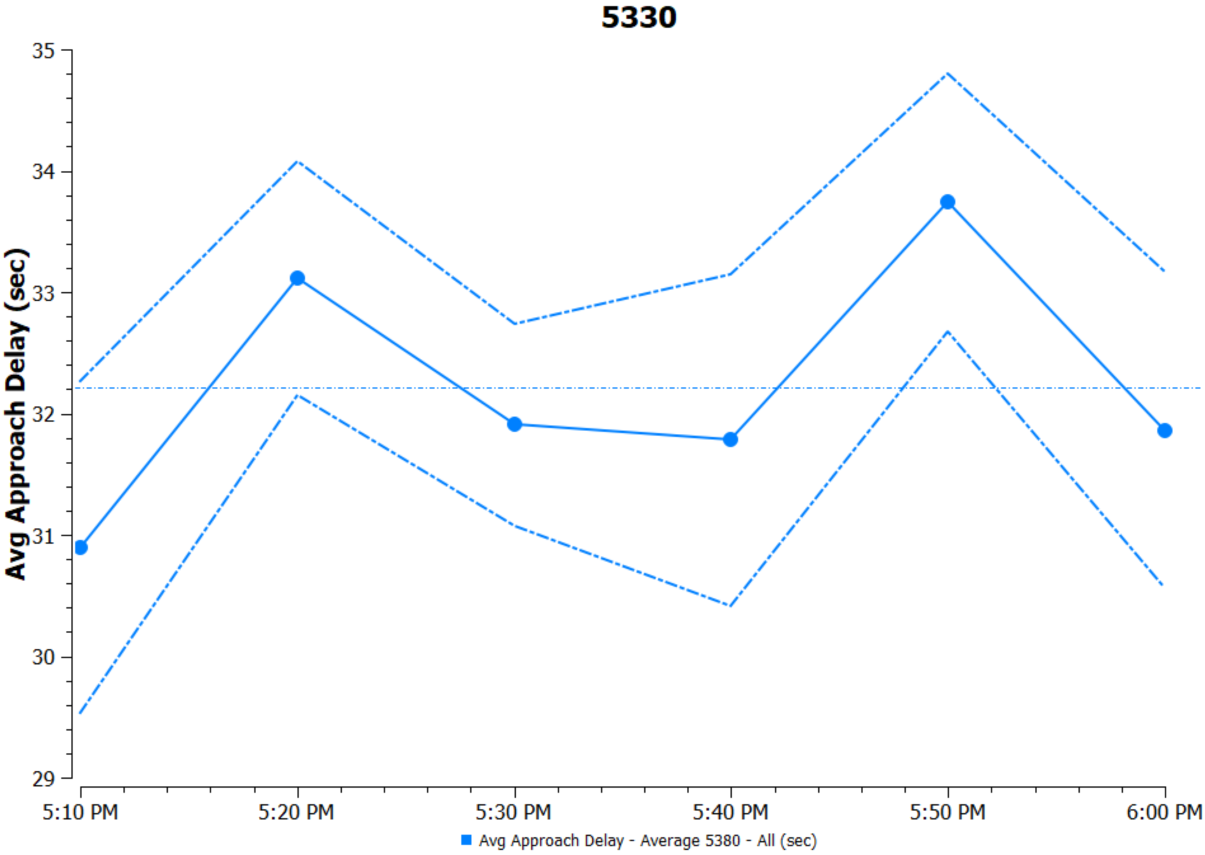


5504: Subpath 5504
Travel Time (sec)
135
130
125
120
115
110
105
5:10 PM
5:20 PM
5:30 PM
5:40 PM
5:50 PM
6:00 PM
Travel Time - Average 5380 - All (sec)



5504: Subpath 5504
Stop Time (sec)
70
65
60
55
50
45
5:10 PM
5:20 PM
5:30 PM
5:40 PM
5:50 PM
6:00 PM
Stop Time - Average 5380 - All (sec)

Annex 11: TS001 Intersection Outputs – 2035 Optimum model



Annex 12: AIMSUN OD Matrices

OD Matrix: 5372, Name: matrix cars {f17cee13-4f76-48db-9d6c-4b182ddf71b9} (Centroid Configuration: 5365: Centroid Configuration 5365)

Main | Cells | Histogram | Path Assignment | Parameters

Headers: ID: Name   Grouping Category: None

Show All Centroids   Hide Empty Rows   Hide Empty Columns   Draw Desire Lines

	5369: 1	5405: 2	5406: 3	5407: 4	5408: 5	5409: 6	5467: D1	5470: D2	5473: D3	5476: D4	Total
5369: 1		172	90	416		50	84				812
5405: 2	256		4	4		4	4				272
5406: 3	284	10		136	604	10					1044
5407: 4	542	20			80	10					652
5408: 5	202	26	862	129		10					1229
5409: 6	203	53	91	294							641
5467: D1				10							10
5470: D2											
5473: D3	32					20					52
5476: D4	230	20									250
Total	1749	301	1047	989	684	104	88				4962

OD Matrix: 5418, Name: matrix heavy vehicles {e76a0e35-4b70-4e94-b0a4-18261c9e965f} (Centroid Configuration: 5365: Centroid Configuration 5365)

Main | Cells | Histogram | Path Assignment | Parameters

Headers: ID: Name   Grouping Category: None

Show All Centroids   Hide Empty Rows   Hide Empty Columns   Draw Desire Lines

	5369: 1	5405: 2	5406: 3	5407: 4	5408: 5	5409: 6	5467: D1	5470: D2	5473: D3	5476: D4	Total
5369: 1		8	5	43			34				90
5405: 2	8										8
5406: 3	22			16	44						82
5407: 4					12				82		94
5408: 5	20		28	9							57
5409: 6			1	3							4
5467: D1											
5470: D2			12	30							42
5473: D3											
5476: D4	27	12									39
Total	77	20	46	101	56		34		82		416