Assessment of Darlington Upgrade using Microsimulation

ENGR9700A-D: Thesis Project

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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.

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Abstract

Freeways and highways are the most important links in the world transportation network. However, as traffic is increasing, many parts of the road network are currently operating at full capacity or will not be able to meet future needs. The consequences of this include travel delays, CO2 and NOx emissions, an increase in total trip cost and danger to driver safety. This thesis paper has been prepared for the assessment of Darlington upgrade using microsimulation and investigates the performance of intersections i.e. Tonsley Boulevard, Ayliffes intersection, Sturt intersection, and Flinders drive. The impact on the performance of the networks was observed on Darlington upgrade in Microsimulation model created in Autodesk Infraworks. The aim of this research is to figure out changes in terms of economic performance, travel time, level of service (LOS) and environmental impact for existing and future models for given SCATS volume data.

Mobility Simulation- a different section of same software is used to generate the microscopic simulation model of the current network and two future models. Future Model 1 follows the DPTI proposed guidelines for the upgrade operation in 2031, having three lanes tunnel in both directions. Future Model 2 includes a change to the 2031 DPTI model network to improve the network conditions, by adding one additional lane in tunnel for both directions. The future scenario was compared to check the changes in traffic delay, Level of Service(LOS) and economic evaluations.

Results were calculated for each performance indicator for all models, and it was found that future model 2 performing best in simulation analysis. Compared with future model 1 – (DPTI version), future model 2 was more economical as the average total cost was reduced by 2.19 %, representing sum of time cost, distance cost and stop cost. Moreover, the average speed of vehicle in network was 45.04 km/h with an increase of 2.67 km/h with future model 1. The level of services of intersection was improved, overall control delay was reduced by 4.67%, the carbon and nitrogen oxides emission were reduced by 0.08% and 2.05% respectively by the addition of extra lane.

Future model 1 also performed better than the existing model on all performance indicators. The average travel time increased by 61.08% and average control delay increase by 40.16%

when it was compared with existing model. Average speed of vehicle in network was 34.06 km/h.

A detailed comparison of DPTI tunnel 3 lanes 2031 AM and Future Model 2 Tunnel 4 lanes 2031 AM is performed for lane merging at a particular time and it was found that observed length of queue is long in model 1 with bad level of service in merging of two lanes and vehicle speed in the lane was 4.9 km/h less when it was compared.

The methodology outlining the method of data collections, input, base model construction, calibration and validation. This information will help to benefit future research in the field of transportation engineering, as it can be used by developers and city planners to design the existing road network for the purpose of redevelopment.

Contents

List of Figures

List of Tables

List of Equations

List of Abbreviations

ITULP=Integrated Transport and Land Use

DPTI= Department of Transport and Infrastructure

SCATS= Sydney Coordinated Adaptive Traffic System

ITS= Intelligent Transport System

ATIS= Advanced Traveller Information System

LOS= Level of Service

MASTEM= Metropolitan Adelaide Strategic Transport Evaluation Model

OD= Origin-Destination (Matrix)

VHT= Vehicle Hourly Travelled

AUD= Australian Dollars

CT= Cycle Time

LCV= Light Commercial Vehicle

SD= Standard Deviation

1 Introduction, Background and Importance

North-South corridor proposes the only continuous route for freight and commercial traffic movement through Adelaide, and it performs a significant distribution and linking for the industry and commerce. The Southern and Northern part of the North-South corridor is already motorway standard and the complete corridor is intended to motorway standard by 2030.

It is recognised by the South Australian ITLUP that "The North-South Corridor upgrade works will be critical in ensuring the efficient connectivity of north-south freight and business movements through the middle of Adelaide" (Government of South Australia, 2013). In an investigation, it is found that the Gawler to Old Noarlunga current network is not working properly and it cannot handle the expected traffic in the future (DPTI, 2013). Many projects are seeking upgrade alongside the network and the Darlington Upgrade Project is an integral component in the progression of the network.

The major reason for road network reaching volume is congestion on expressways and the outcome is an inability in supporting traffic demands. "Most parts of road networks, particularly in densely populated areas, have already touched their maximum capacity or will not meet increasing demands of mobility as assumed for upcoming years. Thus, it is highly desirable to analyse and test road systems to allow for better usage of current infrastructure" (Schreckenberg et al., 2001). Moreover, societies are also getting affected by the over congestion on roads in terms of delay times, compromising safety and increased emission. Recurring and non-recurring incidents are the main factors that exacerbate traffic congestion on expressways. The non-recurring incidents will be attention of the research, such as roadworks, breakdowns and crashes on traffic flow characteristics and also contains the quantifying issues such as queue lengths, travel speeds, influence the society in terms of financially and environmentally.

Figure 1. 1: Darlington Upgrade project location shown in the north-south corridor from DPTI 2015

The study area is the Darlington Upgrade Project, which is a part of a series of transportation infrastructure upgrades to complete the southern end of North-South Corridor. The project involves providing 3.3 kilometres of non-stop motorway to extend the Southern Expressway beyond Tonsley Boulevard as shown in figure 1.1 and area highlighted in orange colour is the section of Darlington Upgrade. This project is still under construction will complete by mid-2020 however, to access the road network performance of the Darlington project and to plan its future development of the network, a software package of traffic simulation known as Autodesk Infraworks and mobility simulator is used.

1.1 Research Aims and Objectives

According to the review of the literature and research gap analysis, there is a requirement of research to be undertaken. To successfully address the knowledge gaps, a set of aim is targeted for the better direction of outcome.

Aims of this research are listed below : -

- Construct a microscopic traffic model of Darlington project for the purposes of analysing model scenarios.
- Analyse current road operations and performance metrics and change in the road network configuration to optimize the performance of the future proposed network.
- Investigate the impact on financial cost, vehicle emission also on key parameters such as -queue, delay, travel speed and number of stops.

- Assessment of project to minimise the level of service with 2031 SCATS volume count by considering the different development scenarios.

The existing road network is analysed by constructing a scaled microscopic traffic simulation in Infraworks and calibrated to quantify the effect of growth on transport engineering parameters.

1.2 Project Scope

This project scope is largely based on the objectives and aims, also investigates the viability of the future model in terms of environmental impact, economic viability and travel time. The important role for the implementation of ITS in the Darlington upgrade is to preserve the free flow or nonstop operational flow of freight and other traffic to ensure the better level of services in lanes.

1.3 Structure of thesis

This paper is divided into seven chapters, further divided into sections and subsections. Chapter 2, after the introduction, will provide a detailed background of north-south corridor section Darlington and significance of Darlington Upgrade. Chapter 4 describes how to create a base model of existing structure using Autodesk Infraworks Simulation software package. This chapter also includes the data collection, input sources, validation and calibration required to build the base model for the purpose of development. This chapter ends with assumptions and limitations that may exist in the generated model.

Chapter 5 discusses the theoretical and experimental methods for creating two future models. These two models include: Proposed DPTI 3 lane tunnel and future model 2 that has 4 lane tunnel.

Chapter 6 presents the results of various traffic models and their future model comparison. The result of the report includes; travel efficiency, emissions, level of service evaluation of economic trip. The results are displayed as tables and graphs with an explanation of pivotal results.

Finally, Chapter 7 provides conclusions drawn from the above results. These conclusions include a recommendation for the DPTI model.

2 Review of Literature

This chapter will overview the current literature on motorway congestion and review the impact of congestion on freeway. Further, study of financial and environmental implications due to congestion is reviewed. Major part of literature outlines the computer simulation and several kinds for different types of development and another section critically analyse the previous case studies.

2.1 Impact from Freeway Congestion

Some of the most important elements of road infrastructure all over the world are Freeways and Motorways which link major transport regions and networks globally. Generally, it is expected that freeways and motorways help in improving the travel time for commuters and allow mass traffic movement and flow; but this case is not always true. Nowadays, the reason of over congestion on motorway and freeway is directly proportional to the increase in population of world and associated consequences on cost of delay, environmental exhaust emissions of vehicles and increase in travel time(Ferrara et al., 2013). A great amount of traffic can be attributed to non-recurring incidents, which are defined by Koorey, McMillan and Nicholson (2014) as being a temporary and unexpected drop in volume due to incidents, road collision vehicle breakdown, where the roadway capacity is the maximum obtainable traffic flow on a particular highway when all lanes are in use (Chin et al., 2002). The consequences of being insufficient capacity on a roadway to support traffic demand on a regular basis, especially in peak hours are referred to as recurring congestion. It is observed that up to 55% of delays on freeways are caused by these non-recurring incidents, termed as incident-induced delay(Chung et al., 2013). The difference in travel time experienced by flow of traffic between normal (incident-free) and incident conditions is known as Incident-induced Delay(Kabit et al., 2014). The main cause of almost 50% of traffic congestion in Australia's major cities is incidents(Taylor, 2008). Further, some of the events are classified into major and minor incidents based on their associated impacts, by Kabit et al. (2011) and found the average duration of a major incident to be 88 minutes. The research by the same researcher also stated that these major incidents are usually associated with multiple vehicle collisions, serious injuries or fatalities, multiple lane blockages, rolled over trucks, hazardous material spills or other detrimental complications. A research by Yu et al. (2014) in order to enhance the impacts of incidents on computer's travel time, found that for an incident of 43 minutes duration on a freeway in The USA, total delay was 9332 vehicle minutes. The substantial financial impacts are correlated with significant increase in travel time, due to hourly travel time rates for different commuters, as will be discussed in Section 2.2.1 (Austroads 2006; Austroads 2008; Kabit et al. 2014).

2.2 Impacts of Incidents

The frequent occurring of freeway congestion can be associated with big traffic accidents (non-recurring incidents) result in huge impacts on public. Mainly, these impacts can be classified into two main categories - financial and environmental implications.

2.2.1 Financial Implications

Significant delays are not only caused by road accidents, but the direct result is impact to the environment and financial cost as well as the above topic of this research. Kabit et al. (2014) propose a relationship between cost and occupant time, vehicle operating expenses and external cost including air pollution. Dia (2011) also stated that environment emissions and secondary accidents are also essential factors of congestion. These factors are also taken into consideration and damaged caused to society is enormous. In urban areas of the United States, congestion costs in 2005 were estimated at $78.2 billion, equivalent to $707 per traveller(Luk et al., 2009). The study found that the cost of traffic congestion during financial year 2015 for all capital cities was estimated $16.5 billion, over a period of 5-year from 2010 levels have increased in Australia (Bureau of Infrastructure Transport and Regional Economics 2015).

Figure 2.1 represents the total cost of road accidents per capita in states and territories of Australia in 2003. In South Australia in the city of Adelaide, it was found that the total cost of road traffic crashes alone have a cost of $ 1.165 billion to the economy in 2003, equivalent to 2.32% of the state's total gross domestic product(Connelly and Supangan, 2006). It is evident that the cost of road traffic crashes in Western Australia and the Northern Territory is well above the national average, which is due to the number of fatalities per capita, which is shown clearly in Figure 2.1. There are numerous factors such as the quality of roads, safety furniture and the distance the crashes occur from trauma care facilities can be attributed also(Connelly and Supangan, 2006).

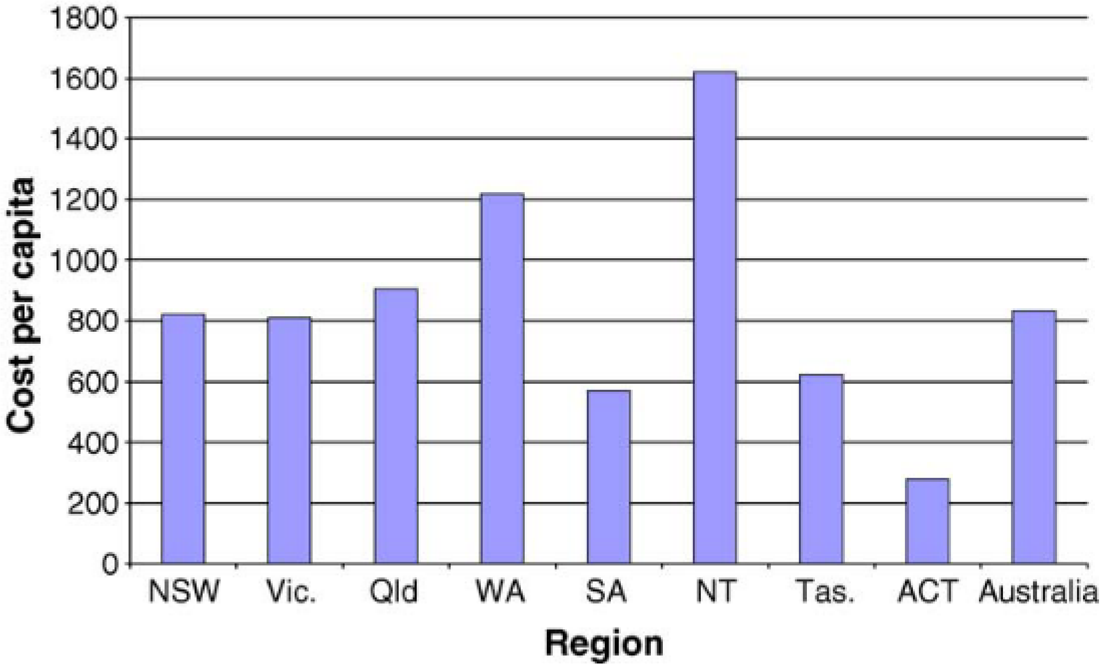


Figure 2. 1: Total cost per capita of road traffic crashes in AUD (2003)(Connelly and Supangan, 2006)

2.2.2 Environmental Implications

According to the environmental effects of big accidents during traffic jams, the efficiency of vehicle engines decreases resulted in an increase in the rate of air pollutant emissions (Bureau of Infrastructure Transport and Regional Economics 2009). For almost 14% of the Nation's gross emissions in Australia, the transport sector is responsible alone, in which approximately 90% is contributed by road transport. In a case study on the Monash Freeway of vehicle travelling, it was observed that from all emissions, 95% is CO2 (Luk et al., 2009). The emissions from transport in Australia in 2012 accounted for 91Mt of Carbon dioxide equivalents (CO_2e), for putting these figures in perspective, in which around 84% of emissions are due to road transport (Commonwealth of Australia 2013). CO_2e is a unit for describing several greenhouse gases, having that much amount of carbon dioxide which equally influence on climate change. Figure 2.2 shows the increase in emission of CO_2e between 1990 and 2020 for multi-mode transport sectors. It is observed from this graph that sector of road transport alone has an increase of 49% in emissions, with the rise in levels of CO_2e range from approx. 73 giga grams in 1990 to 109 giga grams in 2020. A study conducted in Orange Country, California by Chung, Cho and Choi (2013) showed that environmental effects are a direct result of traffic incidents that have 6200 accidents in the study of freeways. It was also observed that the average incidents on roads that is non-recurring incident resulted in rise of CO_2e emissions of 398.4 Kg.

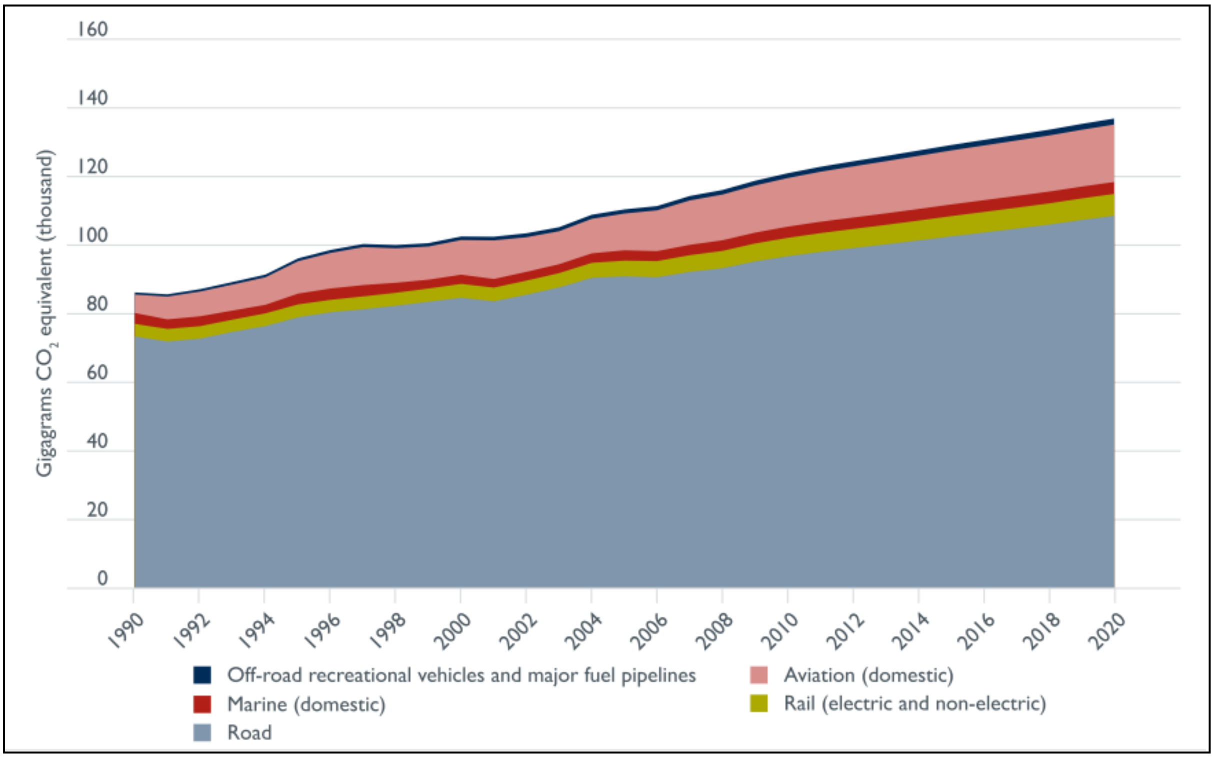


Figure 2. 2: Multi-modal transport sector CO2e emissions between 1990 and 2020 in Australia (Bureau of Infrastructure Transport and Regional Economics 2009)

It is seen from the above figure that there is immense value in quantifying these incident impact parameters with specific application to a hypothetical case study and investigating ways of potentially mitigating these negative consequences for different freeway networks.

2.3 Computer Simulation

There are various studies which are based on a computer-based traffic simulation approach for finding the effects which are incident for a specific transportation network (Avetisyan et al. 2014);(Chung et al., 2013); (Dia and Director, 2011); (Ferrara et al., 2013); (Fontes et al., 2014); (Leclercq et al., 2015);(Kabit et al., 2014);(Song et al., 2017); (Schreckenberg et al., 2001);(Helbing et al., 2002)). The modelling on the computer has many advantages helps in analysing traffic in terms of replicating incidents during peak and non-peak hours and then calculating their impacts based on network performance in a cost-effective and safe manner, eliminating the need to conduct on-site, practical based calculations of flow of traffic characteristics (Dia and Director, 2011). Within the range of computer simulation, having detailed multiple different levels can be achieved in traffic analyses, especially while applicating freeways including macroscopic, mesoscopic, microscopic and nanoscopic. However, the modelling approaches mentioned here are represented in terms of reducing size of area of study, detailed level and complexity that can be obtained from the outputs of these models increases, with macro and nano being the least and most detailed respectively. There is a further usage of computer simulation, which is the testing of policy strategies, performance of operations and changes to networks and services of transport for all different travel modes. Private and public entities use this application of computer simulation very prominently in order to justify or identify differences that have been implemented within a particular road network.

2.3.1 Macroscopic Simulation

Freeway operations can be calculated very efficiently with the help of Macroscopic Simulation, which is also an important tool for modelling very large-scale road networks, especially in metropolitan cities, as stated in a paper by Holyoak et al. 2005. This tool gives a well-defined relationship between global quantities like space-mean flow and density, and represents traffic movements in terms of aggregate vehicle flows ((Holyoak et al., 2005); (Schreckenberg et al., 2001);(Leclercq et al., 2015)). The use of macrosimulation for traffic incident modelling would, however, lead to an underestimation of vehicle emissions due to the fact that this approach only applies a constant speed along with a road link and does not consider detailed road geometry or vehicle outputs(Holyoak and Stazic, 2009). In addition, the level of detail in terms of individual vehicle movements is compromised because of the large study areas associated with macroscopic models. The linking of micro and macro simulation models can be beneficial (Helbing et al., 2002). The models made by microsimulation are more intuitive and detailed in comparison to macroscopic models individually, suggested by this study. The linking of the two is only beneficial in situations that are applicable to the strengths of each respective model.

2.3.2 Mesoscopic Simulation

Generally, the applications which involve regional-scale traffic assignment problems that focus on a specific road corridor use a traffic simulation model on a mesoscopic level (Song et al., 2017). A 250-kilometre road corridor had been analysed by a research conducted by Fontes et al. (2014) for the evaluation of benefits of advanced traveller information systems (ATIS) as a form of traffic incident management. These simulations are computationally more efficient than their microscopic counterparts because the mesoscopic models produce results at a finer level of detail than macroscopic models. As many finer details such as individual vehicle characteristics are not considered, the scales of the networks are studied largely (Barcelo 2010). Although, the implementation of a large-scale network analyses approach on an extremely smaller area than that described in the study by Fontes et al. (2014) in this prescribed work of thesis, would ultimately lead to an inaccurate representation of the impacts of traffic incidents such as emissions, due to the simplification of vehicular dynamics (Barceló, 2010).

2.3.3 Microscopic Simulation

The use of microsimulation modelling is the most commonly adopted technique for analysing the impacts of congestion on freeway traffic, in which many studies have used this method((Avetisyan et al., 2014);(Dia and Director, 2011, Huang et al., 2009); Kabit et al. 2014)(Helbing et al., 2002). The ability for detailed traffic networks to be constructed that capture the movements of individual vehicles and driver interactions and traffic operations through multimodal interchanges is a key outcome that is achieved using microsimulation modelling, according to Holyoak and Stazic (2009). Macroscopic simulation leads to an underestimation of vehicle emissions on a freeway, microscopic analysis considers the effect of acceleration and deceleration of individual vehicles on emissions, thus leading to a more accurate measurement of environmental implications (Holyoak and Stazic, 2009). Also, a micro-simulation modelling approach is the most applicable when information on the movement of individual vehicles is required, suggested by Schreckenberg, Neubert and Wahle (2001). Micro-simulation as the best tool for assessing the network area-wide impacts of traffic incidents and potential mitigation strategies in a safe and cost-effective manner as described by Kabit et al. (2014).

2.3.4 Nanoscopic Simulation

In the Nano-simulation traffic models, where transport networks are considered on a person-based level, moving between different modes of transport, as opposed to the traditional vehicle following models, is also the most detailed level of computer modelling. The replication of the behaviour of individual people that use different modes of travel (for example, public transport, cars, walking, cycling etc.), and is primarily concerned with quantifying waiting times and interactions between people, is the main aim of a model of this nature(Olaru et al., 2014). The extra level of detail allows for a perception-reaction system to be modelled, where the interaction of different driver characteristics (such as aggressiveness) in a multi-modal network is included in the analysis. The key difference between nanoscopic and microscopic modelling is the person-based as opposed to vehicle-based travel, respectively. But these are the similarities between the two modellings which are common for micro simulation packages to have the option of nanoscopic analyses(Roads and Maritime Services, 2013).

2.4 Previous Case Studies

It has been found that on a microscopic level, the simulation of freeways is the best method for calculating the details of performances and the negative effects of congestion on these roads. For the assessment of congestion and understand the performance, the literature can divide into analyses.

2.4.1 Qualitative Analyses

Studies done earlier having the application of using micro-simulation for modelling the incidents including the study of Schreckenberg, Neubert and Wahle (2001), are qualitative by nature and generally assess the universal capabilities of this analytical tool when applied to traffic flow. But the study fails due to the quantification of specific features of road transport networks under different conditions. For example, Schreckenberg, Neubert and Wahle (2001) aimed to show simulation of traffic flow on a network in various locations like Duisberg, Germany by applying various spatial and temporal scales to assess the ability of the software to accurately model parameters such as route divergence and situations where congestion is observed. The ability of micro-simulation is confirmed by this given information to assess certain features of a network, which does not quantify the implications of such parameters.

Same opinions are expressed in work by Schwartz and Laird (1998), finally it has been said that little work is done in the space of modelling accidents and their interaction with recurring delay, and consequently a little guidance is available for traffic engineers to assess the overall impacts of accidents and their performances based on management strategies used to improve them.

The studies completed by Barth (2000) later worked on analyses of general freeway characteristics under 'non-automated' and 'automated' conditions. For the 'Interstate Highway 10' single lane in the metropolitan area of Houstan in the US, it was observed that when AHS (Automated Highway System) operated at 60 mph (95kmph), emissions from vehicle per VKT were around 55% lower than non-automated (congested) conditions. Note that it is very important in this research work in which only single different vehicle type was taken into consideration and however, the outcomes would supposed to vary if more vehicle types were adjusted. In addition to this study, the study failed to estimate some specific emissions levels under different incidents and congestion conditions, by showing the limitations in the methodology. In a research work done by Patel (2006), the work did was in more detail in terms of modelling impacts, but some limitations similar to that study exist regarding the specific effects that they had on performance of the network. Comparable results were made by Kumaresan 2014, in which qualitative analyses were done on a freeway in Las Vegas of the short-term incident showed that an increase in incident duration resulted in greater travel times, fuel consumption and vehicle emissions.

2.4.1.1 Method of Estimating Emissions and Cost

When estimating the vehicle emissions and financial cost, this is significance to check the accuracy and credibility of the using methods. According to the literature described so far, this section will define the methodology used by software package Autodesk Infraworks and other supporting methods for calculating and observing the emissions and total cost.

2.4.1.2 Fuel consumption and exhaust estimators

According to the literature discussion so far it is clear that there are numerous ways to estimate fuel consumption and emissions. It was found from the study that blocking of lane due to capacity reach is the most influential factor for the delay. An extra fuel consumed due to delay is compared with normal time taken by vehicle to clear the section(Kabit et al., 2014). Research conducted by Kabit et al. 2014 cited Austroads (2008) to estimate the litres of consumption of fuel per 100 kilometres. Also, suggests an equation to calculate the consumption of fuel for an average link speed(Austroads 2008).

Vehicle consumption of fuel under normal condition: -

$$F = A + \frac{B}{V} + C \times V + D \times V^2$$

……………………………*Equation 2. 1*

Where

A,B,C,D = model coefficients

F= Vehicle fuel consumption (L/100km)

V= Average link speed in km/h

Table 2.1 summaries the equivalent fuel consumption parameters on freeway for vehicles, according to the variable in vehicle fuel consumption equation 2.1.

Table 2. 1: Fuel consumption parameters for different vehicle classes on freeway(Austroads 2008)

Vehicle Type	A	B	C	D
Cars	-18.433	1306.02	0.15	0.00032
Light Commercial Vehilces(LCV)	-27.456	2060.5	0.191	0.00085
Rigid Trucks	-65.056	4156.75	0.496	0.000679
Articulated vehicles	-80	6342.8	0.484	0.002
Buses	-80	5131.63	0.605	0.0015

Although carbon dioxide ($C0_2$) is the main source of vehicle emissions, there are other component accounts, such as nitrous oxides (NOx), methane (CH4) and carbon monoxide (CO).

Their impact is insignificant on climate compared to carbon dioxide. It has been suggested that carbon dioxide emissions depend on the amount of used up fuel by vehicles, while diesel produces the highest level of emissions (Austroads 2008;(Kabit et al., 2014)). Commonwealth of Australia (2014) suggests Equation 2.2 to estimate the emission on the basis of fuel consumption parameters.

Equation 2.2: Emission of greenhouse gases for different type of fuels (Commonwealth of Australia 2014)

$$\text{Eij} = \frac{Q \times \text{ECi} \times \text{EFijoxec}}{1000}$$

..................................Equation 2. 2

Where

Eij = Emission of gas type (j), from fuel type (i)

Type of gases (j) = Either carbon dioxide, methane or nitrous oxide

Fuel type (i) = CO2-e tonnes

Qi = The quantity of fuel type (i) combusted for transport energy purposes in kilolitres or gigajoules

ECi = The energy content factor of fuel type (i), used for transport energy purposes

$EFijoxec$ = The factor of emission for gas type (j)

The variable of equation 2.2 has corresponding value that is taken from table 2.2.

	Fuel Combusted	**Energy Content Factor(GJ/kL)**	**Emission Factor (kg CO2/GJ)**		
			CO2	**CH4**	**N2O**
General Transport					
	Gasoline	34.2	67.4	0.5	1.8
	Diesel Oil	38.6	69.2	0.2	0.5
	Biodiesel	34.6	0	1.2	2.2
	Ethanol	23.4	0	0.2	0.2
	Fuel Oil	39.7	72.9	0.06	0.6

Table 2. 2: Fuel and energy consumption factor

Emission of vehicle can be estimated for incident-free and incident cases using these equations. On the other hand, Dia and Gondwe (2008) point out that microsimulation models can accurately estimate fuel consumption and emissions, where these parameters are a function of velocity and acceleration of modelled vehicle. They continue to mention that the accuracy of vehicle speed in the model directly impacts the accuracy of estimates.

2.4.1.3 Infraworks Mobility Simulator Emissions Estimations

Mobility Simulator of Autodesk Infraworks Software uses an emission model that estimates the concentration of CO2 and NOX and particulate matters (PM10) (Azalient 2008). Azalient (2008), who is the developer of this software package pointed out that emissions are determined based on vehicle speed and acceleration. In addition, according to a study conducted by Baggot et al., the figure used in the software emission model assumes a 50 % increase in emissions at maximum acceleration. The model was developed based on data 2001 of emission however, it was producing more accurate results than the method previously proposed by Kabit et al. (2014). The emissions produced by models that consider the effect of vehicle dynamics on vehicle are more reliable than those that rely on average speed. Mobility Simulator generates emissions data for different vehicle categories, the one drawback of this model is output after completion of the decided hour of Simulation cannot specify the fuel type.

2.4.2 Infraworks Mobility Simulation Cost Estimation

Similar to section 2.4.1.3, Mobility Simulator can also estimate the economic cost of driving vehicle for all generated trip between all zones. Software automatically applies the travel time cost for private, commercial and business trips per hour. By default, for private vehicle cost of 25c per kilometre and 12.5c per stop is used to calculate fuel and operational cost of vehicle (Azalient 2008). According to Table 2.3, the financial impact of network operations can be accurately estimated by using different cost factors (in Australian Dollars) for various vehicle categories. A summary of default values for economic evaluation for different vehicle class in mobility Simulator is shown in figure 2.3.

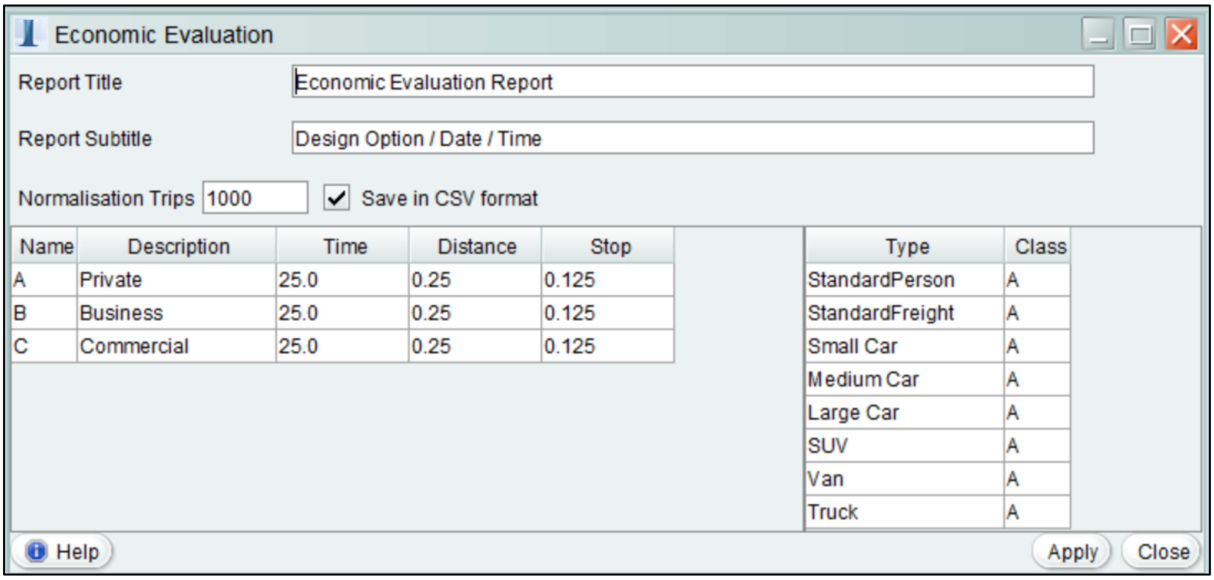


Figure 2. 3: Economic evaluation report (Mobility Simulator)

Vehicle class	Rate of travel time (2017)	Proportion of vehicle Class(%)
Passanger Car(Private)	$72.58	18.5
Passanger Car(Business)	$25.92	62.1
LCV	$43	16.3
Rigid Trucks	$46.46	2.5
Articlulated Trucks	$90.06	0.52

Table 2. 3: Rate of travel time with proportion of vehicle classes(Australian Bureau of Statistics 2016);(Kabit et al., 2014)

2.5 Ramp metering on freeway

Ramp meter or metering light is widely used at freeway on-ramp to avoid traffic congestion and improve the safety of driver. All the ramps on freeway linked to resolving motorway bottlenecks before merge. Ramp metering also helps to manage the rate of traffic entering the freeway (Dia and Director, 2011). Some literature suggests that ramp metering can cause local road congestion due to spill over on freeway(Khayatian, 2013). On the other hand, as traffic demand increases, it can provide benefits for incident conditions (Dia and Director, 2011). Result of this study is shown in table 2.4. Due to implementation of ramp metering in congested conditions, number of stops was reduced by 23% and travel time was reduced by 2.8%.

Performance check	Stream	Existing conditions	Ramp Metering	Difference (%)
Speed (km/h)	On- ramp	57.6	52	-9.7
	Mainline	83.2	83.8	0.6
Number of Stops	On- ramp	0	0.2	200
	Mainline	1.4	1.1	-23
Travel Time (sec)	On- ramp	36.3	40.6	11.8
	Mainline	192.1	186.8	-2.8
Delay(sec)	On- ramp	2.7	7.1	156.5
	Mainline	50.5	45.2	-10.5

Table 2. 4: Percent difference in implementing ramp metering (Dia and Director, 2011)

2.6 Summary of Findings

In Conclusion, after reviewing the research and literature on the topic. First, reviewing the history of case study location, nearby services and existing government plan for North-South Corridor. Second section examined the benefit provided by traffic modelling and related examples for references. The third section investigated the importance of analysis in the Darlington Upgrade. The fourth section discussed the collection of data and discussion about what traffic modelling software should be appropriate to use for the assessment of Darlington intersections.

The reviews recommendation was to first use the Autodesk Infraworks Software and its major component Mobility Simulation. The key point raised for this recommendation is that there is a certain risk in the use of Infraworks as significant literature used in Mobility could use already in same kind of development.

3 Significance of Darlington Upgrade

In this chapter, a background of case study will be given which contains the characteristics of the site and an explanation for the site warrants this extensive research and the factors that are important for the creation of the model.

Some specifications related to general background to the Darlington Project which can be used later references in section 4, where construction of model will be described. Additionally, few references, mainly Australian and South Australia government documents, help in broadcasting the importance of upgrade and installation of tunnel in this thesis.

3.1 General Background and Specifications

Adelaide's most important transport route is the North-South Corridor for north-south bound traffic (DPTI, 2015). The reason for major motorway is that it greatly connects the growing areas and suburbs if northern and southern Adelaide. Expansion is considered to greatly improve traffic conditions. Thus, Australian and South Australian Governments are putting cumulative efforts to make the north-south corridor nonstop (DPTI, 2013).

In the context of infrastructure for transport, The Darlington Upgrade Project is a significant stage for the completion of the southern part of corridor (DPTI, 2016). This project will have an upgraded way of 3.3 kilometres of full free flow between the Tonsley Boulevard and Southern Expressway as shown in figure 3.1. Some key features of this project is meant to deliver the followings: -

- A non-stop motorway between the Tonsley Boulevard and southern expressway.
- Enhancement safety of pedestrians and cyclists.
- No change in intersections on Ayliffes road/south road(Voris, 2000).
- Full free flow and Interchange at the southern expressway.
- Grade separation of the Main South Road / Ayliffes Road / Shepherds Hill Road intersections.
- The existing Main South Road will continue to provide connections to Flinders Drive, Sturt Road and most local roads.

This project is meant to improve the full traffic management system in Adelaide. Ayliffes road/Shepherds road section with main south road is the busiest among the other 3 major sections. This road section carries over 73000 vehicles every day. Therefore, it is vital to keep an innovative approach to management(BRIDGES).

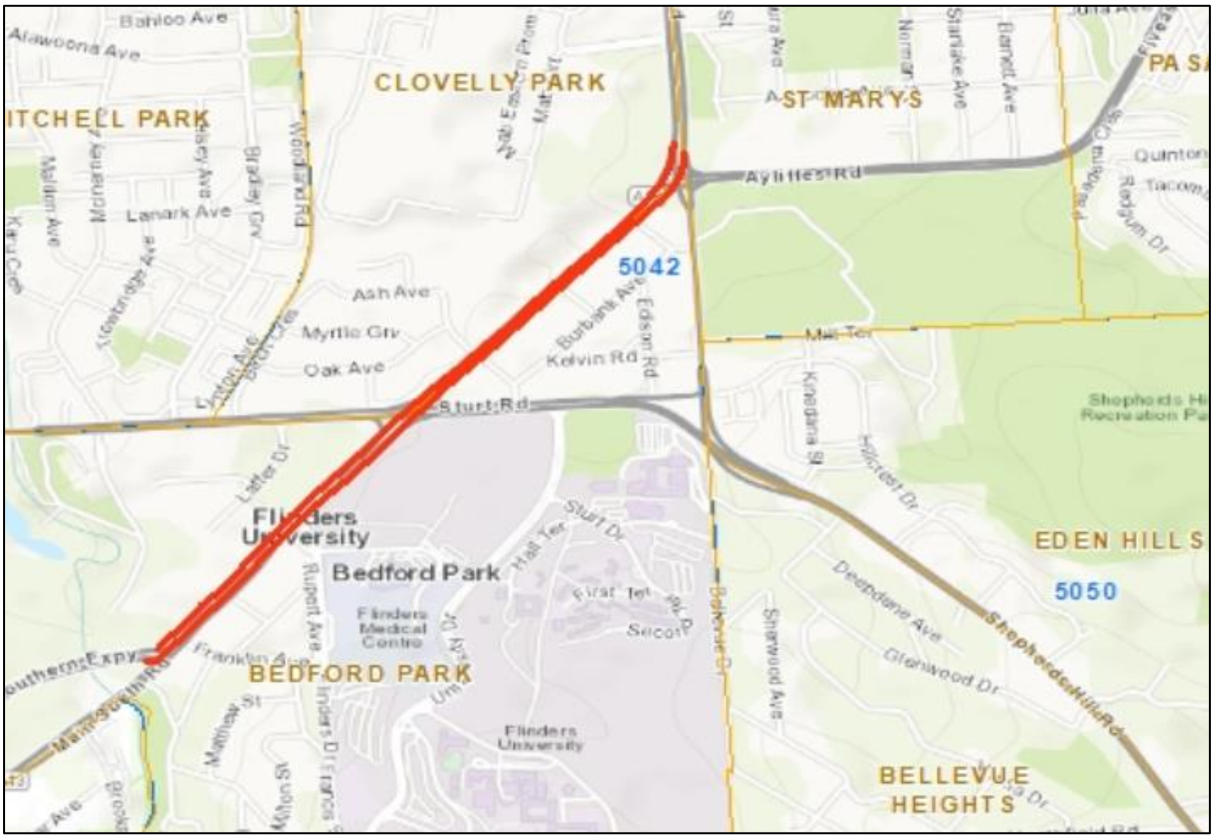


Figure 3. 1: Interactive map of Darlington upgrade section (Sourced Esri, HERE, Garmin, Intermap national geographic map)

3.2 Importance of Research

The importance of this research and the priority of the construction of the roadway network from few states and federal strategies are written in the various government reports (DPTI 2011, 2015a, 2015b, 2016b). According to the DPTI report and The 30 Year Plan for Greater Adelaide, it is highly focused on improving freight efficiency. DPTI(2015a) also wrote some similar statements in the Integrated Transport and Land Use Plan(ITLUP).

Some reports proposed by the State Government such as DPTI (2015b) in the new delivery strategy of 10 years for North-South Corridor, diverging from the importance of freight connections and discussing the improvement that will be made in existing infrastructure which is over congested and unsafe for daily commuter. During this study, it is observed that the Darlington upgrade 3.3 km section in which high delay is experienced and there are long queues due to congestion. It is also stated by DPTI (2011) that there is an expectation for the significant growth in people count and economic growth in the southern and eastern Adelaide in the upcoming years. There is one more benefit of the non-stop motorway, which is given and emphasized in the report of DPTI (2011) in which the consequences are estimated and are come out to be decreased in congested conditions that will equate to reduction in exhaust gases annually of 105.5 kilotonnes of CO_2 by 2031. So, the coupling of this fact with the present driving conditions (in terms of safety and congestion) on current infrastructure, highlighting the need for development in this Darlington Intersections.

4. Project Methodology

The undertaken methodology involves the full process taken during base model creation with the help of a computer program Autodesk Infraworks 360 and Mobility Simulator. It has the main steps involved during the construction of traffic network model. This chapter helps the readers to input and some other key variables useful to build model so that recreation of model can occur if needed.

It defines all steps commenced during the design of the most basic model of traffic with the construction of Infraworks. This base model represents the current road network and present geometry and to model the future simulation, the process of changes in base model will be discussed in chapter Theoretical and Experimental Methodology.

4.1 Selection of modelling software

According to the different approaches of modelling presented in literature review in section 2, the Microsimulation approach of modelling of Darlington Upgrade for calibration of traffic data to compare the delay, traffic volume is preferred. The assessment software used for this study, Autodesk Infraworks, is used to create a network program that is relocated into the mobility simulator, which is an additional plugin of this software. This Mobility Simulator program is flexibility use to do modelling on nanoscopic and microscopic levels that help to produce the traffic reports on a vehicle on vehicle basis. For this research report, the only vehicle to vehicle movement parameter is considered.

In application engine of Mobility Simulation, multi-mode network traffic modelling was conducted on Infraworks. For this research mobility simulation is used to design the animation form of traffic flow for peak hour MASTEM (Metropolitan Adelaide Strategic Transport Evaluation Model) count. Thus, computer simulation for this research will be performed by keeping the aim of this research in mind and Autodesk Infraworks 360 program will be used for modelling.

4.1.1 Construction of Infraworks and Mobility simulator model

This part of the thesis will outline the methodology implemented while constructing the base model of Darlington upgrade in the Autodesk Infraworks. The full detailed construction of the model under simulator along with model calibration and validation is discussed. Confirming that it precisely reflects the real-life conditions for model validation.

4.1.2 Infraworks

Infraworks is an infrastructure design program that is ideal for creating development models. As this software does not generate traffic or personnel movement and therefore it is not suitable for Traffic Impact Assessment (TIA). A simple network built in this tool is easily transferred into Mobility Simulator. The main advantage offered by Infraworks is its inbuilt specification for model building. This function allows user to quickly create a model based on a given area. This tool gives access to users to select the location anywhere in the world. A selected area of interest in model builder is shown in figure 4.1 as it covers all major intersections of Darlington upgrade.

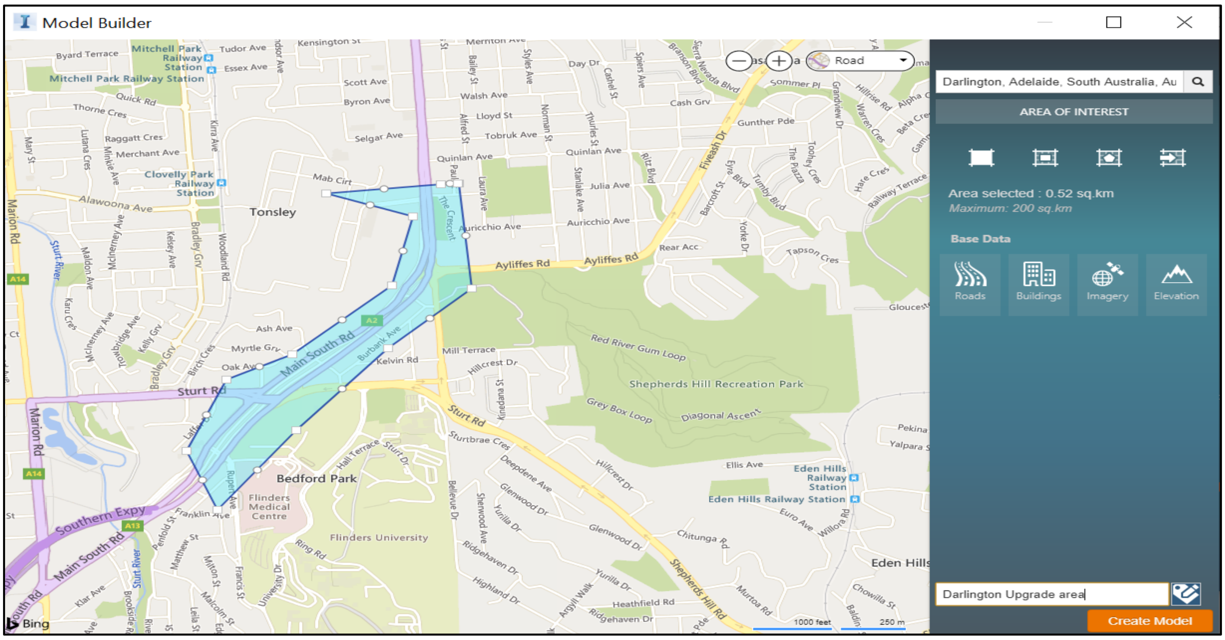


Figure 4. 1: Model builder tool (Infraworks,2019)

Infraworks has property to build a visual 3D model with minimal efforts. Initially model capture some additional data along with road geometry, so some steps were taken to provide a better-looking model to improve its accuracy to edit and add according to the demand of future network.

Figure 4. 2: Beginning stage of intersection TS404, TS111(top view, Autodesk Infraworks 2019)

Some steps involved after selecting area of interest were: -

- Deleted roads that not needed
- Connects roads and add vertex to adjust curves
- Removed unnecessary vertices
- Edited road geometry and lane

These steps help to simplify the network so that planning road has appropriate geometry. As sometimes captured road design given by software is different from original.

In order to be able to accomplish listed tasks, user must learn the techniques and functions of software. Main functions involve online tutorials provided by Autodesk Infraworks 360. Once the model requirements are met, next step is to use another important tool traffic study to build an area from which you can open the plugin Mobility Simulator.

Synchronising the model on the cloud was one of the time-consuming steps, as it took a lot of time. Study area of Darlington has only four major intersections, so it was decided to convert planning road to design road all automatically by selecting all the areas together as shown in figure 4.3.

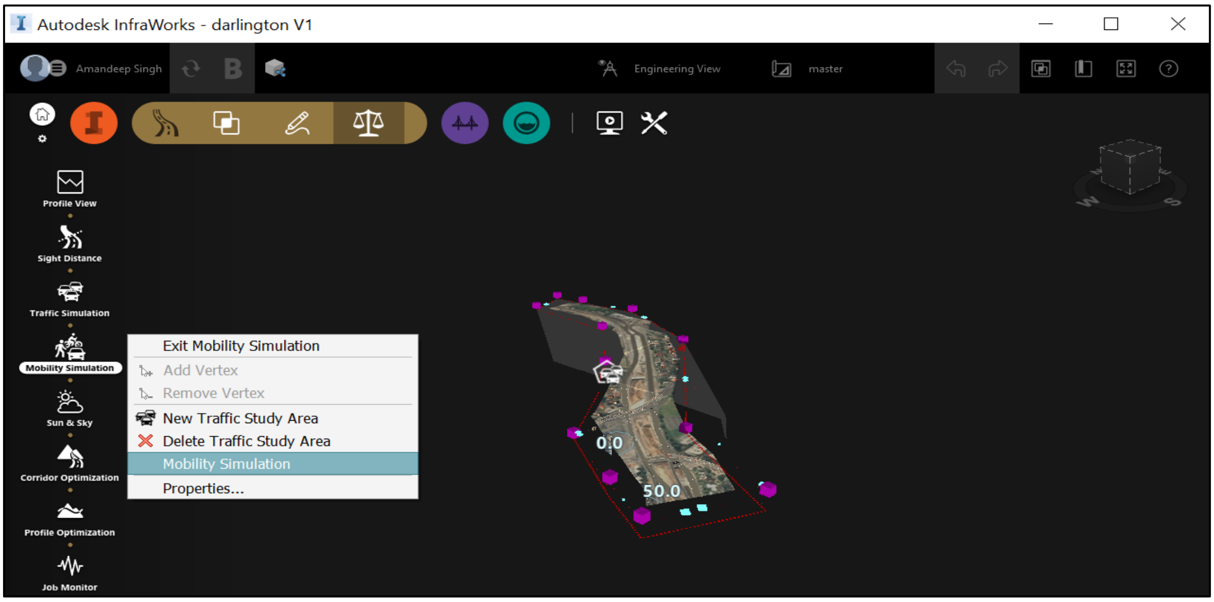


Figure 4. 3: Mobility Simulation, specify traffic area

4.1.3 Mobility Simulator

This section explores the steps to create a model in the plugin tool Mobility Simulator. The program has the greatest detail because it has the Microsimulation capabilities needed to achieve the research goals of identifying and predicting traffic problems caused by the redevelopment of area of interest.

Early model in Infraworks is required for the functionality of Mobility, however, in reality they have slight crossover and are made up of different user functions. Since these programs were first integrated in mid-2016, their functionality still shows signs of imperfect compatibility (Autodesk Help, 2019) and hence they are considered as independent entities in this case study.

Some features that Mobility includes to make it appropriate for this case study are listed below: -

-Simulate actual traffic conditions- Track people across service networks

- Comprehensive multi-modal analysis

- Easily create realistic visualisations

- Trip time and distance

- Economic evaluation report for assessment

When these key performance indicators are combined, they will be used to clearly illustrate the advantage and disadvantage associated with each scenario.

4.2 Data Collection

There is a variety of data sources that can be taken as input for Infraworks, including a given intersection graph, google maps, SCATS count, manual turn count and SCATS operation. Phase peak period and phasing operation and every lane dimensions and intersection approach length and angle of slip was clearly observed from ER viewer Software pictures of intersection and compared with google maps for better understanding and clarity of input. This is an extra benefit of having a lot of input sources. SCATS count and manual turning count were used to calculate the amount of traffic in a lane.

The set of data is in two different categories : -

Observation through the site visit

Collection through the digital mean

4.2.1 SCATS traffic volume data

Monitoring and controlling traffic is conducted by a traffic management system known as Sydney Coordinated Adaptive Traffic System (SCATS). This system measures the traffic flow and volume using the loop detectors and automatically record the performance data mostly used on a signalised intersections for the direction of travel of every vehicle and their respective count. SCATS role is to give recorded vehicle data collections that are near to impossible by human to acquire.

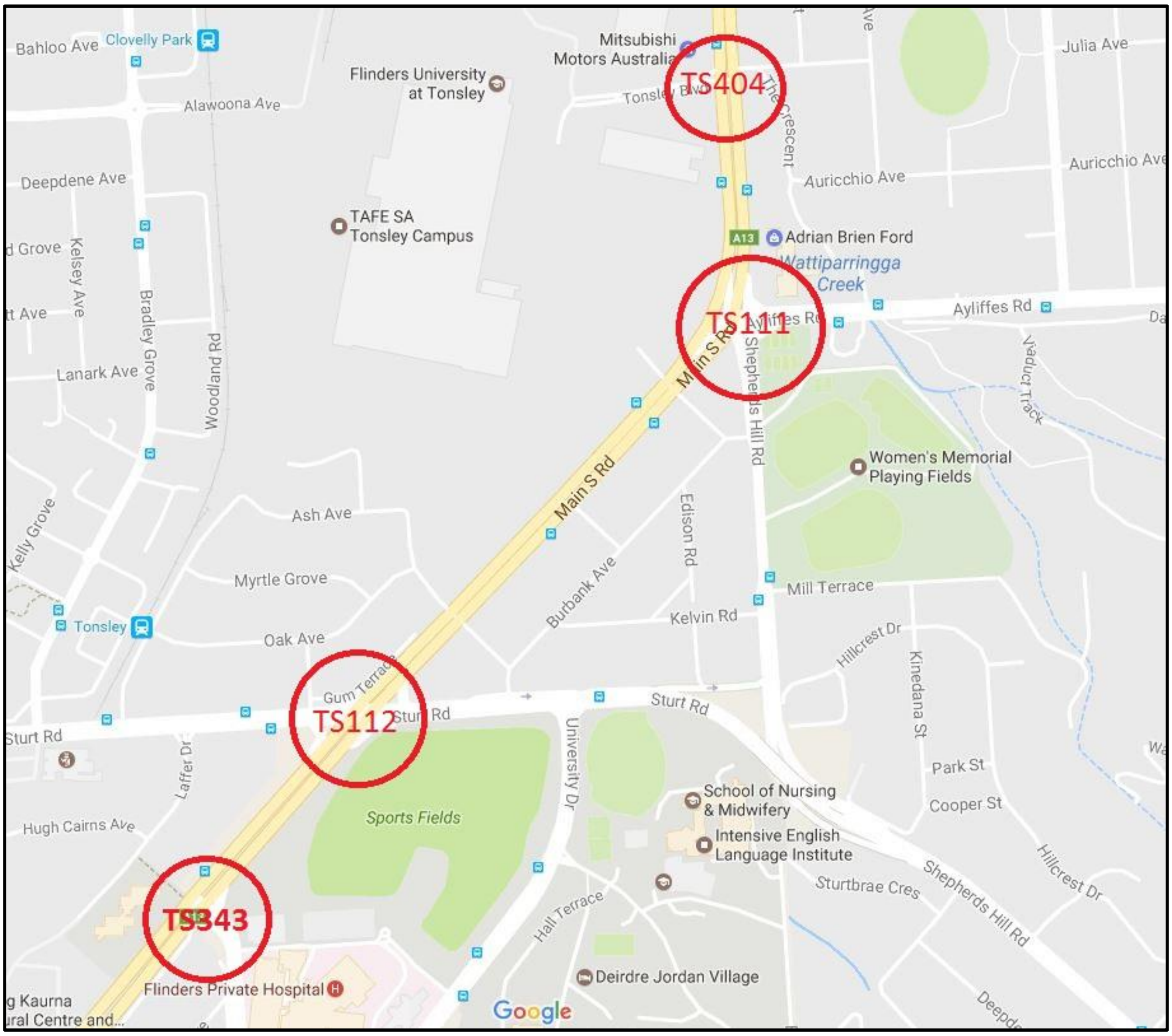


Figure 4. 4: location of Intersections(sourced: google maps)

SCATS data was used to find out the peak AM and PM period for intersections mentioned in figure 4.4 experience in a period of one year. This would ensure that the base model is being calibrated to simulate the network when it is confirmed that the intersection is at its capacity. Therefore, making the upcoming future model applicable to most network simulations.

The SCATS data for 4 signalised intersections (TS343 Flinders Drive, TS112 Sturt Road, TS111 Ayliffes Road/Shepherds Hill Road, TS404 Tonsley Boulevard) of Darlington project was provided in the form of excel spreadsheet with detailed count of traffic interval of 5 minutes for 2015 and 2031. This volume count by different loop data was sourced from DPTI. Data was compared for every month and according to peak hours in order to examine the largest volume count interval for intersection TS111. This intersection is busiest among 4 intersections due to a greater number of approach and exit lane. After interpolation from the spreadsheet, the day with highest number of volume count was determined. Subsequently, 7:30 – 8:30 17th March 2015 was recorded as the AM peak volume for the modelling.

The method for selecting the peak period gave a good estimate of worst-case peak hour conditions, the method of selecting the busiest hour for the input due to limitation of time is by firstly selecting the busiest day of the busiest month, for the busiest intersection, was most effective time constraint of the project. For busiest intersection, busiest day of busiest month was selected for the selection of most busy time.

2015 Data

The existing model was modeled with SCATS 2015 data. Based on traffic analysis, turn count can be used to find peak volume in a 15-minute interval of traffic. Peak volume representation is clearly visible in figure 4.5. Total AM peak flow between 7:30-8:30 was found, with 29337 movements recorded as shown in appendix B.

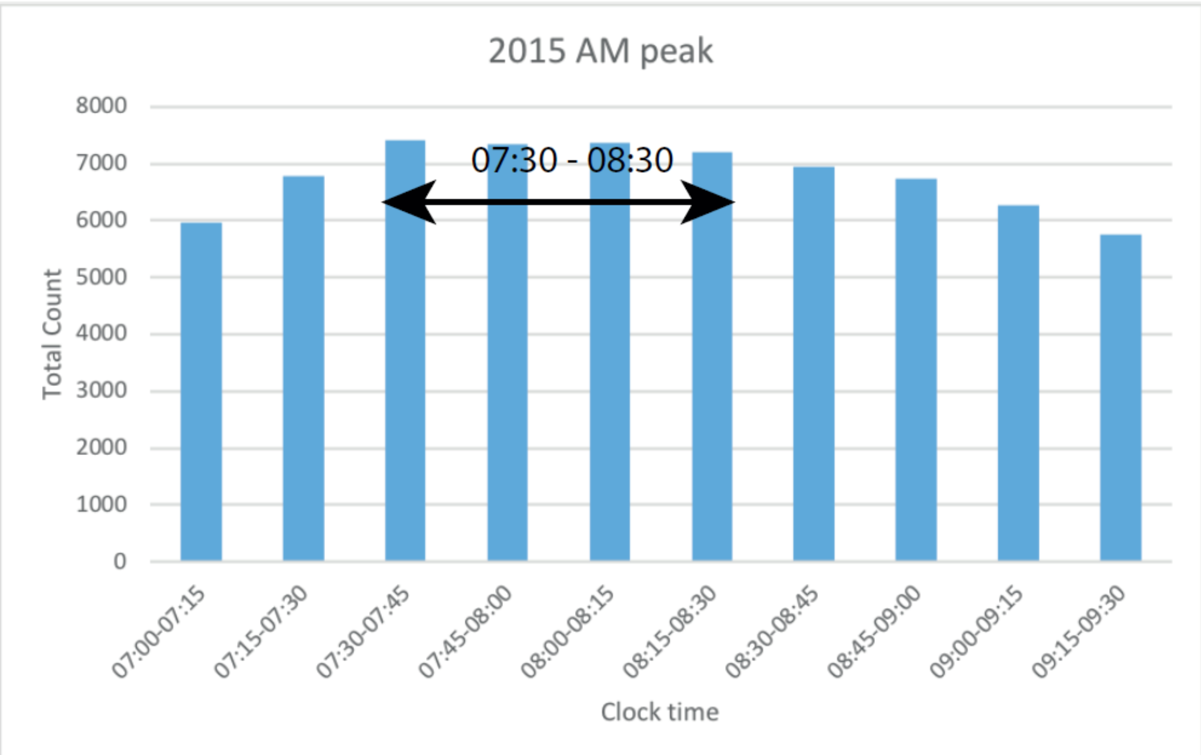


Figure 4.5: 2015 AM peak hour based on vehicle count data

2031 Concept Analysis

As a part of specification provided for the report, SCATS provided count for intersections helped to predict the busiest time for future scenarios. Figure 4.6 below stated that the interval 7:30-8:30 with the volume count 24324 is the busiest period. check appendix B for the selection and count of morning peak. Traffic analysis results for 2031 mid-block volumes were observed and used as input for the OD matrix generation of future models.

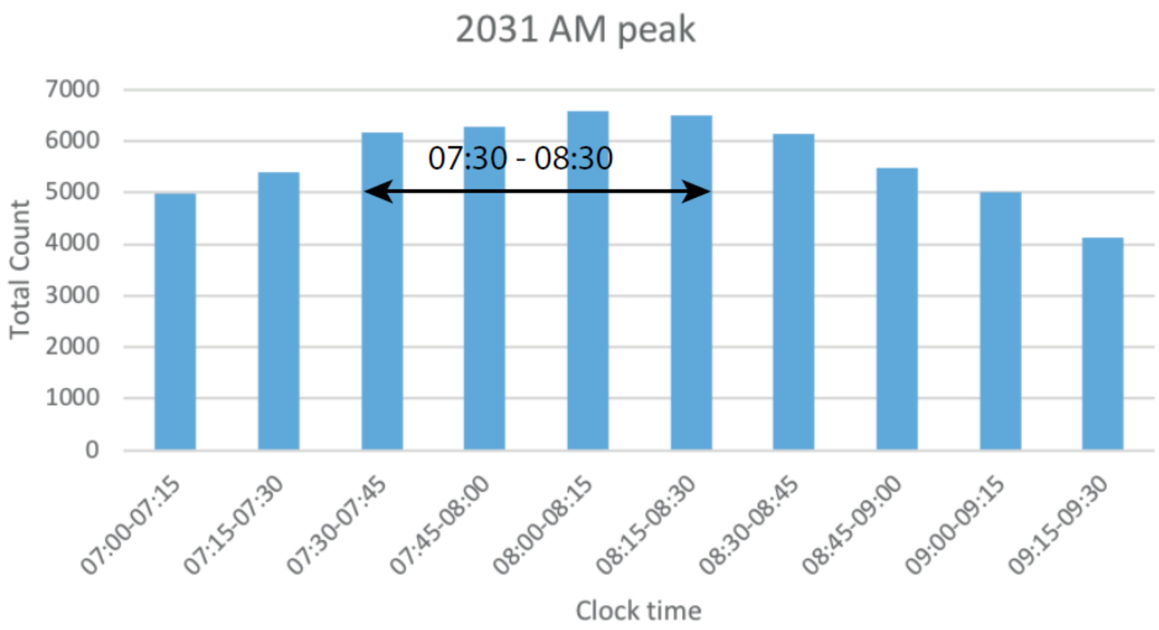


Figure 4. 6: 2031 AM peak hour based on vehicle count data

4.2.2 Manual traffic Count

As the number of vehicles counted by detectors was only for signalised intersection which is displayed by SCATS data. However, there are some instances where the movement is not recorded by the vehicle detector so for those locations manual counting of vehicle was required. Intersection TS343 has one extra slip lane so, that was observed for peak morning period. Manual count and SCATS count together gave better input for origin-destination matrix.

4.2.3 SCATS Intersection Phasing

The source for the phasing data for Darlington intersections is same, SCATS and after knowing the peak period of vehicle volume, the associated phase timing was also required for all 4 signalised intersections. Phases are nominated red, green and yellow light times provided for each turning movement. Also, each intersection has total cycle time (CT) which must accommodate the different phases. Existing 2015 model intersections phasing is represented in table 4.1.

				AM Peak (7:30-8:30)												
Intersection			Intersection phases(seconds)													
		A			B			C			D			E		
	Cycle Time	G	Y	R	G	Y	R	G	Y	R	G	Y	R	G	Y	R
TS404	140	117	4	2	6	5	2	6	4	2						
TS111	140	68	7	2	29	6	2	18	6	2						
TS112	140	6	4	5	16	4	5	14	4	5	34	4	5	25	4	5
TS343	140	43	4	6	31	4	7	20	4	7	19	4	7			

Table 4.1: Intersections phasing

Initial data for intersections specified that there are five phases. After site investigation, it was observed that the phase data is no longer relevant. However, the change in time is not big but it still going to affect the change in congestion more. Therefore, this slight change in phasing time cannot be ignored. After discussion with coordinator the summary of SCATS Intersection for morning peak is shown in table 4.1. The SCATS data collected for each phasing for intersection are attached in appendix B.

4.4 Origin-Destination (OD) Matrix

An OD matrix is the movement of traffic information for a study area between the zones. After determining the peak turn movement from the SCATS count, OD matrix for existing model was developed in excel. Due to limitation of traffic data, it was not possible to develop the accurate origin and destination count of daily traffic. It was assumed that vehicle from one zone travel to the most nearby zone in traffic direction and as the Darlington intersection has no possibility of self-exit for one vehicle, therefore, vehicle entering from and exist from same zone remained zero. These assumptions were used across the same network to allocate the vehicle for each zone.

The simplified 4 steps for the construction of OD matrix networks is as follow:

Step1: Calculate the turning movement for all intersections both ways

Step2: Determine through movement count southbound and northbound

Step3: Examine vehicle route after apply turning movement proportions to vehicles

Step4: Insert traffic routes into OD matrix

Existing Model Origin Destination matrix

All turning movement was drawn in the network diagram and movement of vehicle from zone 1 to zone 8 that is southbound to northbound. While developing the OD matrix count of 118 vehicles was left that should be travel through the intersection. As a result, assumption help to pass these set of vehicles to unsignalised slip road.

Zones	1	2	3	4	5	6	7	8	
1		4	14						18
2	102		25	183	177	188	949		1624
3				38		300	573	354	1265
4		396	294					11	701
5	159	100				644		151	1054
6		59			574			54	687
7	396	1414	2369		293	247		833	5552
8						158	141		299
	657	1973	2702	221	1044	1537	1663	1403	11200

Figure 4. 7: Existing model OD matrix

4.5 Existing network development

4.5.1 Road geometry

Alignment of the road is very important for better accuracy of the model, so this step must be taken before scaling the model .it involves recreating the vertical and horizontal geometry, add a vertex to adjust the curves and remove unnecessary vertices. This was done with the help of ER Viewer Software aerial photos, which gave the ultra-zoom picture of an intersection. Network extracted from a model builder after deleting the extra road was transferred into the mobility simulator, all the roads are manually adjusted in Infraworks. The comparison of geometry between ER Viewer and Infraworks is represented in figure 4.8.

Figure 4. 8: Comparison of geometry layout of Ayliffes intersection

The lane geometry design consideration involves:

Number of lanes

Width of lanes

Median strip widths

Lane speed and elevation

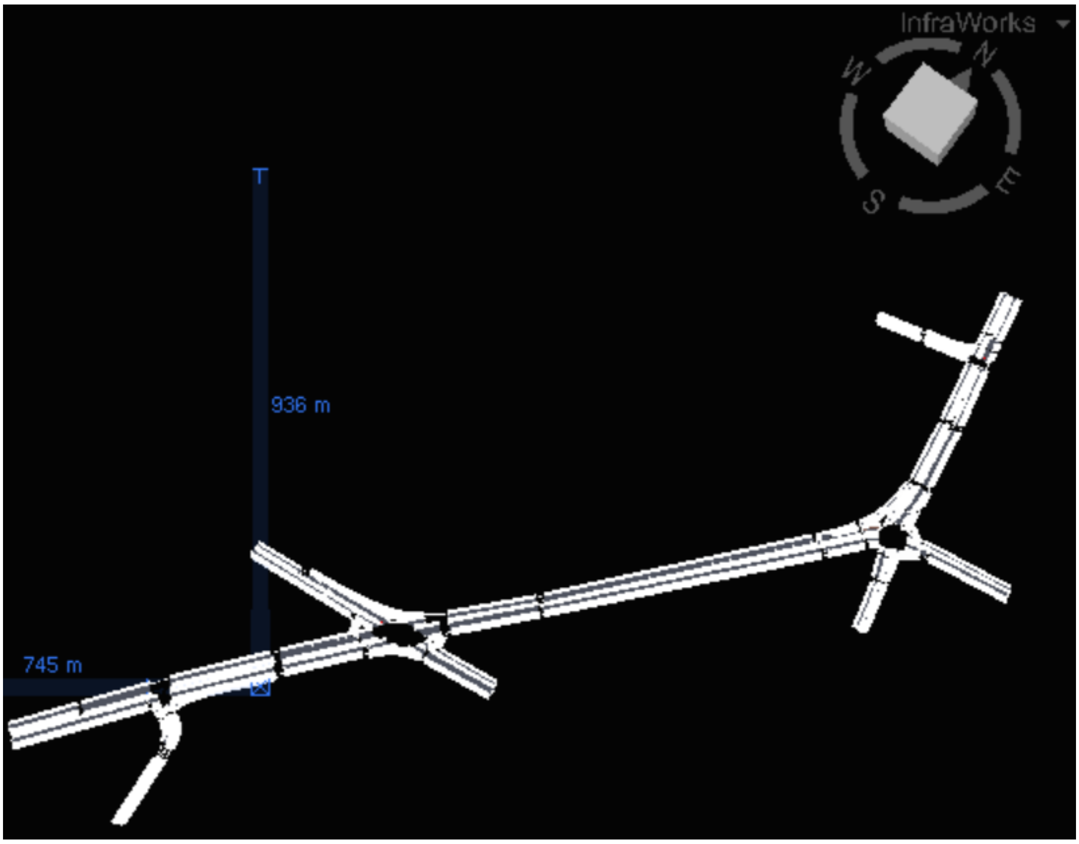


Figure 4. 9: Initial road geometry (Mobility Simulator)

Infraworks software model is better in visual road representation however if we talk about the alignment that is done through the mobility simulator.to create a more accurate model of the intersections, the geometry from Infraworks is transferred into a simulator which is a different section of model. An example of all 4 intersections from Infraworks to mobility is shown in figure 4.9.

4.5.2 Scaling of model

As we discussed earlier that images from ER Viewer allow the road geometry to draw more accurately. In order to make sure that the model of intersections was drawn to scale, the ultra-zoomed images of Darlington were adjusted to represent the real-life geometric dimensions. Infraworks also display the topographical drawing from google earth, therefore, it was assumed that the base layer is an accurate representation of real-life conditions. Imported picture of Darlington upgrade section in Mobility Simulator software is shown in figure 4.10.

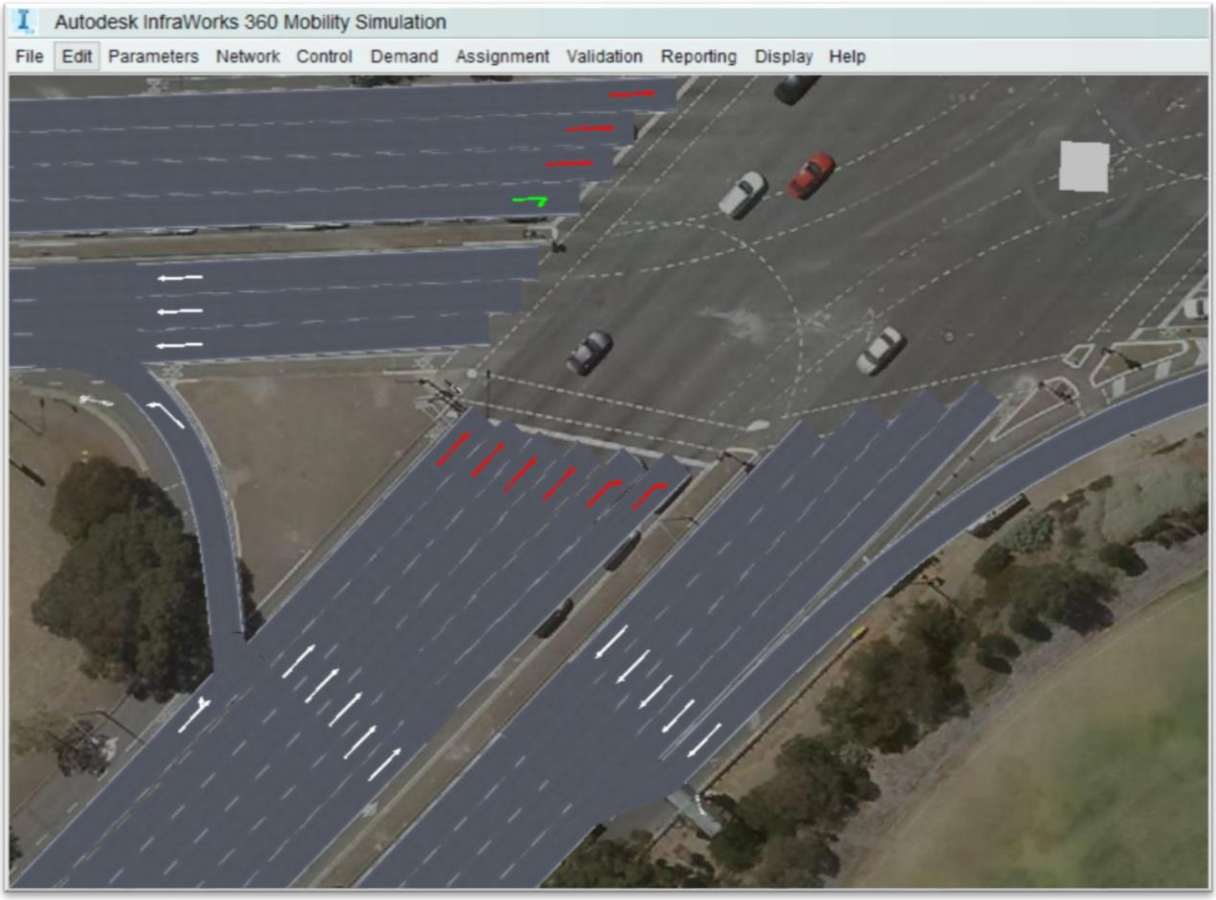


Figure 4. 10: Imported picture of Sturt Road in Mobility Simulator

After importing the picture, the next step undertaken was making the size of drawing equal to the underlying image from the ER Viewer. This step is essential which was done by observing and lining up the key parts of image in order to match the layers of both images. This scaled image is shown in figure 4.10.

4.5.3 Vehicle Types and Size

The calibration of different vehicle types based on data of MASTEM and site survey for light and heavy vehicle, different proportion of vehicle is estimated. MASTEM data for the assessment of Darlington is given for 2015, however due to limitation of time and keeping the change in count, Mobility parameters section vehicle types taken as default value of software for the analysis. According to National Heavy Vehicle Register, the approximate size of the vehicle in every demand division is specified in Mobility Simulator based on traffic demand simulator. It recommends that average size of the truck length 19m (Government of Australia 2017). Regarding the size of light vehicles, the data comes from National Transportation

Commission (2016) which specifies the size of Australian general passenger cars and light commercial vehicles(LCV). The dimensions of vehicle types are displayed in figure 4.11.

Name	Length	Width	Height	Mass	Size Variation	Side Gap	Extras
101: Small Car	3.80	1.70	1.45	1275.00	0.00	0.50	
102: Medium Car	4.70	1.80	1.50	1350.00	0.00	0.50	
103: Large Car	5.00	2.05	1.50	1500.00	0.00	0.50	
104: SUV	5.30	2.05	1.90	2000.00	0.00	0.50	
105: Van	5.60	2.10	2.20	2200.00	0.00	0.50	
106: Truck	19.00	2.50	4.30	7000.00	0.00	0.50	

Figure 4. 11: Vehicle dimensions in simulator

4.5.4 Intersections

Intersections both signalised and unsignalised were designed using the tool control – Intersections. However, the only change with the unsignalised intersection the input of vehicle turn movement needs to be specified. For each of 4 intersections on-site verification and phasing data from SCATS were monitored:

- Turn movements
- Turn groups
- Turn phases
- Phase timing

4.5.5 Zones

The introduction of zone based on the incoming of vehicle between the network. hence, after deciding the site network zones were introduced to all roads in the network. For existing mode, after analysing the traffic flow of incoming and outgoing vehicles a total of 8 zones were used. The location of zones is numbered in figure 4.12.

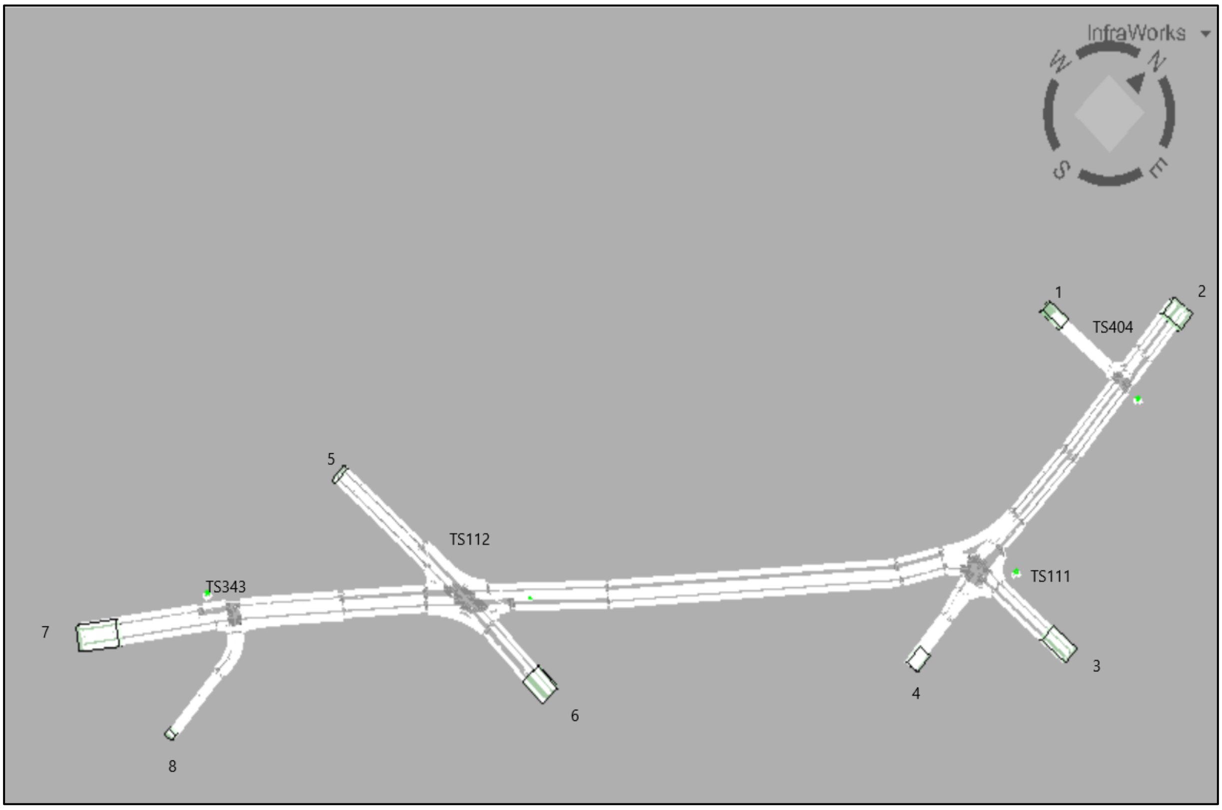


Figure 4. 12: Zones and signalised intersections(Infraworks,2019)

4.5.6 Demands

Using the tool demand – demand division, observation and demand input were inserted into the Mobility.

Demand division: For existing count of private vehicle demand division the output given by mobility was taken same as shown in figure 4.13.

Demand Divisions

People | Private Vehicles | Freight

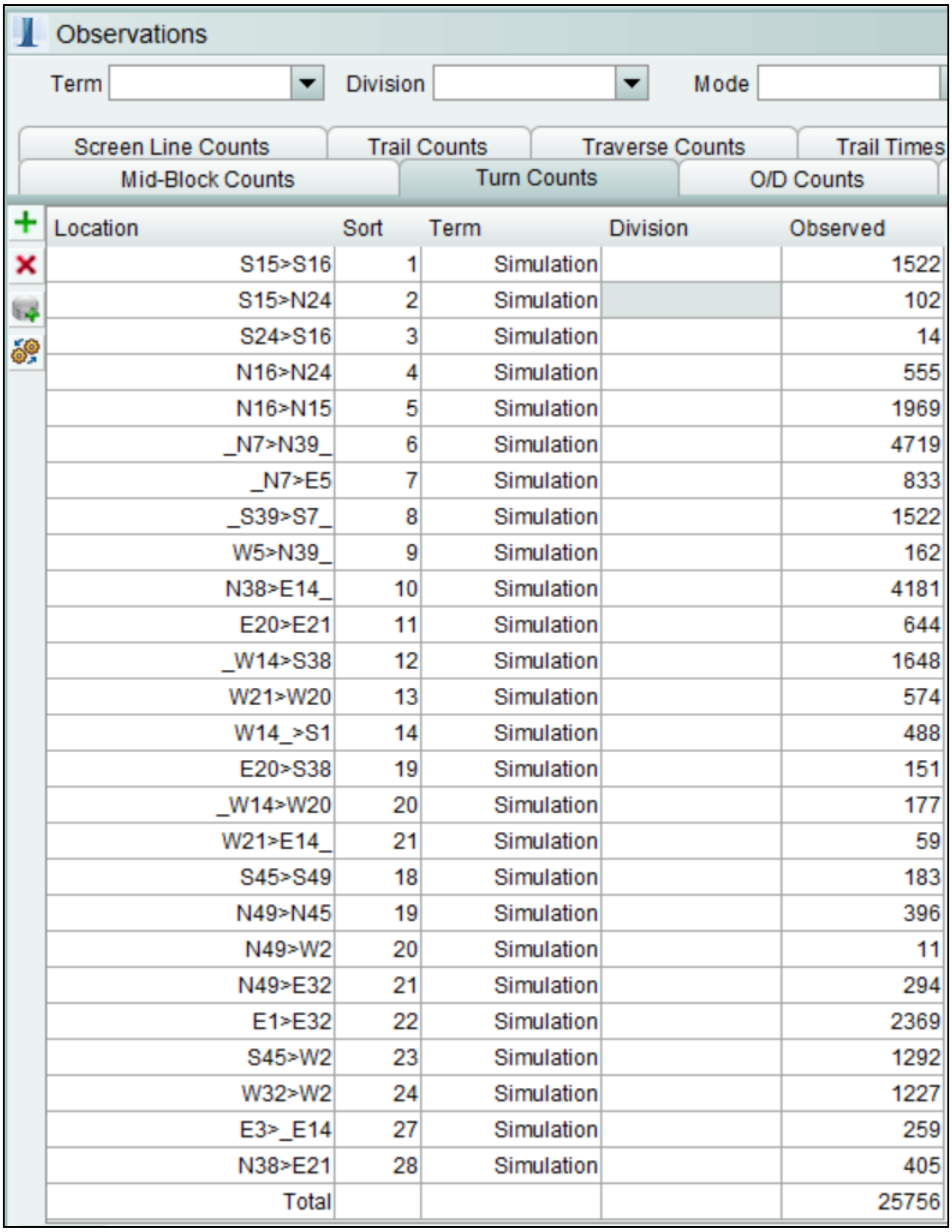
Division	101 Small Car	102 Medium Car	103 Large Car	104 SUV	105 Van	106 Truck
Division	40.0	10.0	30.0	10.0	5.0	5.0
Division1	100.0					
Division2	100.0					
Division3	100.0					
Division4	100.0					
Division5	100.0					

Help | Apply | OK | Reset | Cancel

Figure 4. 13: percentage of vehicle type in division

Observation :

Using the demand tool observation turn count for existing was imported by selecting each intersection and as initial model has no exit other than the zones end so there was no midblock count.



Location	Sort	Term	Division	Observed
S15>S16	1	Simulation		1522
S15>N24	2	Simulation		102
S24>S16	3	Simulation		14
N16>N24	4	Simulation		555
N16>N15	5	Simulation		1969
_N7>N39_	6	Simulation		4719
_N7>E5	7	Simulation		833
_S39>S7_	8	Simulation		1522
W5>N39_	9	Simulation		162
N38>E14_	10	Simulation		4181
E20>E21	11	Simulation		644
_W14>S38	12	Simulation		1648
W21>W20	13	Simulation		574
W14_>S1	14	Simulation		488
E20>S38	19	Simulation		151
_W14>W20	20	Simulation		177
W21>E14_	21	Simulation		59
S45>S49	18	Simulation		183
N49>N45	19	Simulation		396
N49>W2	20	Simulation		11
N49>E32	21	Simulation		294
E1>E32	22	Simulation		2369
S45>W2	23	Simulation		1292
W32>W2	24	Simulation		1227
E3>_E14	27	Simulation		259
N38>E21	28	Simulation		405
Total				25756

Figure 4. 14: Observation turn count for existing model 2015

4.6 Model calibration and validation

After finalising the road geometry construction another essential step was to calibrate the model with traffic volume count to check if the model time will match real-time or not. It is the fundamental step in model building. The better the base model is calibrated the better the model will be suited to forecast future traffic conditions(Department for Transport Energy and Infrastructure, 2010). Model real-life conditions were indicated with this process of calibration. There are so many factors that need to be considered while doing the calibration of a traffic model. In the past time, parameters of the model were manually adjusted so that output is replicate, and this copy of output is validated against the observed data (Australian Transport Assessment and Planning 2016). Due to limited resources in this research, detailed survey data of Darlington was not conducted. Moreover, traffic data collected at the time of project would be incorrect for future when the Darlington upgrade project is completed. Therefore, model was proposed with a different approach. While as a part of project site visits was obtained (including manual turning count and floating car test), the main calibration and validation of traffic volume count were largely taken from the referencing data from the MASTEM. This is a macroscopic traffic simulation model that has been calibrated and validated by the government of South Australia, and it has count of all vehicle movement data of metropolitan Adelaide for future years(Holyoak et al., 2005). Output of model can be used to get volume count it includes the percent of light and heavy vehicle and travel speed for the future Darlington upgrade. The current Darlington intersections without any tunnel were not calibrated and validated for research aim. Hence, it would be more important and beneficial to extract data from the MASTEM model for the year 2031 when the Darlington upgrade is open to commuter to calibrate the model to replicate these future conditions.

Followings are a list of parameters that were calibrated-

Lane usage and road geometry

Driver aggressiveness

Posted speed limits

Demand divisions

The validation tool in the mobility simulation was used the model that accurately shows the existing conditions for morning peak hour.

4.6.1 Validation

The function of this tool was to compare volumes observed and volume in the simulation for turn count and mid-block. The aim was to run the validator to check the GEH (Geoffrey E. Havers). Initially, GEH was used by traffic engineers for modelling and forecasting. The equation for GEH is shown in equation 4.1 and results showed up GEH count as per DPTI standard count displayed less than 5 considered as good match 1.

$GEH=$

$$\frac{\sqrt{2(M-C)^2}}{M+C}$$

.....................................Equation 4. 1

Where

M: Modelled hourly traffic volume

C: Real-world hourly traffic volume

The Criteria for Model Calibration for Mobility Simulator is:-

If GEH 5: Perfect match

GEH between 5 and 10: partial match; could be better

GEH more than 10: data not matching: not acceptable

The output of validator is check for OD matrix. Comparing the value of GEH, it was estimated for models that the modelled traffic volume is close to the volume observed with real-world traffic or not. GEH values less than 5 display for a model that traffic volume is close to real-world traffic.

The results of validator are displayed in appendix D.

4.6.2 Record of Lost and Obstructing Agents

This function of software was used to highlight any vehicle that has been delayed for more than a specified time due to an obstruction. Obstruction can be model error, for example, no exit lane for a right turn in the geometry of intersection. This obstruction function is inbuilt and runs automatically once it was set 5 minutes for simulation. Figure 4.15 displays the base model threshold delay for obstruction and if any vehicle taking longer than 5 minutes for any intersection stop will be notified by the model.

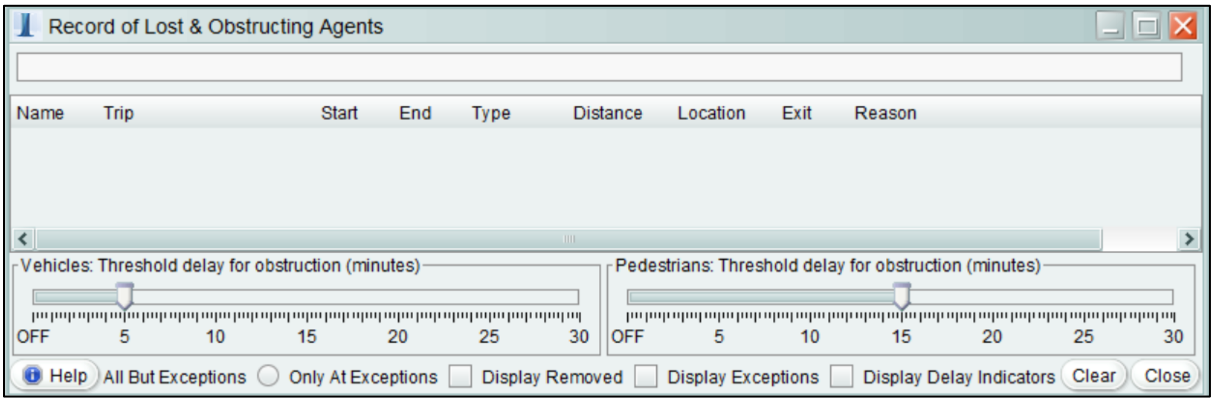


Figure 4. 15: base model AM obstruction check: Mobility Simulator

4.6.3 Model Auditor

The role of this tool was to find if there is any empty area during the checking of standard parameters that area is fixed. The parameters that model auditor check are shown in figure below: -

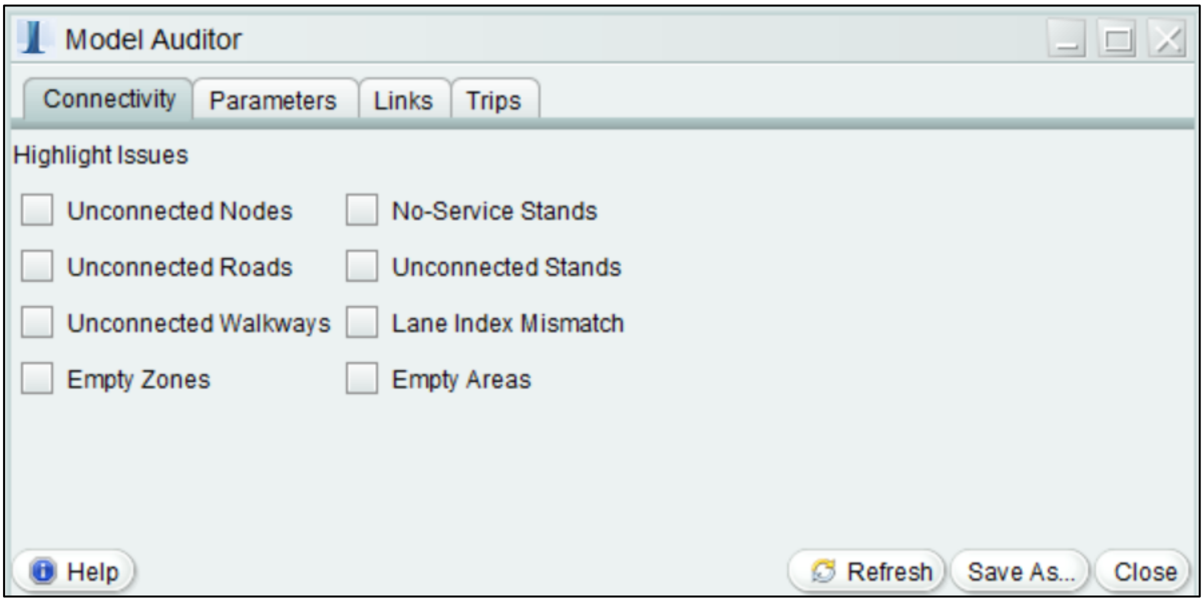


Figure 4. 16: Parameters to check geometry in Simulator

4.6.4 Route analysis

Route decisions for trip are the large part of calibration. Model of network had only one possible route for vehicle entering and exist between the zones and therefore, process of route analysis was not necessary for simulation of Darlington network.

4.6.5 Site Investigation

Site investigation is the final stage of calibration of model the purpose of this task was to observe and compare the real-life queue at intersection with the mobility simulation model during the morning peak hour.

4.6.6 Model Assumption and Limitations

This section of report explains the assumptions that were made and some limitations that might be present to the model after calibration.

During the modelling process, software parameters values were taken as default and some most specific assumptions during the base model construction are listed below:

- One vehicle has one occupant
- Simplified routes followed for vehicle entry and exit
- All roads are equally constructed with no chances of hazards
- vehicle movement restricted while conducting turning movement

After the consideration of these assumptions some limitations arise in models. That impacts the outcome and degree of accuracy. The accuracy rate is equal or greater than 85 percent when compared to real-world network for GEH value is specified as satisfactory (Department for Transport Energy and Infrastructure, 2010).

5 Theoretical and Experimental Methodology

As the base model has been constructed and simulated. The next step is now that the base model can now be adjusted to build the future model. The base model is adjusted to cater to the two different scenarios:

Future Model 1

Future Model 2

Previous chapter discussed the construction of Infraworks for the development of base model, therefore, this chapter only discuss the changes that were made for Individual model.

5.1 Future Model 1

The geometry of this model was taken similar to DPTI proposed model for 2031. The network of this model has tunnel with 3 lanes both ways. Tunnel was added in existing model from southbound to northbound with addition of 2 extra zones at each end of the network as shown in figure 5.1.

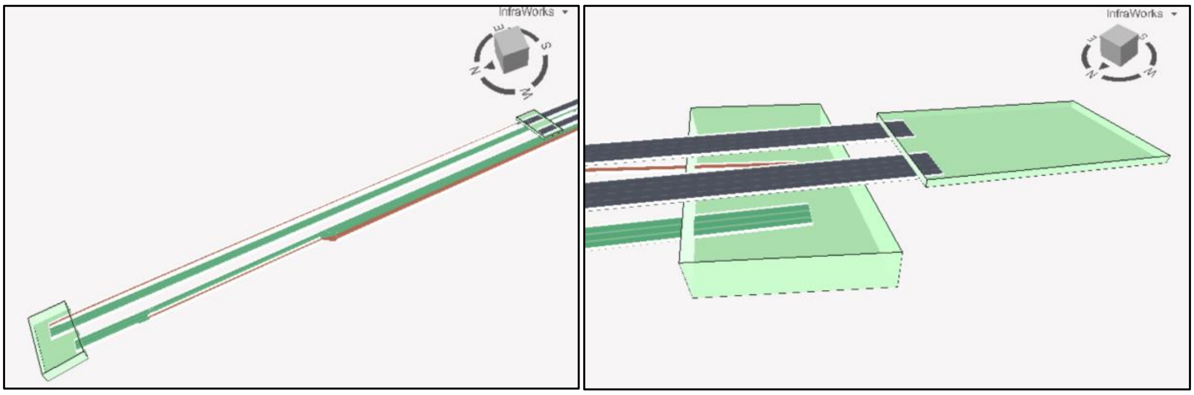


Figure 5. 1: Future model (Additional zone representation of tunnel northbound(left) and Southbound(right))

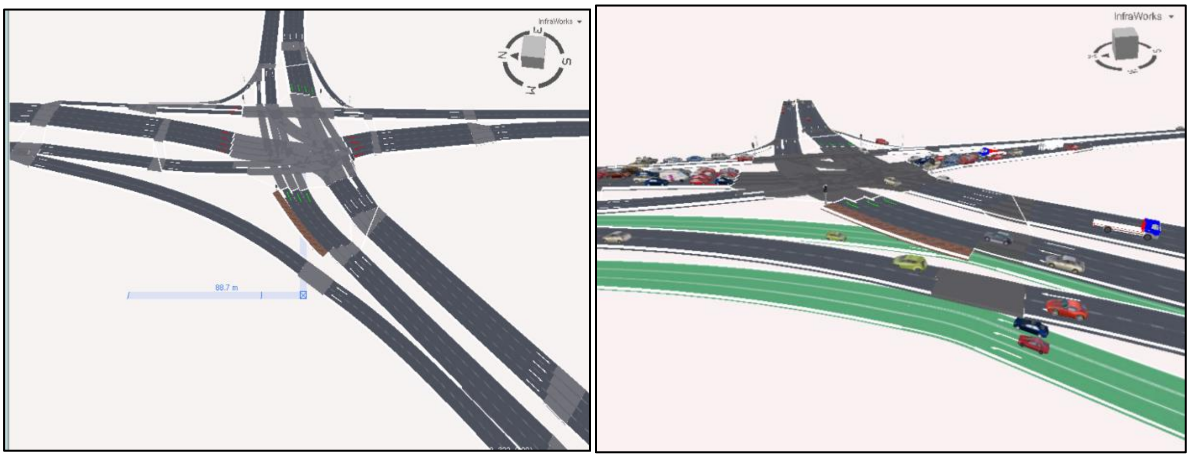


Figure 5. 2: Ayliffes intersection difference between existing model (left) and future model 1 (right), Mobility Simulator

Changes in geometry of Ayliffes intersection is shown in figure 5.2 for Mobility Simulator future model 1. Tunnel with 3 lanes is highlighted in green for better representation of geometry.

Construction of future Model 1 was made by making changes in the following parameters of Mobility Simulator:

- Intersection phasing
- Demand division
- Observation
- Demand editor – OD matrix

5.1.1 Intersection Phasing

The input of phasing data for 2031 DPTI Model was optimized by SIDRA intersection software that has same phasing for intersection TS404 and TS343. However, the green time cycle for TS111 and TS112 was increased for better results.

					AM Peak 2031 (7:30-8:30)											
Intersection			Intersection phases(seconds)													
		A			B			C			D			E		
	Cycle Time	G	Y	R	G	Y	R	G	Y	R	G	Y	R	G	Y	R
TS404	140	117	4	2	6	5	2	6	4	2						
TS111	140	60	7	2	30	6	2	25	6	2						
TS112	140				31	4	5	14	4	5	34	4	5	25	4	5
TS343	140	43	4	6	31	4	7	20	4	7	19	4	7			

Table 5. 1: 2031AM peak Intersection phasing

5.1.2 Demand Division

Default values were taken for base model private vehicle demand division. However, analysis of the total count of vehicle for 2031, it was found that the only heavy vehicle counts 1166 and both (Cars and HV) count 25490 thus HV division 4.572 was considered for software use as shown in figure 5.3.

Division	101 Small Car	102 Medium Car	103 Large Car	104 SUV	105 Van	106 Truck
Division	40.5	10.0	30.0	10.0	5.0	4.5
Division1	100.0					
Division2	100.0					
Division3	100.0					
Division4	100.0					
Division5	100.0					

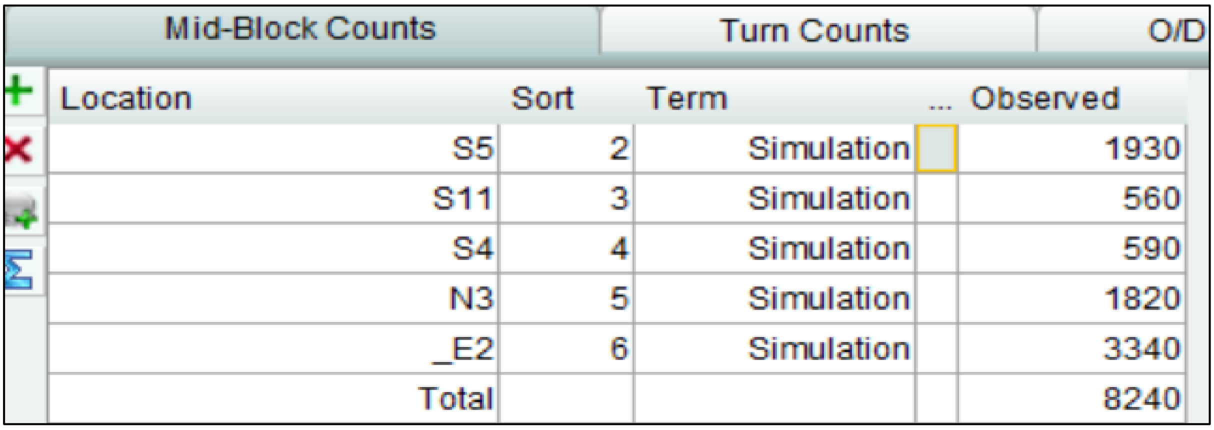
Figure 5. 3: percentage of vehicle type in Mobility Simulator

5.1.3 Observation

Future model scenario pivotal changes were made in tool observation as there is a presence of mid-block count due to ramp on/off in the tunnel.

5.1.3.1 Mid-block count

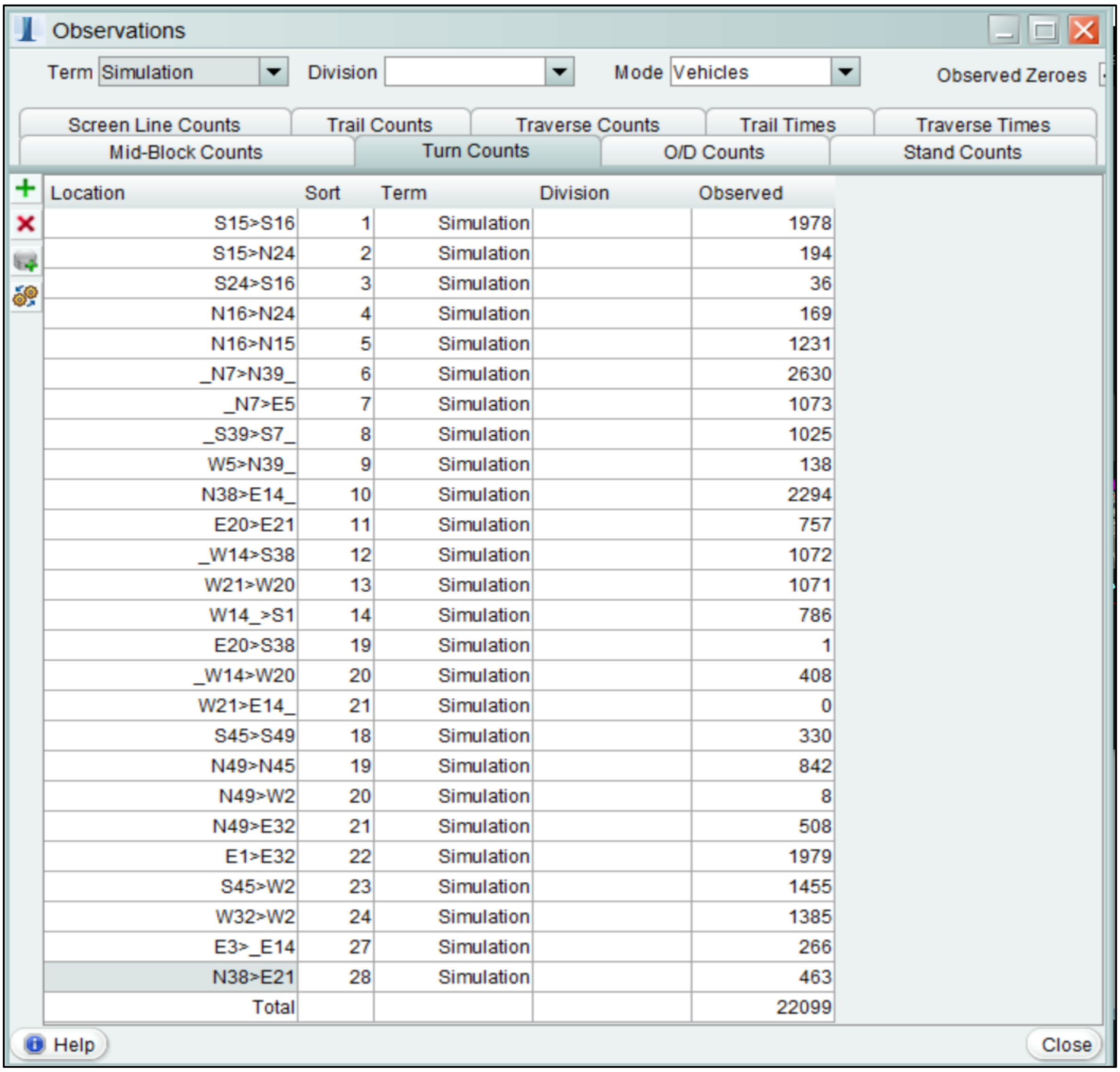
The observed mid-block count in the model for different location is mentioned in figure 5.4 below : -



Location	Sort	Term	...	Observed
S5	2	Simulation		1930
S11	3	Simulation		560
S4	4	Simulation		590
N3	5	Simulation		1820
_E2	6	Simulation		3340
Total				8240

Figure 5. 4: Observed mid-block count for future model(Mobility Simulator)

5.1.3.2 Turn count



Location	Sort	Term	Division	Observed
S15>S16	1	Simulation		1978
S15>N24	2	Simulation		194
S24>S16	3	Simulation		36
N16>N24	4	Simulation		169
N16>N15	5	Simulation		1231
_N7>N39_	6	Simulation		2630
_N7>E5	7	Simulation		1073
_S39>S7_	8	Simulation		1025
W5>N39_	9	Simulation		138
N38>E14_	10	Simulation		2294
E20>E21	11	Simulation		757
_W14>S38	12	Simulation		1072
W21>W20	13	Simulation		1071
W14_>S1	14	Simulation		786
E20>S38	19	Simulation		1
_W14>W20	20	Simulation		408
W21>E14_	21	Simulation		0
S45>S49	18	Simulation		330
N49>N45	19	Simulation		842
N49>W2	20	Simulation		8
N49>E32	21	Simulation		508
E1>E32	22	Simulation		1979
S45>W2	23	Simulation		1455
W32>W2	24	Simulation		1385
E3>_E14	27	Simulation		266
N38>E21	28	Simulation		463
Total				22099

Figure 5. 5: Intersection turn count for future model

For the Origin-Destination matrix development with 2031 AM peak, as we divided the traffic movement between the zones for existing scenario a network diagram was drawn with turning movement labelled, and the OD matrix was completed.

Zones	1	2	3	4	5	6	7	8	9	10
1		92	5	5	5	5	5	5		6
2	184		114	135	103	121	129	206		350
3				115	199	399	216	300		271
4	20	517	508		1	1	1	2	305	3
5	10	50	50			757	0	1	156	0
6	0	0	0		1071		155	5	0	440
7	60	100	700		29	453		1073	1288	
8	10	20	20		10	10	56		138	80
9	10		100	190	100	260	79	100		1930
10	69	544	1209						3340	
	363	1323	2706	445	1518	2006	641	1692	5227	3080

Figure 5. 6: Future model input of OD matrix

Due to addition of 2 extra zones in the future models, traffic movement was for total of 10 zones in network diagram and formed input matrix is shown in figure 5.6 with 2031 AM peak (Cars and HV). The red colour in the table showing no movement of traffic in the zones.

5.2 Future Model 2

Model 2 is an updated version of model 1, in this case, one additional lane for the tunnel was added in both directions for the modelling of this model as the DPTI studies shows poor level of service for 2-lane tunnel.

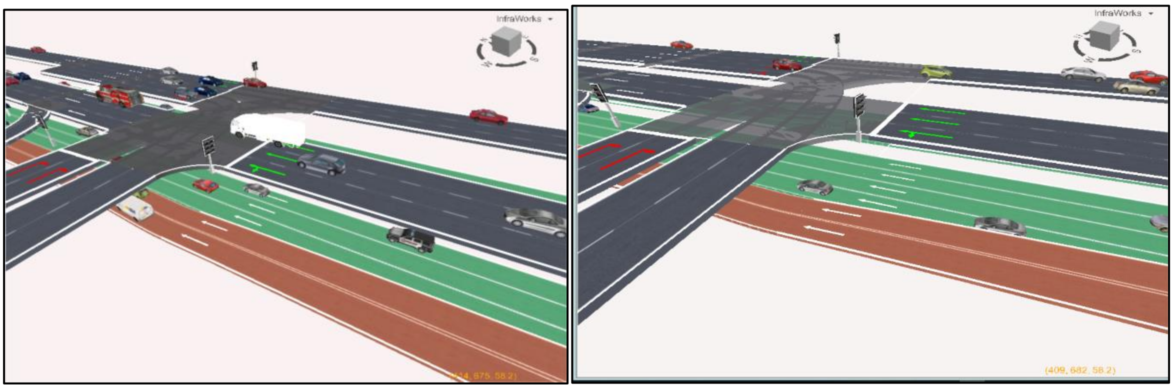


Figure 5. 7: Tonsley BLVD difference between the future DPTI 3 lane (left) and future model 2 4 lane (right), Mobility Simulator

This model requires changes in future model 1:

Lane geometry

An additional lane was added to the tunnel as represented in figure 5.7 (right) using the same process as described in section 4.5.1.

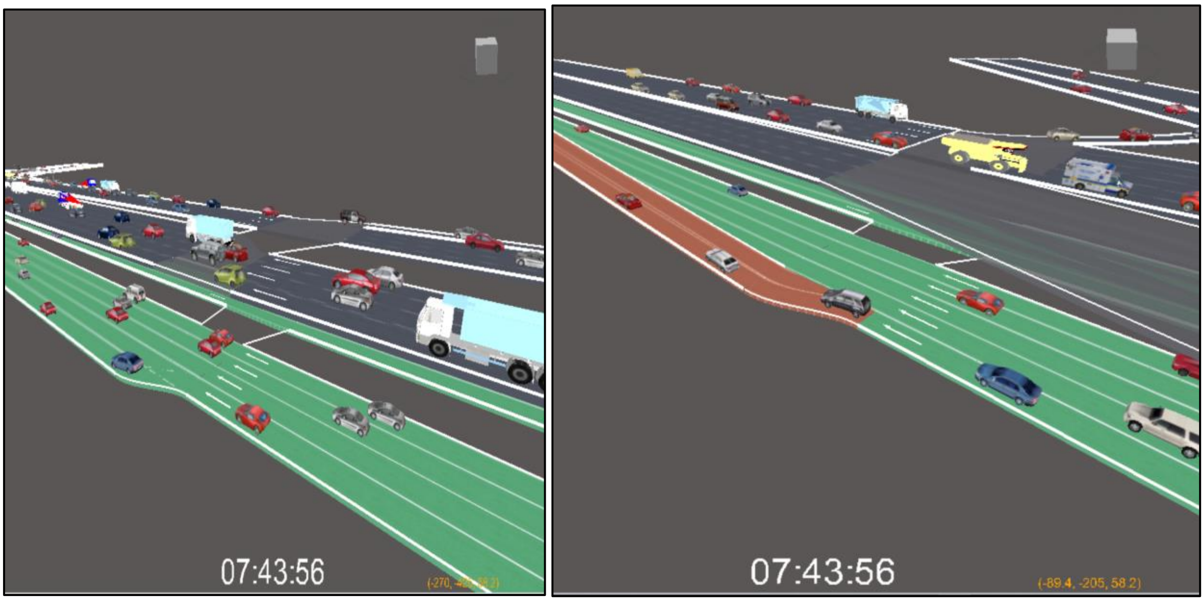


Figure 5. 8: Geometry additional lane for ramp off (future model 2)

During the construction of future model 2, before the ramp off an additional lane to the tunnel was added in order to avoid queue before the lane merge so that vehicles those who want to exit to the main stream can take most left lane for ramp exit.

6 Result and Discussion

This chapter will describe the microsimulation results evaluated from the report of Mobility Simulation. As explained before, peak AM period impact more in network, therefore, assessment of AM period was conducted for reporting. Different outputs will be explained in the upcoming three sections.

6.1 Economic Evaluation Report

An economic evaluation report was produced in reporting toolbar of mobility simulation. This evaluation was performed for each scenario and summarises of individual are attached in appendices in terms of total mean and standard deviation (S.D) of :

- Cost
- Speed
- Number of stops
- Delay
- Trip completed
- Time travelled by vehicle

The comparison of economic evaluation report for each development was conducted to check the performance in terms of cost and speed for each model.

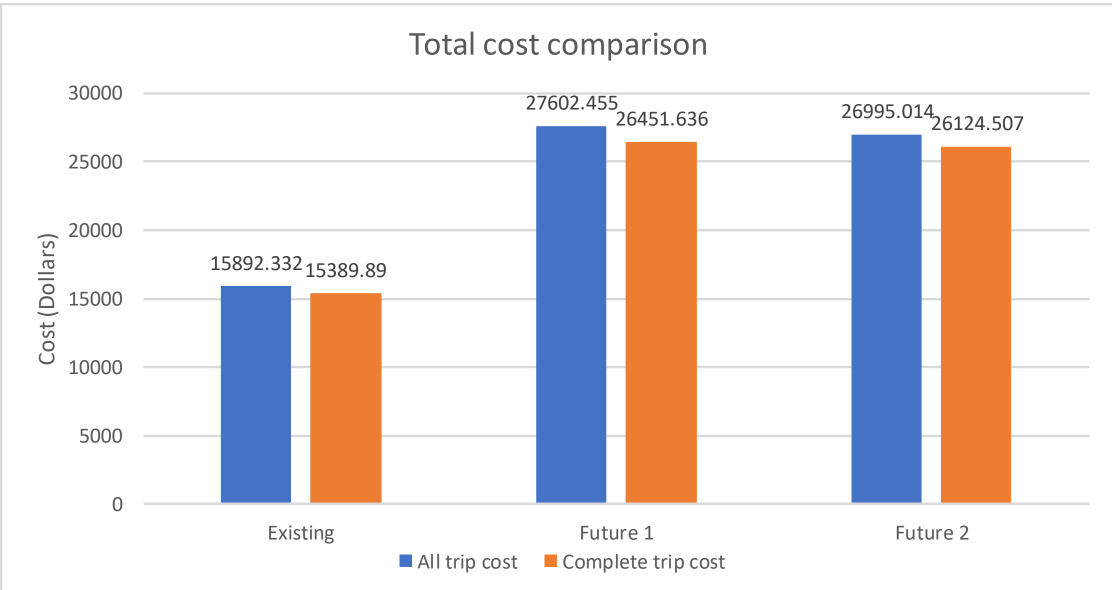


Figure 6. 1: Total cost comparison for AM peak

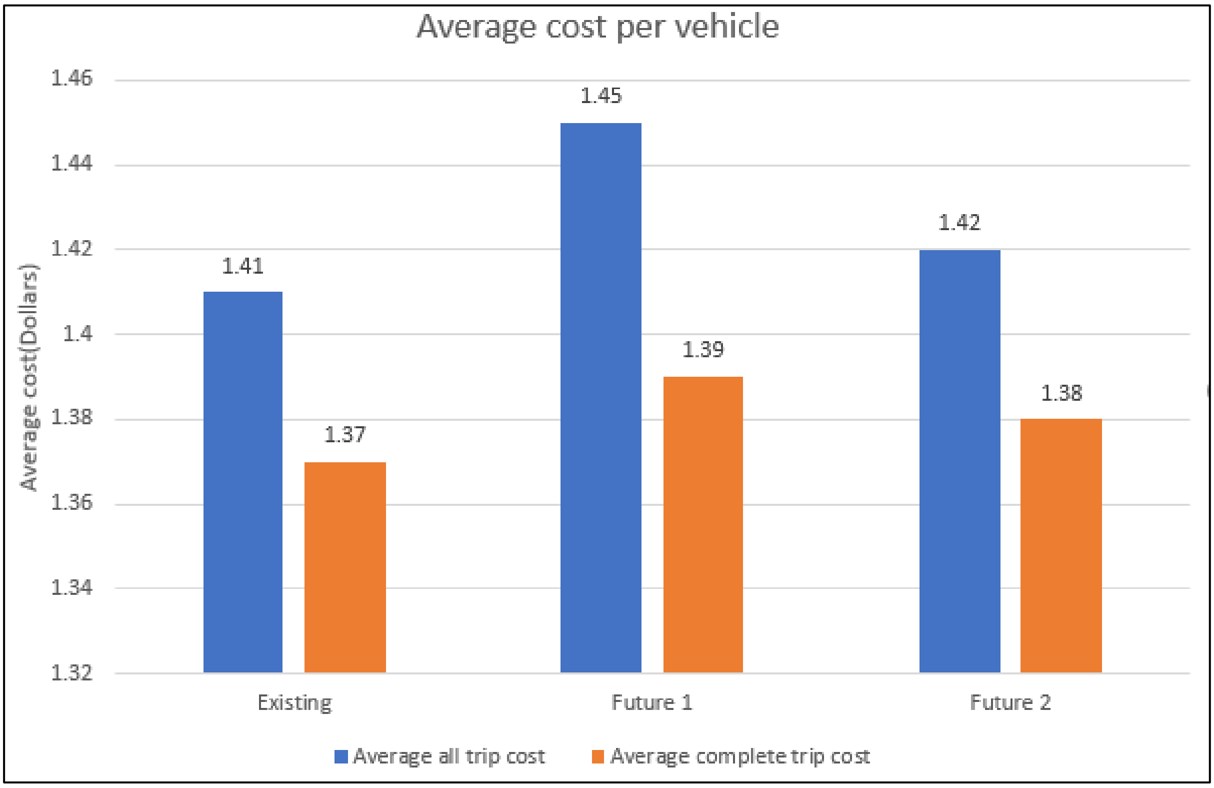


Figure 6. 2: Comparison of Average cost per vehicle

For existing, future model 1 and future model 2 complete evaluation of each scenario is presented in appendix C. For AM peak, all trips and complete trips was different for each model and total cost comparison on that basis is shown in figure 6.1.

There is no significant difference in trip cost for future models however, comparing of existing 2015 model with future model 2 AM 2031 gave a difference of $606.44 per hour for total cost comparison that make the future model 2 more economical.

Despite this, Average vehicle speed for future models is extremely close to a difference of 2% as shown in figure 6.3. future models exceed the existing model average speed with an approximate difference of 10%.

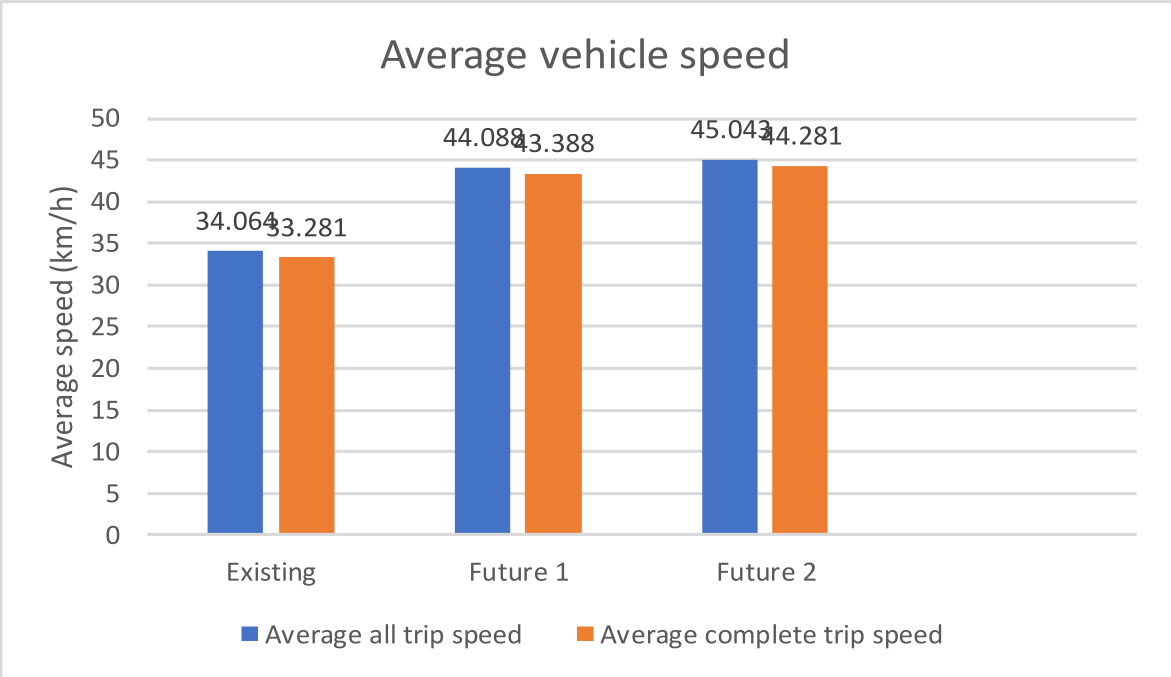


Figure 6. 3: Average vehicle speed for all and completed trips

Speed and Queue comparison for future models :

Future model scenarios were observed for 2 lanes ramp off to tunnel from mainline northbound traffic. Figure 6.4 & 6.5 clearly stated that for time 7:35:05 AM the observed mean speed from traffic report for tunnel lane 1 for future model 1 was 68km/h for speed limit 90 km/h and which is not considered as a good performance for the network. The reason can be the number of lanes in the model. Future model 2 observed the mean speed 72.9 km/h for the same instance with 401 vehicles in the stream. However, the vehicle counts for tunnel lane 1 for future model 1 was 218 vehicles and with fewer vehicles the lane of tunnel had speed less than 4.9 km/h for model 2, eventually as the vehicles were passing with high speed in the lane. practically performance of Future model 2 will be better as high volume of traffic can pass the lane with better level of service. For the same instance of time, queue length was observed as shown in figure 6.4 and examine that model 1 has a long queue for the intersections.

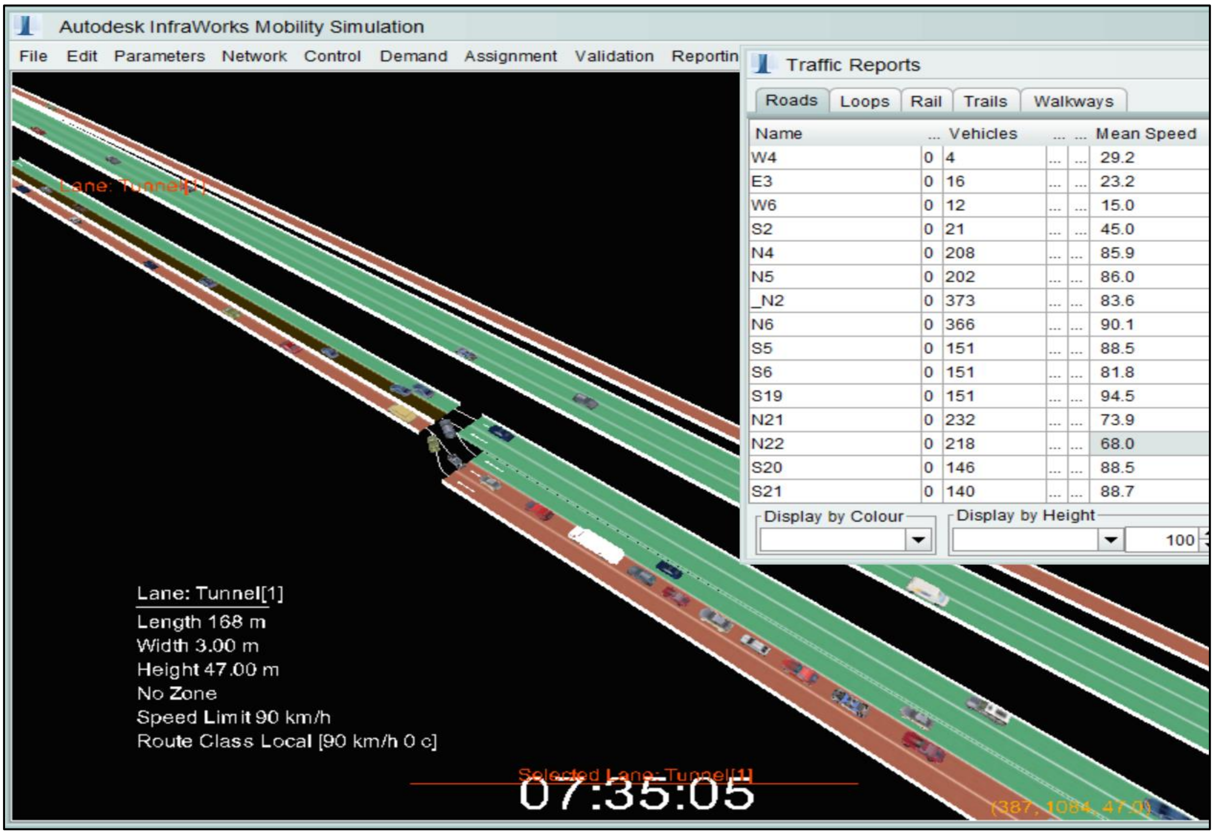


Figure 6. 4: Future model 1 ramp off to tunnel northbound

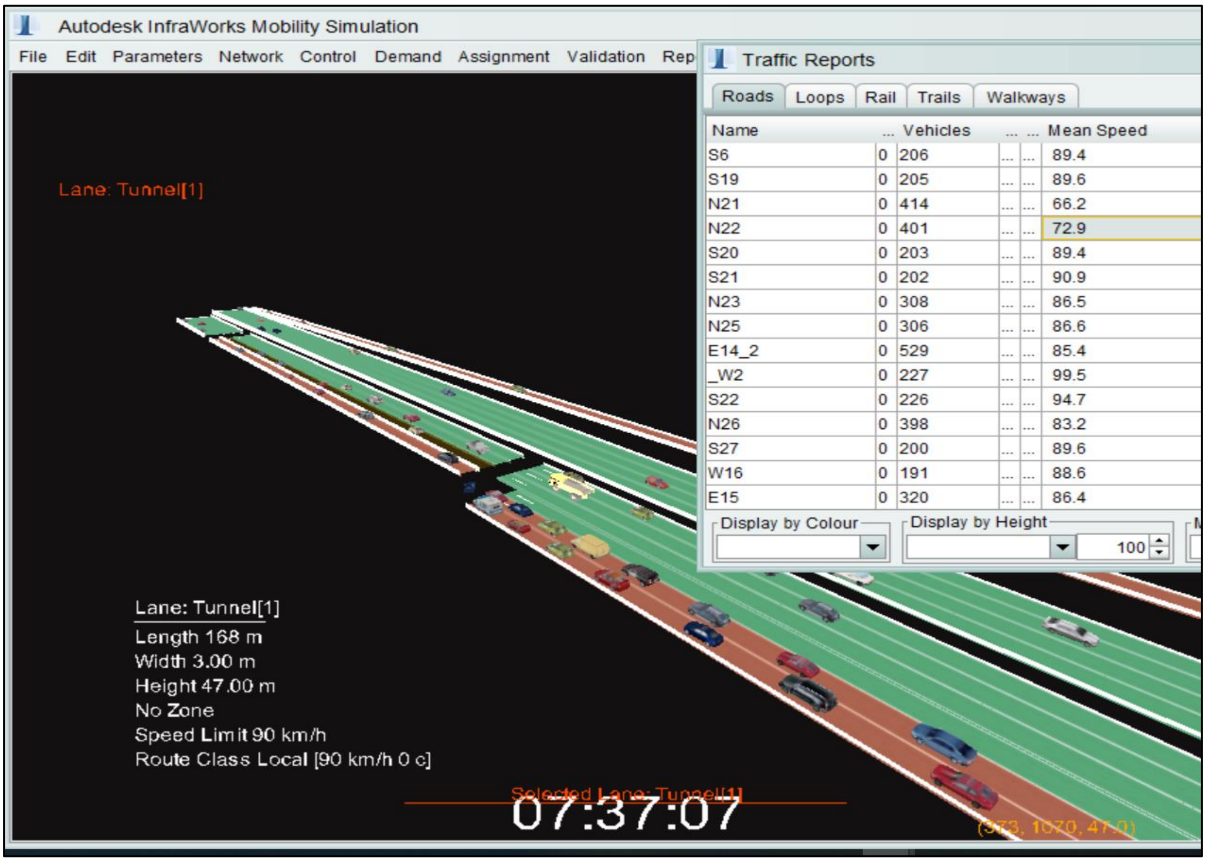


Figure 6. 5: Future model 2 ramp off to tunnel

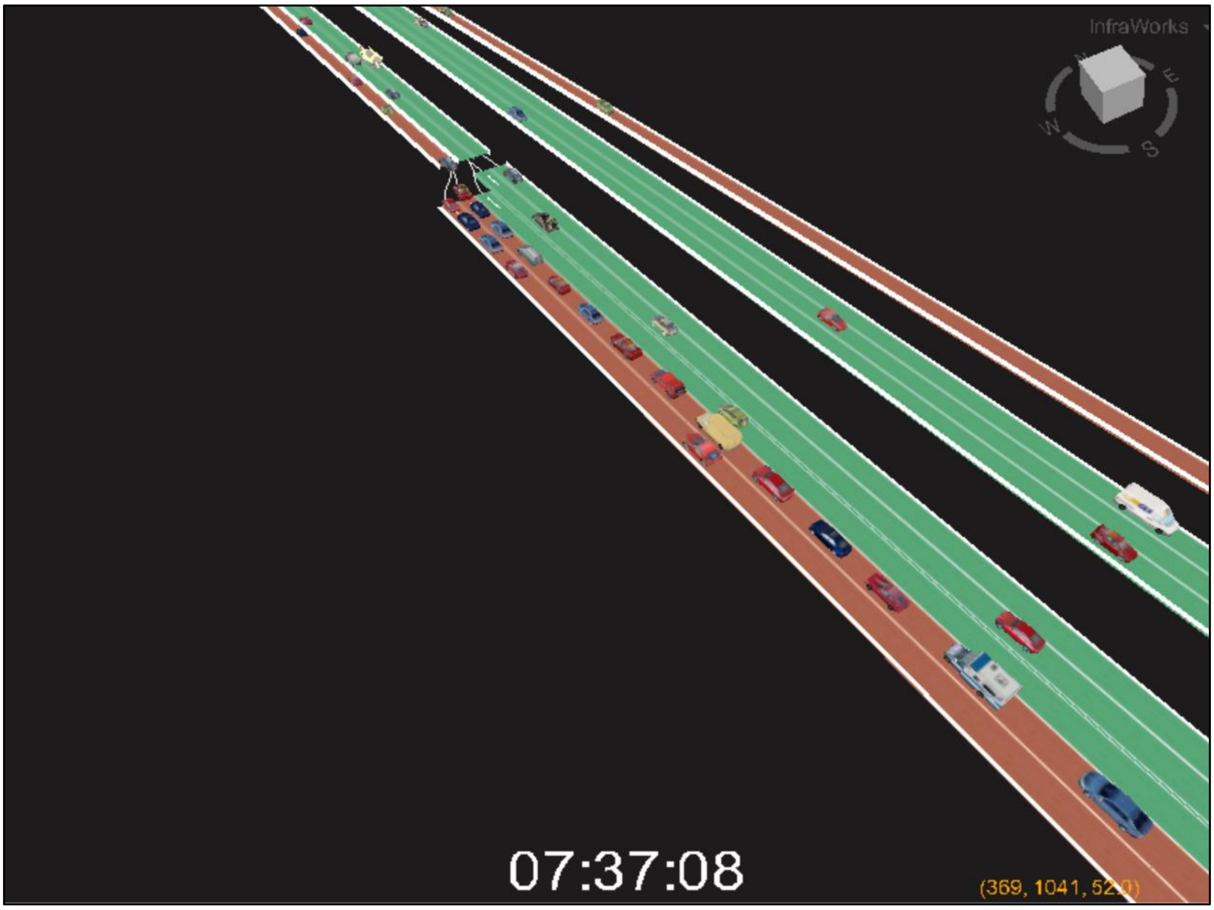


Figure 6. 6: Observation of queue for ramp metering location tunnel merging Tonsley BLVD(northbound)

6.2 Level of service

Level of service (LOS) is a measure of the performance of an intersection. It uses multiple variables to measure the control delay, which is the time all vehicles are delayed in the approach lane of intersection. This value depends on the approach delay, which is the time it takes for the vehicle to leave the intersection to maintain its speed. LOS is represented by a single letter A to E. Table 6.1 lists all values of signalised intersections for each type of development. It was observed that future model 2 has level of service 'B' for Tonsley BLVD, Ayliffes intersection and Sturt Intersection. However, Flinders Drive still experiences control delay between (28.5-42.5) seconds. Hence output of Mobility gave level of service C for this intersection. Table 6.2 defined the level of service for Mobility Simulator of NSW government traffic mode(Roads and Maritime Services, 2013).

Development	Intersection	Entry	Approach Delay(Secs)	Accelertation Delay(Secs)	Control Delay(Secs)	LOS
Existing network	TS404	All	13.67	4.06	17.74	B
	TS111		29.49	4.15	41.97	C
	TS112		13.46	2.21	15.67	B
	TS343		24.99	3.08	28.07	B
Future Model 1	TS404		13.29	3.54	16.83	B
	TS111		17.66	2.47	20.13	B
	TS112		31.91	4.19	36.11	C
	TS343		30.45	3.05	33.5	C
Future Model 2	TS404		12.57	3.55	16.13	B
	TS111		21.36	3.67	24.6	B
	TS112		20.26	2.67	22.93	B
	TS343		30.45	3.05	33.51	C

Table 6. 1: level of service for signalised intersections , AM peak

Level Of Service	Control Delay (seconds)	
	Lower Limit	Upper Limit
A	0	14.5
B	14.5	28.5
C	28.5	42.5
D	42.5	56.5
E	56.5	70.5
F	70.5	∞

Table 6. 2: LOS value definitions (Azalient,2012)

6.3 Environment Impact

This section will look at the emissions generated by each development based on the relevant vehicle travel conditions. This is another assessable metric that can be used to reason and justify the overall impact of development types on the networks. Measurement for carbon dioxide and nitrogen oxides are given, which are emissions from the engine and exhaust system of a vehicle operating at normal operating temperatures(Boulter et al., 2009). The emission values used by the Mobility Simulation are taken from the UK Transport Research Laboratory Database of Emission Factors, 2001.

Table 6.3 below shows the emissions, type and average value of each trip.

Table 6. 3: Per development pollution increase representation

Development	CO2(kg)	NOX(kg)	Vehicle Trips	CO2 per trip(kg)	NOX per trip(kg)
Existing Model	2556682	4690.075	11200	228.275	0.419
Future Model 1	5174399	11072.39	18930	273.344	0.585
Future Model 2	4519641	10304.11	18930	238.755	0.544

Figure then shows the total emissions generated by each development.

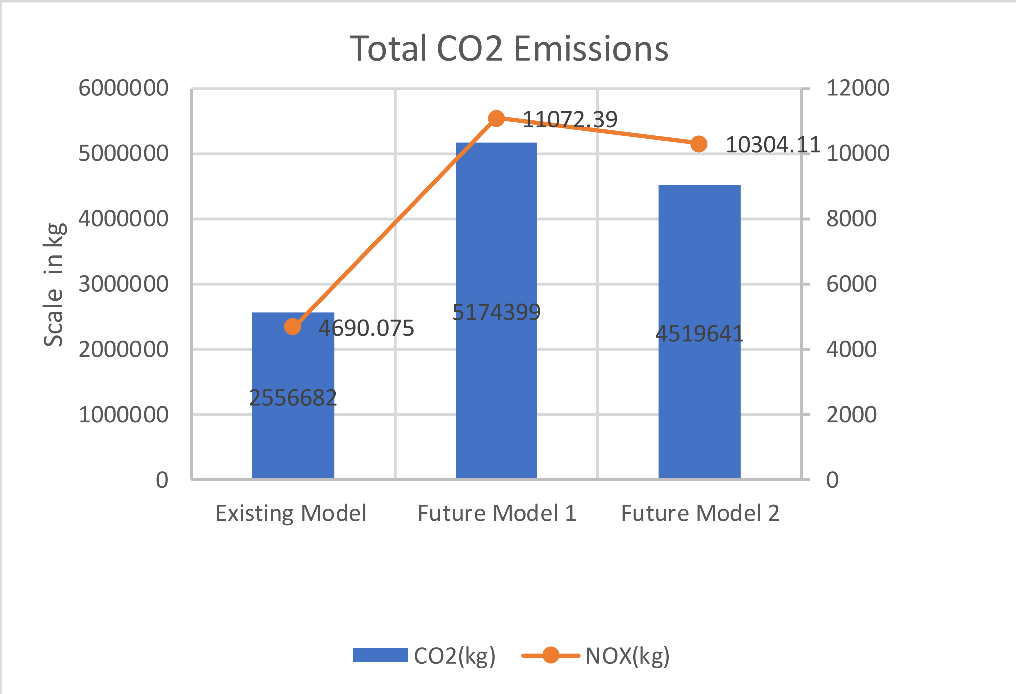


Figure 6. 7: Total CO2 and NOX emission per development

Emissions displayed in the result table 6.3 defined that the pollution will increase in 2030 due to high count of total vehicle trips 18930. This increase of 1730 total trips also influences the total distance travelled and mean time of travel with a difference of 15,778 km and 9 seconds. Figure 6.6 display that future models has a significant increase in the value of carbon and nitrogen oxides emissions.

Overall, future model 2 has a significant reduction in both emissions for the peak period analysis duration 7:30-8:30 due to less congestion and less queue in the network. Therefore, total number of stops in model 2 reduced by 1940. Also, the representation of emission per trip is shown in figure 6.8 for better justification of the model.

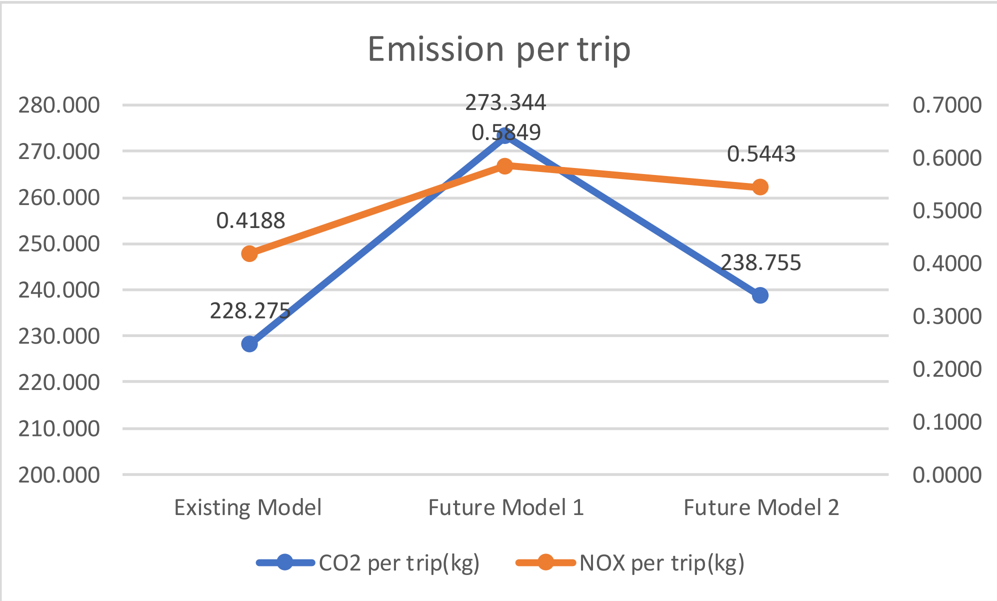


Figure 6. 8: Trip efficiency per development

7 Research Conclusion and Future Recommendation

In conclusion, this thesis sought to assess the Darlington upgrade using the microsimulation software Infraworks and Mobility Simulator. The aim was to quantify the impact of congestion during morning peak on Intersections – Tonsley Boulevard, Ayliffes, Sturt Drive and Flinders Drive in terms of financial cost, CO_2 emissions, intersection LOS, travel time and queue length. A detailed comparison of extra lane tunnel in future model 2 and future model 1 was explained in order to access the performance of complete network.

Results found that Future Model 2 performed the best among the three different models simulated, for each performance indicator. Compared to the existing model, Model 2 achieved; a 2.19 % reduction in average total cost which is a difference of $606.44 per hour. Also, the model 2 has less number of stops in the 3.3 km road network with average vehicle speed of 45.04 km/h. Speed and queue comparison analysed with future model 2 and recorded that for one instantaneous time for lane merging speed experienced by model 1 was 4.9 km/h less with a long queue at intersections as explained in section 6. Performance of network for intersection in future model 2 was 'B' with control delay ranging between (14.5 - 28.5) seconds with exceptional intersection flinders drive with a level of service C. Reduction in carbon and nitrogen oxides content is 654.75 tonnes, 0.78 tonnes respectively.

Both future models have not much difference for economic evaluation reports. However, future Model 1 performed better than the existing model for all performance indicators and produced comparable total cost and CO_2 emission results to model 2. Existing model was the worst-performing network, with a bad level of service for Ayliffes and sturt intersection with a long queue at intersections.

Taking everything into consideration, future model tunnel 4 lanes 2031 AM is viable for Darlington upgrade with the best performing network. There are some other factors in the research, which were not considered during the assessment of this project that includes; constructional cost, public transport, Flinders Link Project and safety. These will heavily influence the development results for economic and environmental implications.

Further recommendations on this research for future work are based on some limitations that the project identified. The specific recommendation is outlined below :

- Test incident scenarios by identifying critical incident locations in the network.
- Doing a similar analysis on this thesis for PM peak.
- Chane the duration period of simulation after collecting more traffic data.
- Explore the relationship between variables that are identified in the thesis.
- Conduct sensitivity analysis for a greater period of simulation and compare the results for vehicle emissions and financial cost.

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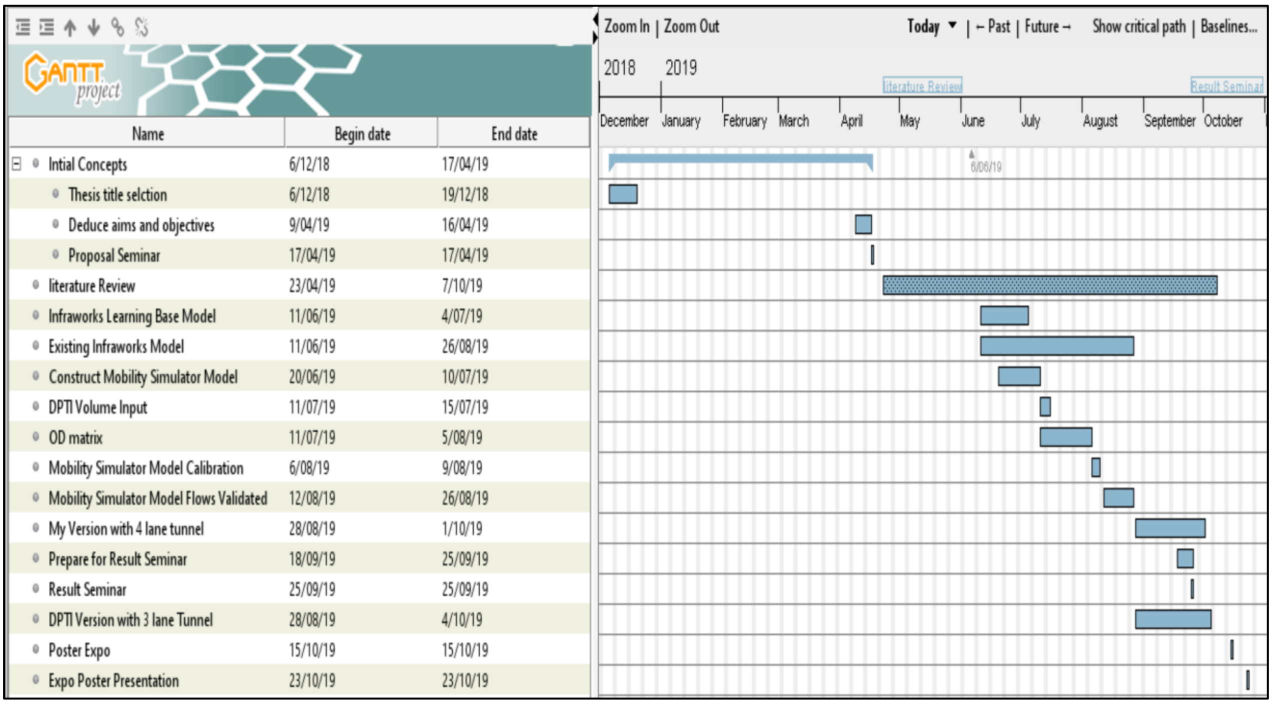
Appendices

Appendices A : **Timeline Chart for the project**



Name	Begin date	End date
Intial Concepts	6/12/18	17/04/19
Thesis title selction	6/12/18	19/12/18
Deduce aims and objectives	9/04/19	16/04/19
Proposal Seminar	17/04/19	17/04/19
literature Review	23/04/19	7/10/19
Infraworks Learning Base Model	11/06/19	4/07/19
Existing Infraworks Model	11/06/19	26/08/19
Construct Mobility Simulator Model	20/06/19	10/07/19
DPTI Volume Input	11/07/19	15/07/19
OD matrix	11/07/19	5/08/19
Mobility Simulator Model Calibration	6/08/19	9/08/19
Mobility Simulator Model Flows Validated	12/08/19	26/08/19
My Version with 4 lane tunnel	28/08/19	1/10/19
Prepare for Result Seminar	18/09/19	25/09/19
Result Seminar	25/09/19	25/09/19
DPTI Version with 3 lane Tunnel	28/08/19	4/10/19
Poster Expo	15/10/19	15/10/19
Expo Poster Presentation	23/10/19	23/10/19

Appendix B :Traffic Volumes

Existing model

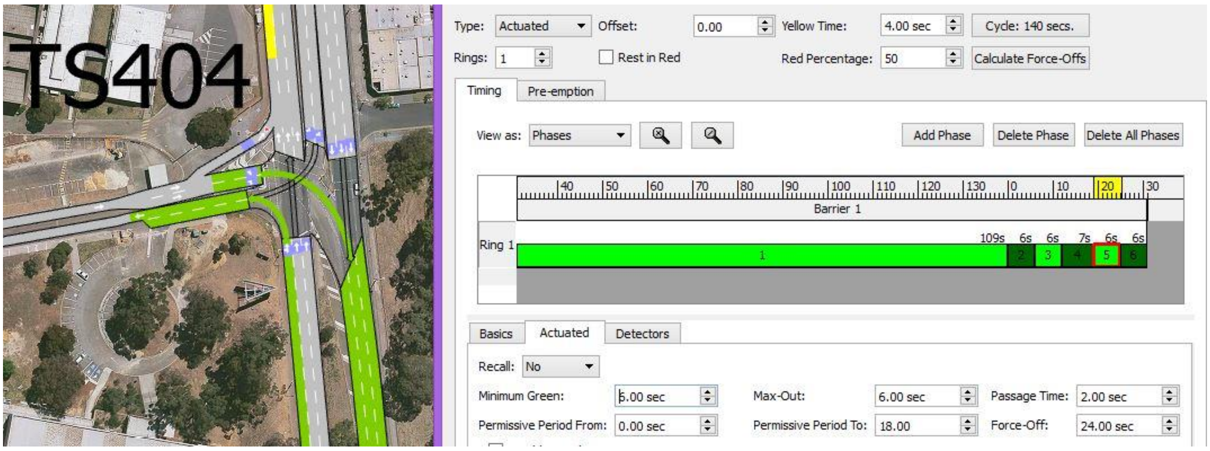
Intersection	Approach	Turn Movement	Turn Count										
			07:00-07:15	07:15-07:30	07:30-07:45	07:45-08:00	08:00-08:15	08:15-08:30	sum	08:30-08:45	08:45-09:00	09:00-09:15	09:15-09:30
TS404	North	Through	200	258	333	384	381	424	1522	455	386	329	355
TS404	North	Right	12	13	20	23	24	35	102	29	38	24	14
TS404	South	Through	635	566	535	519	464	451	1969	489	470	457	417
TS404	South	Left	55	133	126	130	180	120	555	73	76	57	80
TS404	West	Left	1	1	1	1	1	1	4	1	1	1	1
TS404	West	Right	0	3	1	2	3	8	14	11	7	6	8
TS111	North	Right	166	232	277	329	329	357	1292	384	309	271	297
TS111	North	Through	22	26	38	47	42	56	183	65	63	42	43
TS111	North	Left	6	4	11	10	5	13	39	14	16	17	18
TS111	East	Through	133	196	269	314	312	332	1227	335	307	296	268
TS111	East	Left	4	5	5	13	10	10	38	13	23	27	22
TS111	South	Through	80	80	105	104	92	95	396	116	116	91	62
TS111	South	Left	1	1	2	3	4	2	11	5	4	4	5
TS111	South	Right	33	44	71	80	69	75	294	59	62	56	39
TS111	SW	Left	602	633	579	536	545	470	2130	427	448	412	418
TS111	SWBus	Through	1	2	1	3	1	1	6	1	0	1	1
TS111	SW	Through	611	651	693	569	616	485	2363	396	399	448	421
TS112	NE	Through	224	320	389	458	401	400	1648	408	371	337	363
TS112	NE	Left	11	38	65	103	121	199	488	183	167	119	89
TS112	NE	Right	23	27	32	37	40	68	177	111	97	94	85
TS112	East	Right	3	7	12	12	17	18	59	20	23	22	18
TS112	East	Through	61	86	101	133	155	185	574	162	177	171	127
TS112	East	Left	54	60	96	103	96	71	366	77	88	91	37
TS112	SW	Left	28	30	55	58	83	97	293	109	78	55	34
TS112	SW	Through	1189	1268	1202	1055	1048	877	4181	765	765	779	716
TS112	SW	Right	40	48	77	78	110	141	405	143	143	103	75
TS112	West	Right	28	35	36	43	33	39	151	52	42	35	46
TS112	West	Left	46	55	73	68	68	50	259	48	55	60	63
TS112	West	Through	40	75	125	163	146	210	644	190	201	177	124
TS343	NE	Through	225	290	343	389	393	397	1522	368	354	374	379
TS343	NE	Left	71	111	170	172	114	114	570	115	159	124	107
TS343	SE	Right	25	37	42	37	37	46	162	49	43	42	60
TS343	SE	Left	21	43	64	26	28	23	141	27	29	30	28
TS343	SW	Through	1231	1309	1292	1154	1204	1069	4719	968	943	895	765
TS343	SW	Right	80	105	167	196	207	263	833	281	286	225	168
									29337				

Future model 2031 AM Turn count

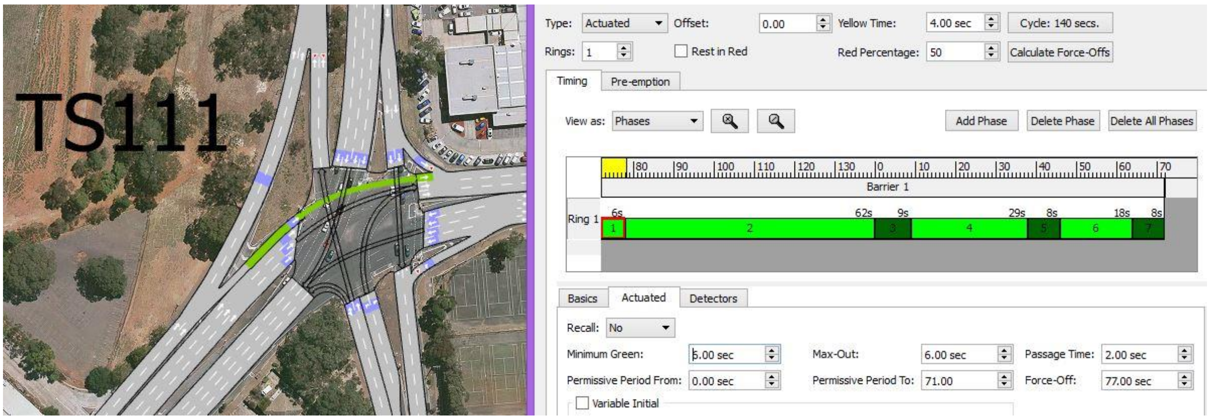
Intersection	Approach	Turn Movement						Turn Count					
			07:00-07:15	07:15-07:30	07:30-07:45	07:45-08:00	08:00-08:15	08:15-08:30	Sum	08:30-08:45	08:45-09:00	09:00-09:15	09:15-09:30
TS404	North	Through	365	382	448	446	466	471	1832	442	385	358	298
TS404	North	Right	28	38	42	41	50	45	179	45	35	33	28
TS404	South	Through	232	242	272	304	285	301	1163	255	238	221	183
TS404	South	Left	27	39	38	46	42	39	165	41	34	33	28
TS404	West	Left	14	17	16	19	22	19	76	15	15	14	11
TS404	West	Right	8	6	8	6	10	7	31	8	5	6	5
TS111	North	Right	264	276	349	319	389	327	1383	346	277	272	236
TS111	North	Through	56	63	73	70	82	71	295	83	62	62	51
TS111	North	Left	35	35	43	39	47	48	176	51	33	32	30
TS111	East	Through	250	289	291	347	334	350	1322	298	279	259	203
TS111	East	Left	22	24	31	24	28	29	112	27	25	21	19
TS111	South	Through	165	167	210	197	197	208	811	171	167	139	133
TS111	South	Left	1	1	1	1	1	1	4	1	1	1	1
TS111	South	Right	105	97	131	118	124	124	496	103	102	85	79
TS111	SW	Left	104	118	125	142	140	140	547	133	115	116	86
TS111	SWBus	Through	5	5	5	5	5	5	20	5	5	5	4
TS111	SW	Through	379	417	420	496	454	509	1879	494	455	413	311
TS112	NE	Through	207	199	252	246	266	257	1021	235	223	194	171
TS112	NE	Left	163	161	181	191	200	209	781	185	183	152	134
TS112	NE	Right	73	91	94	92	114	95	396	101	81	86	67
TS112	East	Right	0	0	0	0	0	0	0	0	0	0	0
TS112	East	Through	208	212	280	245	278	247	1049	227	218	175	167
TS112	East	Left	118	115	152	137	148	131	569	122	121	97	92
TS112	SW	Left	7	11	10	9	10	9	39	10	8	7	8
TS112	SW	Through	434	427	544	504	554	580	2182	516	506	418	381
TS112	SW	Right	77	101	105	101	124	108	439	116	95	90	70
TS112	West	Right	0	0	0	0	0	1	1	0	0	0	0
TS112	West	Left	55	51	55	66	68	64	252	60	55	52	44
TS112	West	Through	132	172.9	167.8	204.5	173	194.4	740	178.2	149.5	158.6	109.2
TS343	NE	Through	187	195	238	226	262	238	964	227	216	186	160
TS343	NE	Left	124	126	143	151	150	155	599	140	137	117	104
TS343	NE	Right	1	0	0	0	0	0	1	1	0	1	0
TS343	SE	Right	28	29	37	31	29	32	129	28	31	27	22
TS343	SE	Left	36	46	50	44	54	54	202	43	43	39	33
TS343	SE	Through	22	18	25	27	27	28	106	24	23	15	13
TS343	SW	Through	469	552	602	602	667	634	2504	645	529	523	397
TS343	SW	Right	189	254	235	286	271	274	1068	280	210	231	158
TS343	SW	Left	117	117	145	138	149	154	586	143	128	124	85
TS343	West	Left	0	0	0	1	1	0	2	0	1	0	1
TS343	West	Through	34	32	39	42	37	43	161	34	36	29	23
TS343	West	Right	10	10	9	10	11	15	45	11	9	9	6
									24324				

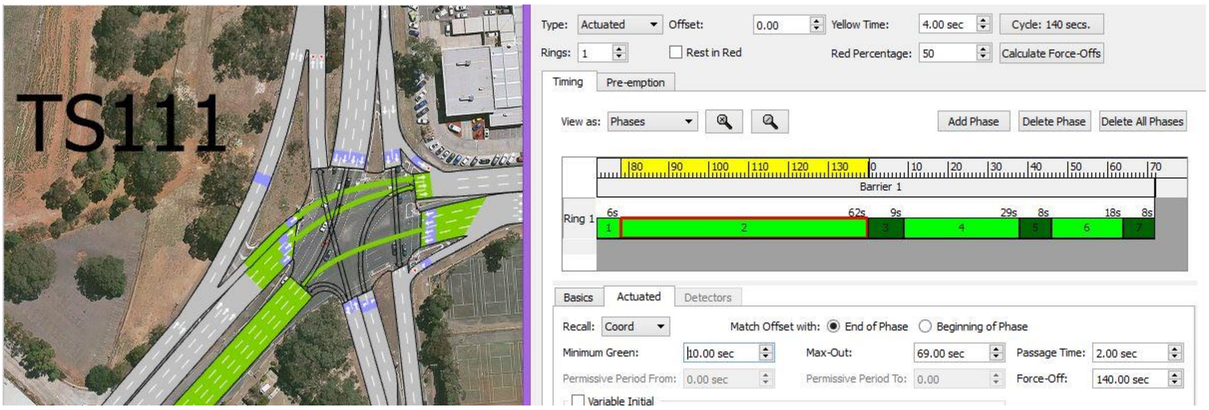
Signal Phasing 2015

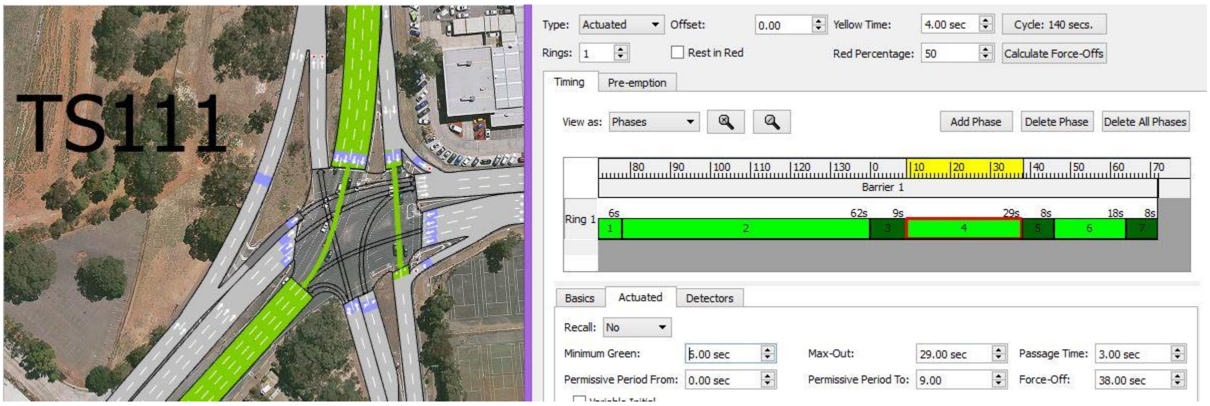
TS404 AM phasing

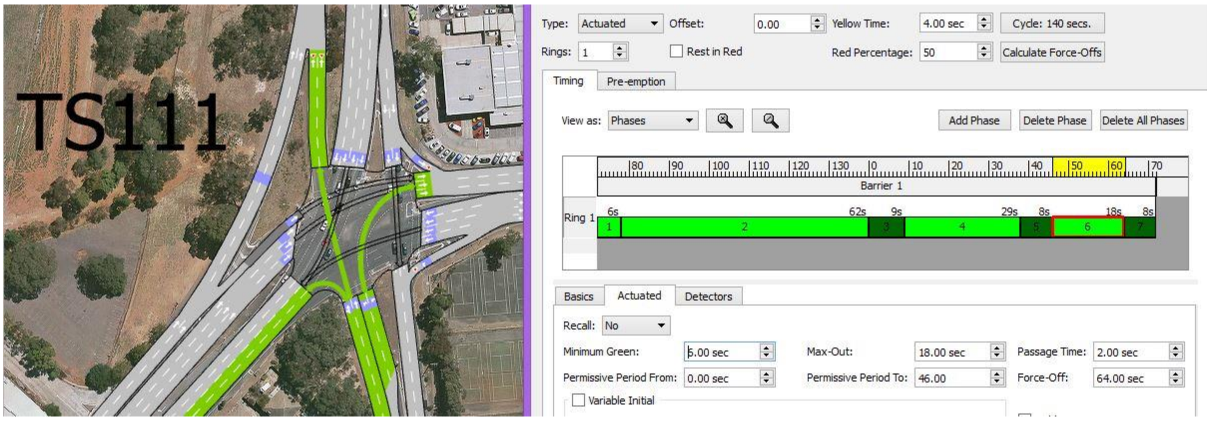


TS111 AM Phasing

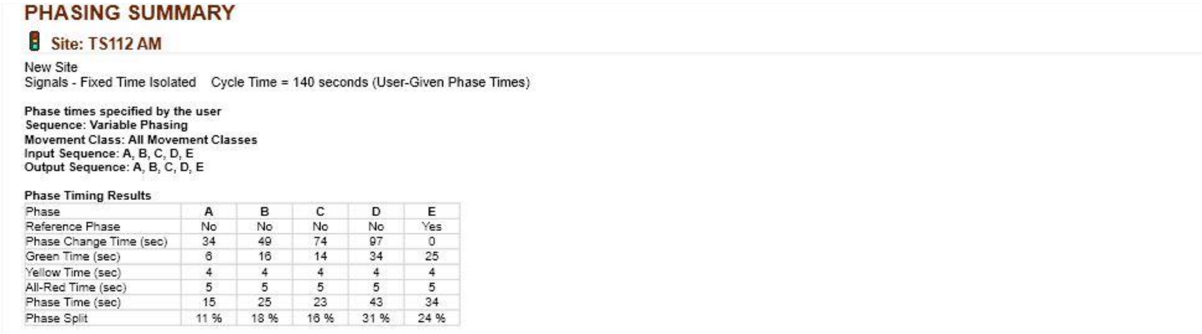








TS112 AM Phasing



PHASING SUMMARY

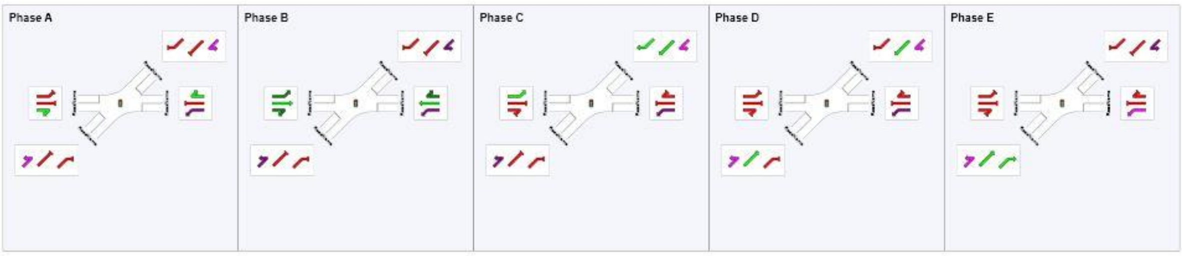
Site: TS112 AM

New Site
Signals - Fixed Time Isolated   Cycle Time = 140 seconds (User-Given Phase Times)

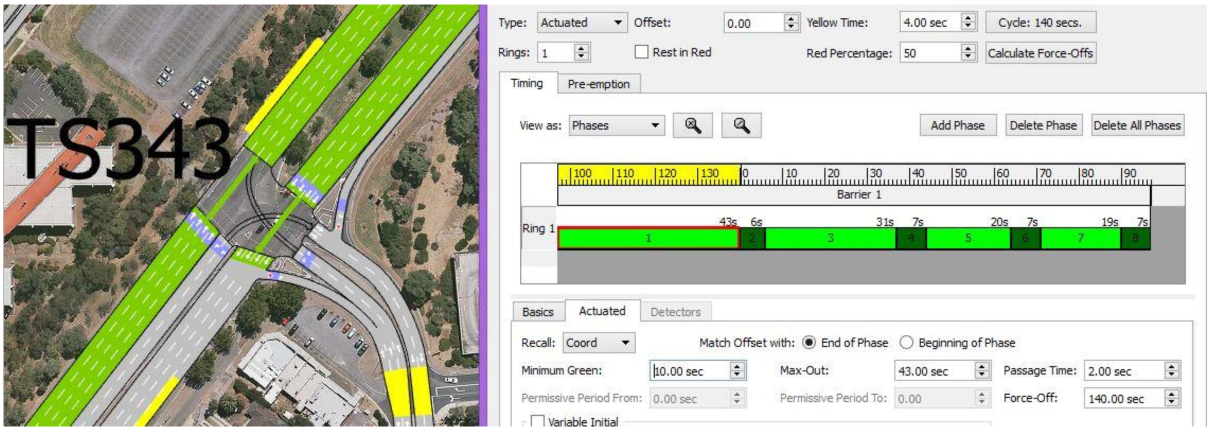
Phase times specified by the user
Sequence: Variable Phasing
Movement Class: All Movement Classes
Input Sequence: A, B, C, D, E
Output Sequence: A, B, C, D, E

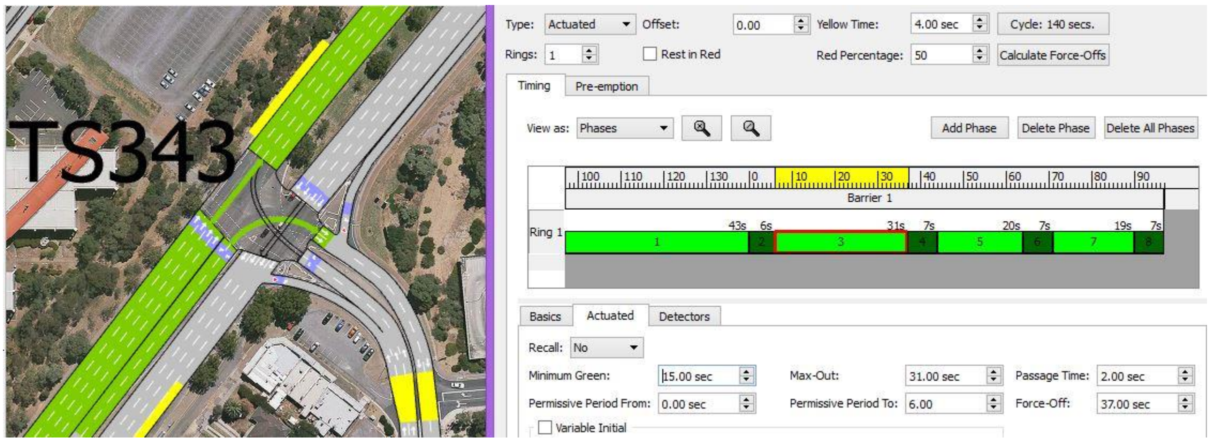
Phase Timing Results

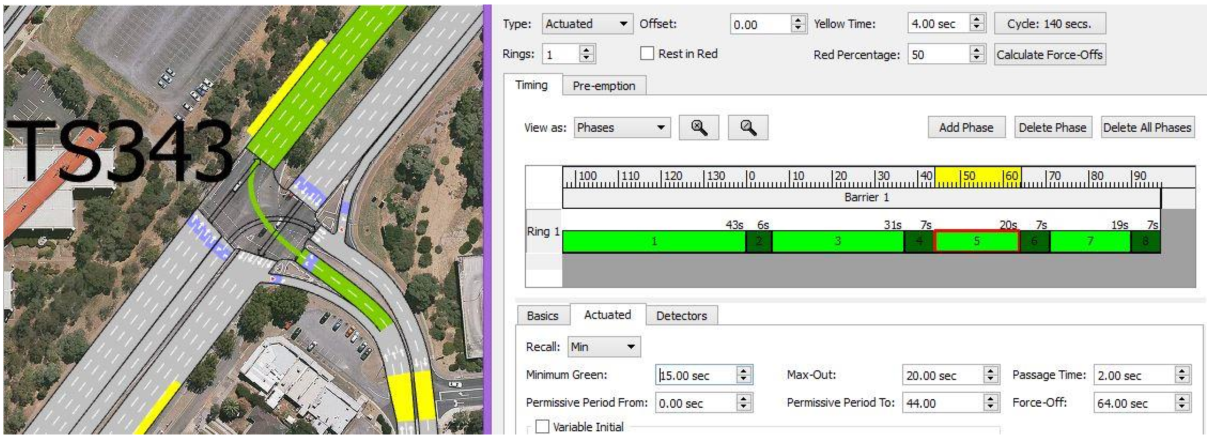
Phase	A	B	C	D	E
Reference Phase	No	No	No	No	Yes
Phase Change Time (sec)	34	49	74	97	0
Green Time (sec)	6	16	14	34	25
Yellow Time (sec)	4	4	4	4	4
All-Red Time (sec)	5	5	5	5	5
Phase Time (sec)	15	25	23	43	34
Phase Split	11 %	18 %	16 %	31 %	24 %

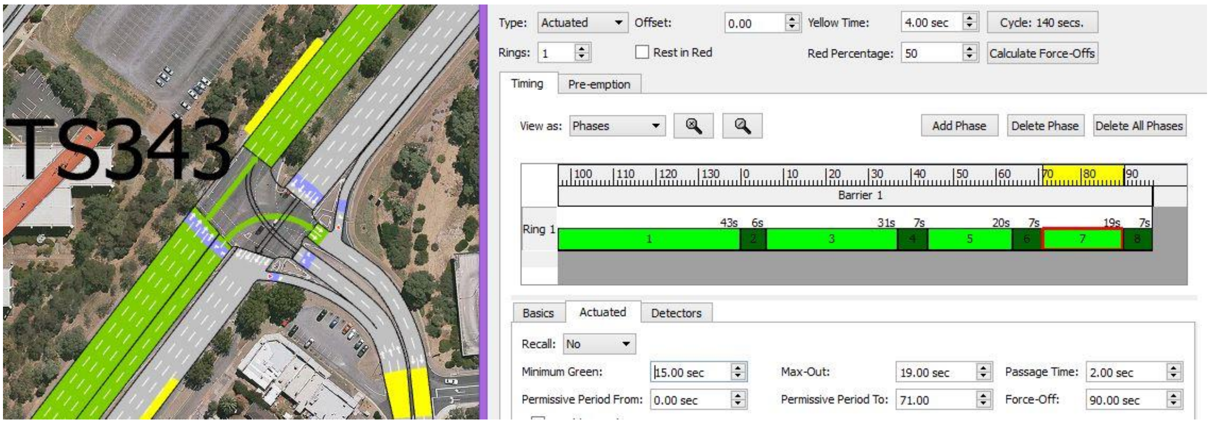


TS343 AM Phasing









OD matrix Input

Existing

1	2	3	4	5	6	7	8		Total
	4	14							18
102		25	183	177	188	949			1624
			38		300	573	354		1265
	396	294					11		701
159	100				644		151		1054
	59			574			54		687
396	1414	2369		293	247		833		5552
					158	141			299
657	1973	2702	221	1044	1537	1663	1403		11200

Future 2031

1	2	3	4	5	6	7	8	9	10	Total
	92	5	5	5	5	5	5		6	128
184		114	205	103	121	129	206		280	1342
			115	199	399	216	300		271	1500
20	517	508		1	1	1	2	305	3	1358
10	50	50			757		1	156		1024
				1071		155	5		440	1671
60	100	700		29	453		1073	1288		3703
10	20	20		10	10	56		68	150	344
10		100	120	100	260	79	100		1930	2699
69	544	1209						3340		5162
363	1323	2706	445	1518	2006	641	1692	5157	3080	18931

Appendix C : Economic Evaluation Reports(Mobility Simulator)

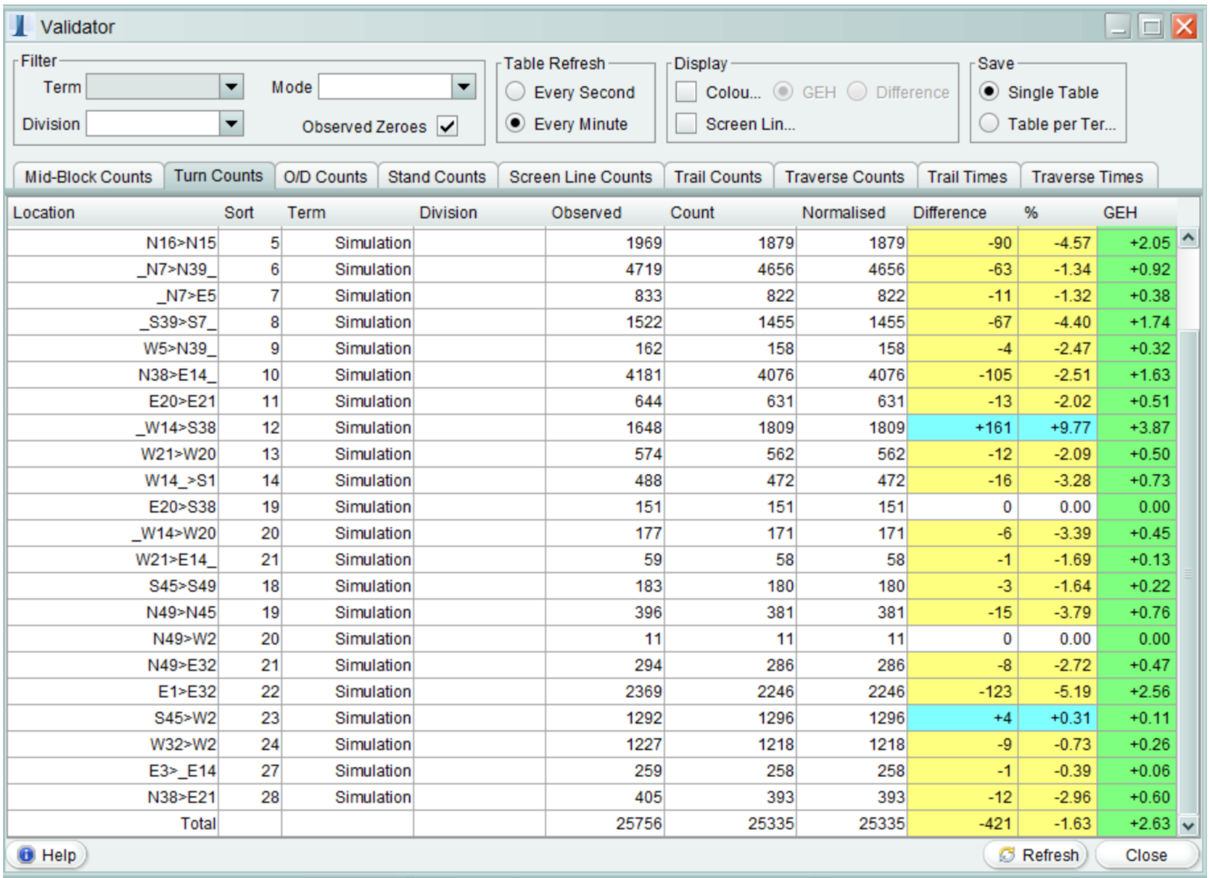
Title	Economic Evaluation Report										
Subtitle	Design Option / Date / Time										
Simulation file	C:/Users/Aman_2015_AM_V2.aza										
Model run at	Mon Oct 14 12:55:39 ACDT 2019										
Simulation date	25 / 06 / 2016				Last Clear:		07:30:00.000		Version:		6.00.006
Simulation duration	07:30 to 08:30				This Save:		08:30:00.000				
		Count	Distance	Time	Speed	Stops	Delay	Distance Cost	Time Cost	Stops Cost	Total Cost
			(km)	(h:m:s)	(km/h)		(h:m:s)	($)	($)	($)	($)
Complete Trips	Total	10732	13877.72	416.988	33.281	11966	238.334	3469.429	10424.711	1495.75	15389.89
	Mean		1.293	00:02:19		1.115	00:01:19	0.323	0.971	0.139	1.434
	Std Dev		0.607	00:00:58		0.722	00:00:42	0.152	0.406	0.090296	0.565
All Trips	Total	11200	14546.46	427.031	34.064	12639.573	244.34	3636.616	10675.77	1579.947	15892.332
	Mean		1.299	00:02:17		1.129	00:01:18	0.325	0.953	0.141	1.419
	Std Dev		0.606	00:00:59		0.726	00:00:43	0.152	0.415	0.090757	0.566
All (Normalised)	Total	1000	1298.791	38.128	34.064	1128.533	21.816	324.698	953.194	141.067	1418.958

Title	Economic Evaluation Report										
Subtitle	Design Option / Date / Time										
Simulation file	C:/Users/Aman_2031_DPTI_Tunnel_3lanesAM.aza										
Model run at	Mon Oct 14 13:01:02 ACDT 2019										
Simulation date	25 / 06 / 2016				Last Clear:		07:30:00.000		Version:		6.00.006
Duration	07:30 to 08:30				This Save:		08:30:00.000				
		Count	Distance	Time	Speed	Stops	Delay	Distance Cost	Time Cost	Stops Cost	Total Cost
			(km)	(h:m:s)	(km/h)		(h:m:s)	($)	($)	($)	($)
Complete Trips	Total	18085	28806.301	663.922	43.388	21216	328	7201.575	16598.061	2652	26451.636
	Mean		1.593	00:02:12		1.173	00:01:05	0.398	0.918	0.147	1.463
	Std Dev		0.82	00:01:07		1.138	00:00:57	0.205	0.47	0.142	0.668
All Trips	Total	18931	30325.151	687.83	44.088	22603.362	342.351	7581.288	17195.747	2825.42	27602.455
	Mean		1.602	00:02:10		1.194	00:01:05	0.4	0.908	0.149	1.458
	Std Dev		0.817	00:01:09		1.145	00:00:57	0.204	0.481	0.143	0.674
All (Normalised)	Total	1000	1601.878	36.334	44.088	1193.987	18.084	400.469	908.338	149.248	1458.056

Title	Economic Evaluation Report										
Subtitle	Design Option / Date / Time										
Simulation file	C:/Users/Aman_2031_Tunnel_4lanes_AM.aza										
Model run at	Mon Oct 14 13:07:24 ACDT 2019										
Simulation date	25 / 06 / 2016				Last Clear:		07:30:00.000		Version:		6.00.006
Duration	07:30 to 08:30				This Save:		08:30:00.000				
		Count	Distance	Time	Speed	Stops	Delay	Distance Cost	Time Cost	Stops Cost	Total Cost
			(km)	(h:m:s)	(km/h)		(h:m:s)	($)	($)	($)	($)
Complete Trips	Total	18206	29076.762	656.638	44.281	19515	317.849	7269.19	16415.942	2439.375	26124.507
	Mean		1.597	00:02:09		1.072	00:01:02	0.399	0.902	0.134	1.435
	Std Dev		0.82	00:01:07		1.143	00:00:57	0.205	0.471	0.143	0.66
All Trips	Total	18930	30324.716	673.233	45.043	20663.998	326.762	7581.179	16830.835	2583	26995.014
	Mean		1.602	00:02:08		1.092	00:01:02	0.4	0.889	0.136	1.426
	Std Dev		0.817	00:01:08		1.155	00:00:57	0.204	0.476	0.144	0.661
All (Normalised)	Total	1000	1601.94	35.564	45.043	1091.601	17.262	400.485	889.109	136.45	1426.044

Appendix D: Mobility Simulation

Validator turn counts result after simulation (Existing model)



Location	Sort	Term	Division	Observed	Count	Normalised	Difference	%	GEH
N16>N15	5	Simulation		1969	1879	1879	-90	-4.57	+2.05
_N7>N39_	6	Simulation		4719	4656	4656	-63	-1.34	+0.92
_N7>E5	7	Simulation		833	822	822	-11	-1.32	+0.38
_S39>S7_	8	Simulation		1522	1455	1455	-67	-4.40	+1.74
W5>N39_	9	Simulation		162	158	158	-4	-2.47	+0.32
N38>E14_	10	Simulation		4181	4076	4076	-105	-2.51	+1.63
E20>E21	11	Simulation		644	631	631	-13	-2.02	+0.51
_W14>S38	12	Simulation		1648	1809	1809	+161	+9.77	+3.87
W21>W20	13	Simulation		574	562	562	-12	-2.09	+0.50
W14_>S1	14	Simulation		488	472	472	-16	-3.28	+0.73
E20>S38	19	Simulation		151	151	151	0	0.00	0.00
_W14>W20	20	Simulation		177	171	171	-6	-3.39	+0.45
W21>E14_	21	Simulation		59	58	58	-1	-1.69	+0.13
S45>S49	18	Simulation		183	180	180	-3	-1.64	+0.22
N49>N45	19	Simulation		396	381	381	-15	-3.79	+0.76
N49>W2	20	Simulation		11	11	11	0	0.00	0.00
N49>E32	21	Simulation		294	286	286	-8	-2.72	+0.47
E1>E32	22	Simulation		2369	2246	2246	-123	-5.19	+2.56
S45>W2	23	Simulation		1292	1296	1296	+4	+0.31	+0.11
W32>W2	24	Simulation		1227	1218	1218	-9	-0.73	+0.26
E3>_E14	27	Simulation		259	258	258	-1	-0.39	+0.06
N38>E21	28	Simulation		405	393	393	-12	-2.96	+0.60
Total				25756	25335	25335	-421	-1.63	+2.63

DPTI 3 lane Turn count result

Location	Sort	Term	Division	Observed	Count	Normalised	Difference	%	GEH
N16>N15	5	Simulation		1231	1174	1174	-57	-4.63	+1.64
_N7>N39_	6	Simulation		2630	2604	2604	-26	-0.99	+0.51
_N7>E5	7	Simulation		1073	1056	1056	-17	-1.58	+0.52
_S39>S7_	8	Simulation		1025	984	984	-41	-4.00	+1.29
W5>N39_	9	Simulation		138	138	138	0	0.00	0.00
N38>E14_	10	Simulation		2294	2223	2223	-71	-3.10	+1.49
E20>E21	11	Simulation		757	753	753	-4	-0.53	+0.15
_W14>S38	12	Simulation		1072	996	996	-76	-7.09	+2.36
W21>W20	13	Simulation		1071	1066	1066	-5	-0.47	+0.15
W14_>S1	14	Simulation		786	753	753	-33	-4.20	+1.19
E20>S38	19	Simulation		1	1	1	0	0.00	0.00
_W14>W20	20	Simulation		408	374	374	-34	-8.33	+1.72
W21>E14_	21	Simulation		0	0	0	0	0.00	0.00
S45>S49	18	Simulation		330	324	324	-6	-1.82	+0.33
N49>N45	19	Simulation		842	800	800	-42	-4.99	+1.47
N49>W2	20	Simulation		8	8	8	0	0.00	0.00
N49>E32	21	Simulation		508	492	492	-16	-3.15	+0.72
E1>E32	22	Simulation		1979	1884	1884	-95	-4.80	+2.16
S45>W2	23	Simulation		1455	1381	1381	-74	-5.09	+1.97
W32>W2	24	Simulation		1385	1374	1374	-11	-0.79	+0.30
E3>_E14	27	Simulation		266	263	263	-3	-1.13	+0.18
N38>E21	28	Simulation		463	456	456	-7	-1.51	+0.33
Total				22099	21387	21387	-712	-3.22	+4.83

Mid-Block Count result for future DPTI 3 lane

Location	Sort	Term	Division	Observed	Count	Normalised	Difference	%	GEH
S5	2	Simulation		1930	1915	1915	-15	-0.78	+0.34
S11	3	Simulation		560	544	544	-16	-2.86	+0.68
S4	4	Simulation		590	575	575	-15	-2.54	+0.62
N3	5	Simulation		1820	1776	1776	-44	-2.42	+1.04
_E2	6	Simulation		3340	3301	3301	-39	-1.17	+0.68
Total				8240	8111	8111	-129	-1.57	+1.43