OAKLANDS CROSSING GRADE SEPARATION EVALUATION

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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

Oaklands Crossing is located 1 kilometre away from Westfield Marion shopping centre. The intersection is between Morphett Road, Diagonal Road and Seaford Railway. There are 42,000 vehicles passing through this intersection every day. This report will briefly introduce the background of Oaklands Crossing, include location and local business. Then the purpose of this project will be interpreted, followed by literature review with existing issues in this intersection, including traffic business and safety concerns. The grade separation design methodology for other similar situations and for Oaklands Crossing will be mentioned in the literature review as well. The types of grade separation will be reviewed, including railway underpass and overpass road, road underpass and overpass railway. Then the software others used for Nano-scale analysis to do grade separation or similar situation will be reviewed hence to related to methodology of this project.

The methodology of this project then will be introduced and detailed steps will be listed, including data collection and analysis, SIDRA modelling and analysis, Infraworks modelling and analysis and evaluation. The detail of collecting data, issues during data collection, detailed data analysis and calculation will be interpreted. Two software packages used in this project, SIDRA and Infraworks, will be briefly introduced and explained why they were selected to be used. All steps of model building and analysis process will be explained. There are 4 different scenarios in this report including DPTI design, additional lane on North Morphett Road, additional lane on Diagonal Road and Unsignalized intersection design, they will be listed and the reason for the different designs explained. Then in discussion, all scenarios will be compared and all results will be discussed and evaluated in order to present ~~hence~~ the best economic and environmental scenario to be selected in the conclusion section. Following the conclusion of this project. All the help from supervisor and other teachers will be mentioned in the acknowledgement.

Contents

1. Introduction

The Oaklands Crossing is located at the intersection of Morphett Road, Diagonal Road and Seaford Crossing. There are 42,000 vehicles going through this intersection every day. This causes huge traffic delays at the peak time, lots of accidents happen and negatively impacts on local business. To address these issues, grade separation is suggested and two software packages, SIDRA and Infraworks are used to build models, for analysis and to evaluate.

The objective of this paper is to find the most economic and environmentally appropriate future grade separation design to reduce traffic delay time, enhance local business and avoid safety hazards.

This paper will review the background of Oaklands Crossing, existing issues, grade separation methodology in similar situations, existing design plans for Oaklands Crossing in the literature review. Then in methodology, data collection and analysis will be explained, followed by building and analysing models on SIDRA and Infraworks. In discussion, four different scenario will be compared and evaluated in both environmental and economic directions, the limitation of the model and scenario will also be briefly mentioned. In the conclusion section, the most economic and environmentally appropriate model will be selected and the impact of the model will be discussed. Followed by acknowledgment to thank my supervisor and others involved in this project.

2. Literature Review

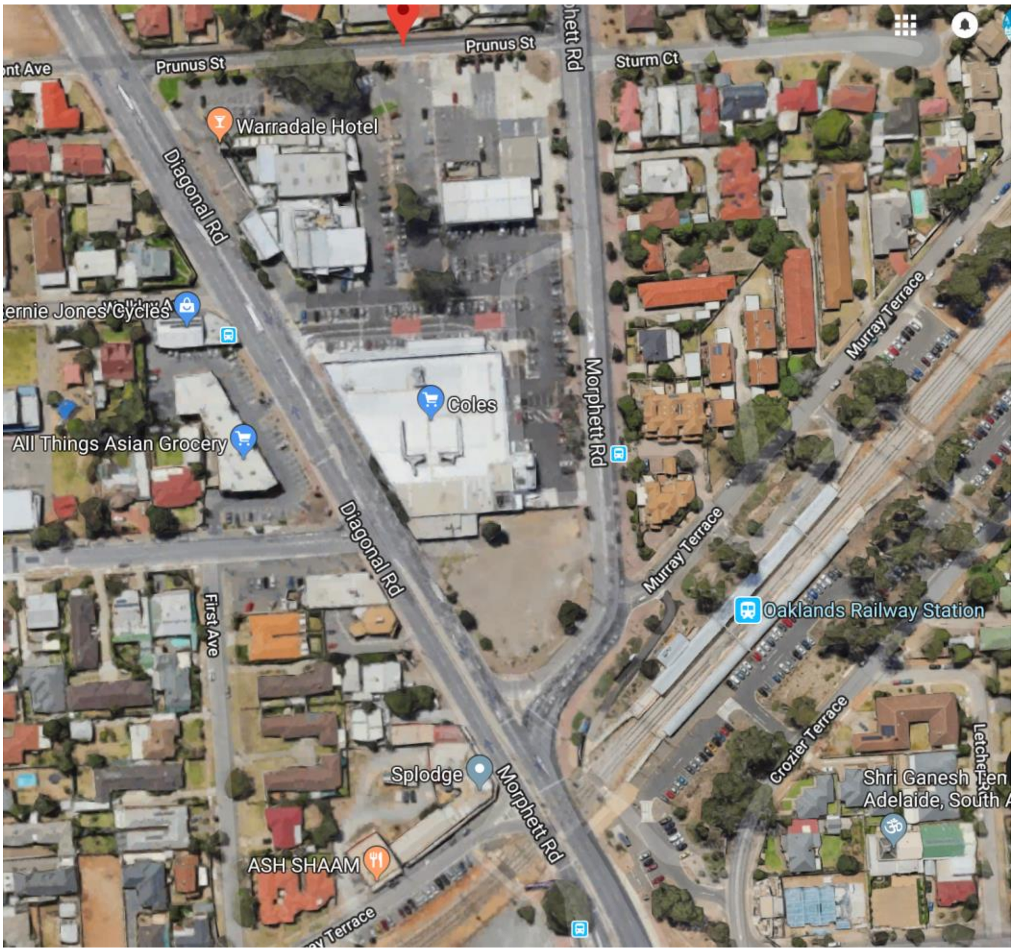
2.1 Background

In Adelaide, train travel is playing a significant role. There are 12 railways, Seaford railway is one of them and Oaklands Crossing is one stop on the Seaford railway line. Oaklands Crossing is 12.8 km from the city of Adelaide, it is on the Seaford railway line near the intersection of Morphett Road and Diagonal Road. The current Oaklands Crossing has traffic delays because of the operation of the boom gates for trains. This operation has limited traffic movement, it also puts pressure onto nearby facilities, such as Marion shopping centre and Leisure Centre. Marion shopping centre is located in Oaklands park and it is the largest shopping centre in South Australia. There are approximately 340 stores, which means there is giant amount of stuff and customers go in and out every day. The Oaklands Crossing is only 1 km away from Marion shopping centre so the traffic volume on Diagonal Road and Morphett Road is huge. There are about 42,000 vehicles pass the Oaklands Crossing every day, approximate 33,200 vehicles from Diagonal Road and 8,800 vehicles from Morphett Road. In the Concept planning report, it mentioned for northbound, in the AM peak hour there were 2100 vehicles per hour, in the PM peak hour there were 1590 vehicles per hour; for southbound, in the AM peak hour there were 1580 vehicles per hour, in the PM peak hour there were 2270 vehicles per hour. For the train crossing, in the AM peak hour there are 12 trains cross in both ways, in the PM peak hour there are 13 trains cross in both ways.

2.2 Existing Issues

2.2.1 Delay Issues

Due to increasing numbers of cars and growing population, delays in Oaklands crossing have increased significantly over the years. A recent study (DTEI 2011) has mentioned that the morning peak is quite so the delay is regular. From 7:00 to 9:30 am the railway closure time is 25 minutes. The evening peak has much bigger delay. From 3:00 to 7:00 pm the railway closure time is 45 minutes. During the peak hour, the southbound road capacity reduced 40 – 50 % because of pedestrian walk across, railway closure happened at the same time. Marion shopping centre is only 1 km away from Oaklands crossing. On Thursdays the Marion shopping centre opens until 9:00 pm, that means lots of people will come for late night shopping and the volume of vehicles will increase a lot on Thursday night. This is the worst day of the week for Oaklands crossing. The queues on Diagonal Road are quite long and it is shorter on Morphett Road. Travel time surveys show the crossing time for Diagonal Road to railway crossing needs 4 minutes, for Morphett Road to railway crossing needs 8 minutes. There is a Coles and the Warradale Hotel between Morphett Road and Diagonal Road as shown in Figure 1.



(Google Map 2018)

Figure 1. Coles and Warradale Hotel between Morphett Road and Diagonal Road

For Coles, the business time is from 6 am to 9 pm from Monday to Friday. For Warradale Hotel, the business time is from 10 am to 4 am. The Warradale Hotel will have less effect on Morphett Road and Diagonal Road than Coles. As shown in Figure 1, there is a carpark for Coles staff and costumers, there will be many customers in and out the carpark and go on Morphett Road and Diagonal Road. Therefore, the delay in the evening peak is a significant issue.

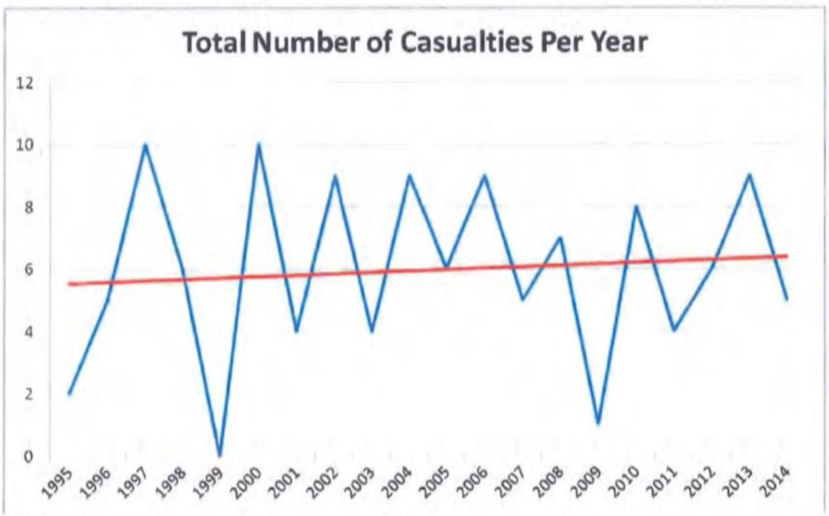
The significant delay have also influenced local residents. Wingard (2017) outlines that a lady called Mary Nixon has delay issue in the Oaklands Crossing when she finished visiting her husband in Allambie Nursing Home and coming back home by taxi. The distance from her house to nursing home is only 2 km and it costs her $65 for taxi fee. The lady is worried she cannot afford to buy food and visit her husband again until her next pension cheque. The delay issue not only impact the traffic on Oaklands Crossing, it also has negative impact on local residents.

2.2.2 Business Concerns

The delays also cause the local business problems. Kara (2013) mentioned that a lady called Vivian Lomman had a gym on Diagonal Road at Warradale. Because of the traffic delay, it is really hard for customers to park in and get out of the carpark in front of her gym. In last year, she lost about 20 customers. She is considering sell her business because of the Oakland Crossing issues. She mentioned if customers coming from Seacombe Heights, they can wait in Oaklands Crossing for 20 to 30 minutes when train is crossing the intersection. Another article wrote by Eleanor (2016) mentioned the business owner Peter Ramsey also think the situation is getting worse and worse. He thought 3 pm is the worst time of the day. The general manger of Warradale Hotel consider the late afternoon traffic had a bad influence on their hotel bottle shop.

2.2.3 Safety Issues

A risky road survey has been done by RAA (RAA 2017). The purpose of this survey was to find out similar road safety issues for different roads and intersections. All the roads are nominated from online and paper submission. There are 2931 nominations in total. Top 10 most nominated roads and intersections are listed, the top 1 intersection is Oaklands Crossing. The reason for the 'most' nomination is because the layout is confusing, the crossing or tunning opportunity is insufficient, the traffic signals are inadequate and surface is uneven and undulated. There are 101 risky road nominations received in this intersection, there were 13 casualty crashes happened between 2011 and 2015 and they were all major injury crashes. South Australia Police reported 100 collisions at the Oaklands Crossing and two crashes had pedestrians involved. Figure 2 shows the total number of casualties per year from 1995 to 2014 in (Transport Service Division 2015).



(Source: Transport Service Division 2015, p. 11)

Figure 2. Diagonal Road and Morphett Road, Total Number of Casualties Per Year

Figure 2 indicates the decrease trend of total number of crashes per year, Figure 3 indicates the slightly increase trend of total number of casualties per year. This shows the Oaklands Crossing is a major safety hazard.

The safety issues do not only exist at Oaklands Crossing, in other railway and road crossing intersections, accidents can also happen. On the afternoon of 24 October 2002, passenger train 5AL8 crashed with a light vehicle and a bus (Australian Transport Safety Bureau 2002, pp. 4-10). As the result, four passengers were killed and 26 injured. The small car and the bus were destroyed. Another two vehicles were slightly damaged. The small car and the bus were stuck on the railway because of other vehicles, the driver of the small car managed to jump out of the vehicles and run away from the railway but the passengers on the bus could not run away. The train driver saw the situation and sound a warning on the horn and used emergency brake. However, the sight distance is 250 meters and the train could not stop in time. The collision happened because the small car and the bus drove through the crossing when they were unable to do it due to Australian Road Rules. Also, the road traffic signals at the Park terrace intersection did not work as designed. The traffic on the western side of the railway was stopped and this caused the vehicle to be stopped over the level crossing. The bus driver, a student and another two passengers were killed and 26 people injured. Two passengers on the train were slightly injured including one driver. To prevent similar accidents, there are few points need to be considered: the road design, train level crossing warning system, the width of level crossing.

To manage the railway crossing safety, the Australian Level Crossing Assessment Model (ALCAM) is used for identifying risks at the level crossing and helping improve safety (ALCAM 2016, pp. 9-16). The ALCAM can be used to determine the expect result for accident, it can determine the probability of an accident happening. It can show where the highest risk exists. To improve the road safety, the crossing safety strategy is reviewed (DPTI N.D). There are few treatment options to be considered. It includes advance the warning signs, improvement for queuing, traffic signal coordination, upgrade flashing lights or boom gates, use high intensity lights, improve the sight line improvements, reduce the speed limits from road to railway or closure the crossing. The crossing safety strategies are grade separate railway and road, assess high risk level crossing, use CCTV cameras to monitor the traffic situation.

2.3 Grade Separation Design

Before design Oaklands Crossing, some other grade separation design will be reviewed. The methodology of grade separation, positive and negative impact will be analysed, hence a suitable design can be created for Oaklands Crossing.

2.3.1 Site Visit

To decide what design will be suitable the level crossing, site visit is required. The site visit will give a practical situation, it may contain some issues that is not shown in report. The site visit include lane configurations, lane width, traffic signals, railway, sight distance, horizontal and vertical alignment for the road, local business, pedestrians and bicycles.

The Jackrabbit lane is in the City of Belgrade and it is a part of Montana Rail Grade Separation Project (Montana Department of Transportation 2016) in the USA. The level crossing has more than 16,400 vehicles of daily volume. There are 28 trains cross this lane every day. From the site visit there are two lanes for each direction and a right turn lane in northbound. There is a traffic signal at the intersection of Gallatin Farmers, W. Northern Pacific Avenue/Arden Drive, and W. Central Avenue. The elevation of Jackrabbit lane is lower than the elevation of railway, hence the Jackrabbit lane underpass the railway requires less changes than other grade separation options. There are few business around this area which include an automobile dealership at the east of crossing, a bank at the north of main street. Some other businesses are located on the Gallatin Farmers Ave.

Another example is the Rengstorff Avenue Grade Separation Design (ALTA 2014). It is located between Rengstorff Avenue, Crisanto Avenue and Central Expressway in the USA. There are few businesses in this area which include a Mi Pueblo food centre, a shell gas station, a Walgreens shopping centre. On Leland Avenue, there are some on street parking place, this could be improved in future design.

From the site visit, when pedestrians and bicycles want to cross Rengstorff Avenue, from North Park Apartments to Walgreens shopping centre, the closest way is at the South of Central Expressway, lots of pedestrians and bicycles choose to cross Rengstorff Avenue directly and this increase the risk of safety. Another pathway for pedestrians and bicycles is located on Leland Avenue, cross the south of Central Expressway. By site observation, the amount of people who go to Mi Pueblo Food Centre by walking is more than driving. The city of mountain view (City of mountain view 2014, pp. 9-12) pointed the pathway at Leland

Avenue has more demand than the pathway at Stanford Avenue.

An important infrastructure in South Australia that mentioned by AECOM (2016) is the Torrens Rail Junction Project. The Torrens Junction is between north of the River Torrens and west of North Adelaide. The train lines cross each other and creates safety issues. It also limited the capacity, length and travel speed of trains. Therefore, it is necessary to separate the grade of two train lines and hence reduce traffic delay and improve safety.

By site visiting, relevant people will have better understanding of the traffic situation and how this impacts the life of local residents. There will be more practical considerations for engineers to improve their designs.

2.3.2 Overpass or Underpass Considerations

For level crossing grade separation, there are mainly two solutions: overpass and underpass. To design an overpass or underpass solution, geometry of road and railway, impact to local environment, road and railway profile need to be considered. As mentioned in Montana Rail Grade Separation Study report (Montana Department of Transportation 2016, pp. 2-3 – 3-4), an overpass design need to extend approximately 180 meters for both direction, the height is approximately 9 meters. An underpass design need to about 129 meters for both direction, the depth is about 6 meters. The overpass in the report means the road overpass the railway and the underpass means the road underpass the railway. The study not only considered the engineering solution, but also considered the problem that cannot be solved by an engineering solution, such as historical buildings around or big impact on local business. This grade separation study did not consider railway overpass or underpass the road due to historical function of the railway.

For Frankston city level crossing removal (Frankston City Council 2016, p.12), there are few considerations. The report used a Multi Criteria Analysis (MCA) to assess the crossing options. The MCA table is shown in Table 1.

Table 1. Multi-Criteria Analysis

Group	Outcomes	Weight
Economic	Create suitable development opportunities	10.0%
Access	Better, safer access for pedestrians and cyclists	30.0%
	Better, safer road access	
	Supports strategic transport networks and improved transport efficiency	
Social	Enhanced local land use	20.0%
	Enhanced community connectivity	
	Improved personal safety	
Amenity	Visual Amenity	30.0%
	Noise impacts	
Environmental	Improved local natural environment	10.0%
	Quality open space and urban Design	

(Source: Frankston City Council 2016)

The table indicates each criteria, outcomes and their weight. There are 4 different grade separation types, which are road under railway, road over railway, railway under road and railway over road. The access and amenity have the highest weight, which is 30%. This indicates that safety for pedestrians, cyclists and drivers are considered the most, same as visual amenity and noise impact. The lowest weight is economic and environmental consideration. Therefore, the purpose is to make road users and pedestrians safe first, then consider the design in economic and environmental way. Based on these criteria, each option has been considered and assessed carefully and the outcome is shown in Table 2. As shown in Table 2, the road over rail has moderately positive in access, which means by using this option, it will increase safety of the pedestrians and bicycles and support the traffic network. However, this option has highly negative in social and amenity, it will decrease the community connectivity, personal safety will be a problem, poor visual amenity and very noisy. For the road under rail option, it has moderately positive on access and highly negative on social, which is same as road over rail. Highly positive on amenity, which means the visual and noise amenity improved. For rail over road, it has highly negative on amenity. For rail under road, there is no highly negative, just moderately negative on environment. Based on the Table 1 and Table 2, it is very clear to see that rail under road is the best option out of 4 grade separation options.

Table 2. Multi-Criteria Analysis for Seaford Road

SEAFORD	Road Over Rail	Road Under Rail	Rail Over Road	Rail Under Road
ECONOMIC	Neutral	Neutral	Neutral	Neutral
ACCESS	Moderately Positive	Moderately Positive	Highly Positive	Moderately Positive
SOCIAL	Highly Negative	Highly Negative	Mildly Positive	Neutral
AMENITY	Highly Negative	Highly Positive	Highly Negative	Moderately Positive
ENVIRONMENTAL	Neutral	Mildly Negative	Mildly Positive	Moderately Negative

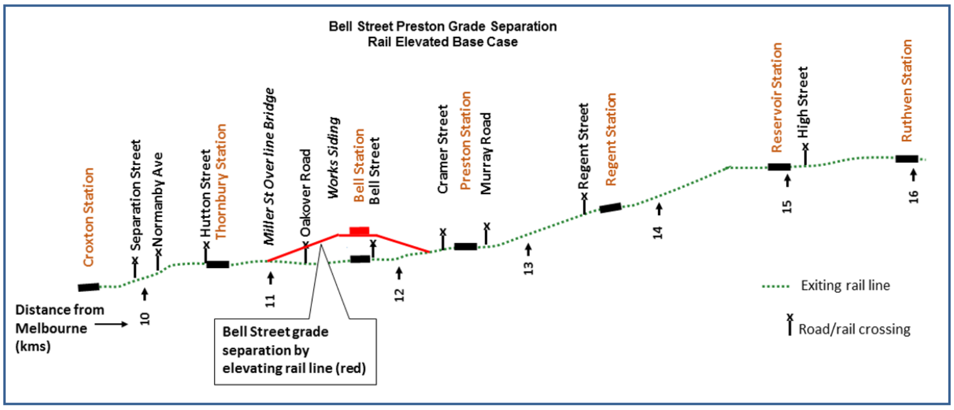
(Frankston City Council 2016, p.13)

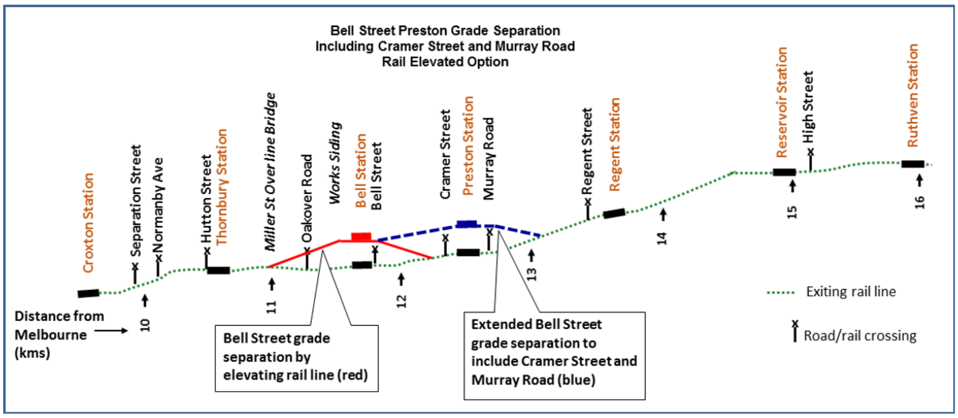
A similar grade separation criteria is used for GO Road/Rail grade separations (John & James 2016). There are totally 185 railway crossing on the GO system. The road and rail volume, existing conditions, geometry, community impacts, cost and alternatives such as road closures are considered. They identified four main criteria: usage and existing conditions, operations, social environmental and cost. Operations include service reliability and special road users. The weight for usage is 60%, for operations is 20%, social environmental and cost are 10% each. The weight of criteria is different to the one in Frankston Report due to different situations and each operator has their own objectives.

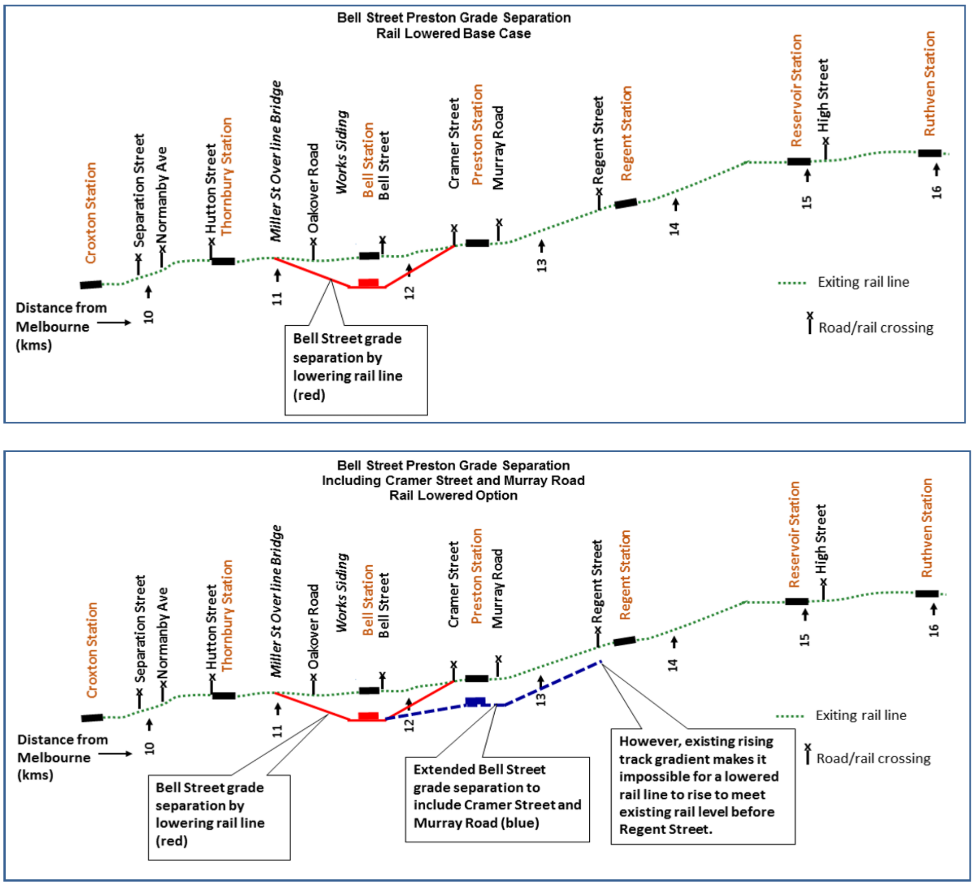
Another way to consider overpass and underpass options is argued by Raylink Consulting, John Hearsh Consulting and Rail Asset Partnership (2017). The example is located within Bell Street, the grade separation is from Oakover Road to Murray Road.

To consider whether use overpass or underpass, the report list different scenarios with longitudinal sections. By showing longitudinal sections, it becomes very clear to see each option. The road overpass railway or road underpass railway is not considered due to council's urban renewal objectives. The four scenarios are shown in Figure 3. The top left shows the railway overpass the road, Bell Station will be reconstructed and Bell Street will not be changed. The advantages of this option include less cost than railway underpass road, railway barrier removed, less damage during construction and less impact on local traffic. The disadvantage is it has more visual impact compare with railway underpass road. Top right shows the extension of overpass railway. This option include both Cramer Street and Murray

Road for grade separation. The extended railway can connect with existing railway between Murray Road and Regent Street. Compared with other options, this option has minimum cost. The bottom left shows the railway underpass the road, the railway will be under Oakover Road. This option is more expensive than railway overpass road but it reduced the visual impact. Bottom right shows the railway underpass with extension. The railway will go underpass Bell Street, Cramer Street and Murray Street. The connection between the underpass railway and existing railway is very difficult. The bottom right option is not considered due to a massive cost estimation. Based on similar criteria assessment, the railway overpass road with extension is selected as the best scenario. Considering the geological and hydrological risk, such as flood, this option has the minimum risk.







(Raylink Consulting, John Hearsh Consulting and Rail Asset Partnership 2017, pp. 17-22)

Figure 3. Four Scenarios for Bell Street

Mainroads (2015) in Western Australia mentioned that to decide whether use grade separation option or not, need to make sure the current exposure level is more than 5 million. To calculate the exposure level, there are three factors needed, which are weighted conflict (C_W), Heavy vehicle factor (H_v) and Vehicle delay factor (D_v). To calculate weighted conflict, the average annual daily traffic, average number of train movements per week, vehicle speeds (in km/h) and maximum train speed (in km/h) are used. Heavy vehicle factor needs the percentage of heavy vehicles, road grade factor. Vehicle delay factor requires longest train length and maximum speed of the longest train.

2.3.3 Grade Separation Design

After deciding which type of grade separation to be used, next step is detailed design. A very detailed design is shown by city of mountain view (ALTA 2014) by using railway overpass option. The design concept is based on pedestrian and bicycle pathway, railway overpass features and urban design. The complete streets design put a planted median in Rengstorff Avenue, railway overpass road, pedestrian and bicycles overpass the road from Crisanto

Avenue to Mi Pueblo.

Road Safety is a crucial part in design. There are some additional controls are mentioned In Railway Crossing Control in Western Australia report (Mainroads 2015) to enhance the road safety, which are additional overtaking lanes and seal lengths, CCTV, inductions for heavy vehicle drivers, radio messaging for heavy vehicles, use GPS tracking to control vehicles. There are some more considerations, such as consider material falling from another level and safe clearance traffic for railway underpass the road.

2.3.4 Cost Estimation

To find a suitable design for project, cost estimation is required. To estimate the value and benefit of a project, the Benefit-Cost Analysis (BCA) is used by Montana Department of Transportation (2016, Appendix C). There are five areas in this model, which are travel time impacts, safety impacts, vehicle operation cost impacts, environmental impacts and pavement damage impacts. For travel time impacts, the average train length, speed and lead and leg time can be used to calculate the gate closure time per train. The number of trains per day will give the internal arrival time of trains. The probability of the gate being closed can be determined, with the number of vehicles per year, hence vehicle delay can be determined, with the average number of people per vehicle and value of time, the travel time benefit can be estimated. To work out the travel time cost, distance of detour, average vehicle speed, annual average delay traffic growth rate and at the closed crossing is used. For the safety cost, number of train related accident death and injuries, average cost per accident injury, value of human life, average property damage are used to calculate reduced accident cost. The detour accident cost is based on distance of detour, average annual delay traffic at closed crossing, accident rate on the detour road etc. Vehicle operation benefit is depending on oil and fuel consumption, cost is depending on fuel and oil price, detour distance etc. Environmental impact is based on emission cost. Pavement damage is based on pavement damage cost and it does not have benefit. The benefit of this project worth $6.40 million in present value term while the total cost is $27.78 million.

Another example of cost estimation is the Preston grade separation project (Raylink Consulting, John Hearsh Consulting & Rail Asset Partnership 2017). In this project, they considered earthworks, track work, rail electrification, stations, bridges, retaining walls, parking, roads, utility serves, rail system shutdowns, pedestrian crossing access, land purchase, traffic management etc. The risk cost is 25% of sub total cost. The contractor margin, design cost and level crossing authority costs need to be considered.

The benefit cost analyses is also used for Springvale rail grade separation project (Greater Dandenong 2007). To value the benefits, they considered the vehicle operation cost savings, urban consolidation benefits, amenity, business efficiency, reduced level crossing crashes, noise reduction, delay savings and emission reduction.

2.3.5 Grade Separation Evaluation

The most important part is to assess the model in economic and environment impact terms. Highways (N.D.) mentioned the methodology to evaluate economic and environment impact on grade separation. For economic assessment, the future model should have less travel time, less accidents and less vehicle operating costs. To assess the environment impact, air quality, landscape, noise and vibration, road drainage need to be considered. Washington State Department of Transportation (2012) mentioned visual quality, public services and utilities are part of environment impact as well.

An example is Bridgeport way SW in Lakewood (Washington State Department of Transportation 2012). The existing railway cross the Bridgeport Way SW road and the grade separation option roadway overpass railway. The future option is evaluated compare with existing situation. For transportation, the grade separation will reduce the traffic delay. For noise and vibration, the situation is similar to existing conditions. For visual quality, the roadway overpass railway will be bridge structure in area. The expectation on local business is unknown. For public services, short term bridge construction may cause minor delays but after construction it will be of no impact. For air quality, there are no measurable effects. The estimate cost range is from $53.6 to $93.9 million. Based on these evaluations, this project can be identified as environmental and economic success.

2.4 Designing Plan on Oaklands Crossing

For Oaklands Crossing, because of the huge traffic delay, it is not safe for drivers and pedestrians and business concerns, grade separation is suggested to be used to solve these issues. Which option is best for this project and how to do the traffic modelling, pedestrians and bicycles pathway need to be considered.

2.4.1 Grade Separation Options

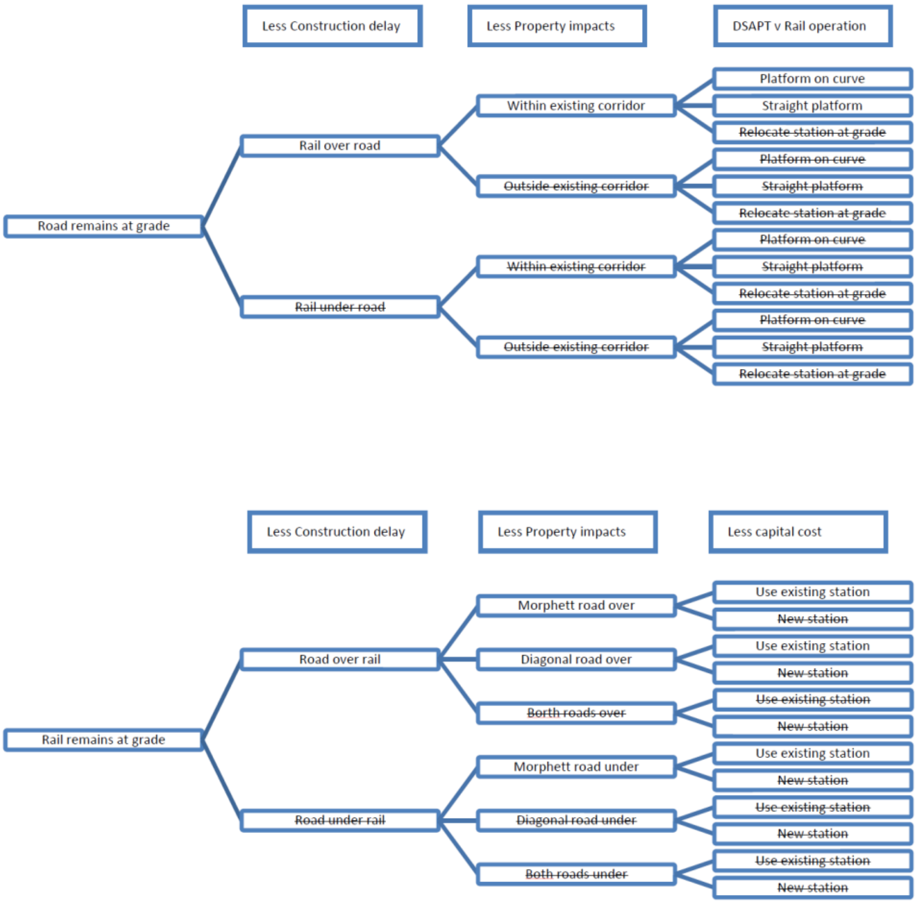
Transport Service Division (2015) mentioned a few options, which include:

1. road overpass and railway overpass from South Morphett Road to North Diagonal Road,

2. road overpass and railway overpass from North Morphett Road to South Diagonal Road,
3. road overpass and railway overpass from North Diagonal Road to South Diagonal Road,
4. road overpass and railway overpass from North Morphett Road to South Morphett Road.

There are few interim solutions as well, which include upgrade Prunus Street, make railway crossing wider and provide two right turn lanes for North Morphett Road, modification to crossing closure time, make Morphett Road, Diagonal Road and Prunus Road as a triangle clockwise one-way road and the function of this triangle is like roundabout, provide three through lanes on Diagonal Road.

DPTI (2012) listed Four options. For rail over road option, the design is to construct an elevated railway overpass the road, extending 600 m to the East and West. The Warradale Station needs to be removed. For rail under road option, this option consists of a railway underpass the road, extending 500 meters to the East and West. The road overpass railway should extend 200 meters to the North and South. The wide of the bridge should be seven lanes. The span is about 30 meters. The road under rail extend 200 meters to the North and South of the railway. The intersection between Morphett Road and Diagonal Road is closed. To decide which option is used, the key objectives need to be achieved by preferred options. The preferred option is shown in Figure 4. First decision is based on less construction delay and the rail over road is chosen. Then need to consider less property impacts, within existing corridor and diagonal road under is chosen. For less capital cost, best solution is using existing station. For rail operation, the curved platform or straight platform is considered.



(DPTI 2012, ‘Oaklands Park Grade Separation Planning Study’, p. 39)

Figure 4. Grade Separation Options

In the Oakland Park Grade Separation Feasibility Study report (DPC Engineering 2017), the best designs are selected by using red light, green light evaluation in 5 areas, environmental, transportation, structural, services, urban design and community consultation. Four options are railway overpass, railway underpass, road overpass and road underpass. In the environmental section, the existing environmental conditions, site contamination then, air quality, hydrology and water quality, noise and vibration and tree impact are considered. For transportation section, traffic management, pedestrians and bicycles access, public transport access, business concern, local street concern, land acquisition and future development are considered. The services are done by disturbance, resourcing, complexity, services relocation, risk and cost. For urban design, the current urban design evaluation, 30 plan for greater Adelaide, heritage, impact on community, security and crime prevention, local access impacts are reviewed. The result of red light, green light evaluation is shown in Table 3. This results indicates the rail over is the best solution.

Table 3. Red light, green light evaluation for Oakland Park Grade Separation

		Transport	Structures	Geotechnical	Services	Urban Planning	Environmental
Rail Over	Option 1	1	1	1	1	1	1
Road Over	Option 2	0	1	1	1	1	1
Rail Under	Option 3	1	0	0	0	0	0
Road Under	Option 4	0	0	0	0	0	0

(Source: DPC Engineering 2017, 'Oakland Park Grade Separation Feasibility Study')

As mentioned on Department of Planning, Transport and Infrastructure official website, railway will go underpass road due to cost effective and time efficient. This option will have less noise and visual amenity impact on local residents.

2.4.2 Traffic Modelling

To make model for current and future, SIDRA is used for traffic modelling in the Oaklands Park Road Capacity Improvements Traffic Analysis (DPEI 2011). This software is used to model the Morphett Road and Diagonal Road intersection north of the level crossing. There are three options for the North Morphett Road and four options for the South Morphett Road. For North Morphett Road, option 1 has degree of saturation over 1 and long queues, option 3 is similar, hence option 2 is better than others. For South Morphett Road, option 2 is preferred due to less delays, better level of serves and less degree of saturation.

Because SIDRA cannot find the traffic impact from the intersection nearby, hence AIMSUN analysis is used for further traffic modelling. The AIMSUN modelling gave peak time and average delays and assess the future performance.

As mentioned on Project Update (PTP Alliance 2018), a left turn from Morphett Road to Railway Terrace will be add in only traffic change. There will be two right turn lanes on the North of Morphett Road, right turn from Morphett Road to Murray Terrace will be removed.

2.4.3 Pedestrians and Bicycles Pathway

The pathway for pedestrians and bicycles needs to be considered. The Oaklands Park Grade Separation Planning Study (DPTI 2012) shows the design for pedestrians and bicycles pathway must be guided by design decisions. Consideration of the safety for pedestrians and bicycles, the corridor to rail station is an important part. It will make more people use the station if it has good accessibility. The pedestrian and bicycle should have their own lane on grade separation crossing. For disabled people, wheel chair access should be considered as well.

By reviewing the project upgrade (PTP Alliance 2018), the pedestrian crossing on Diagonal Road is going to relocate to new Dunrobin Road traffic signals, an additional pedestrian crossing is added on Diagonal Road on the north of railway line, the pedestrian crossing between Carlton Road and Johnstone Road is removed and will be changed to pedestrian and bicycles pathway overpass the bridge.

2.5 The software others used for similar issues

As the technology developed, there are more and more powerful software for traffic analysis. High accuracy models can significant help people analyse and evaluate different traffic situations, such as road infrastructure elements, buildings around, they can also be used for traffic flow analyse. Micro simulation model is estimate the impact of traffic change by simulating the individual vehicle behaviour, the traffic change can be traffic flow change or physical environment change (Arliansyah and Bawono 2014).

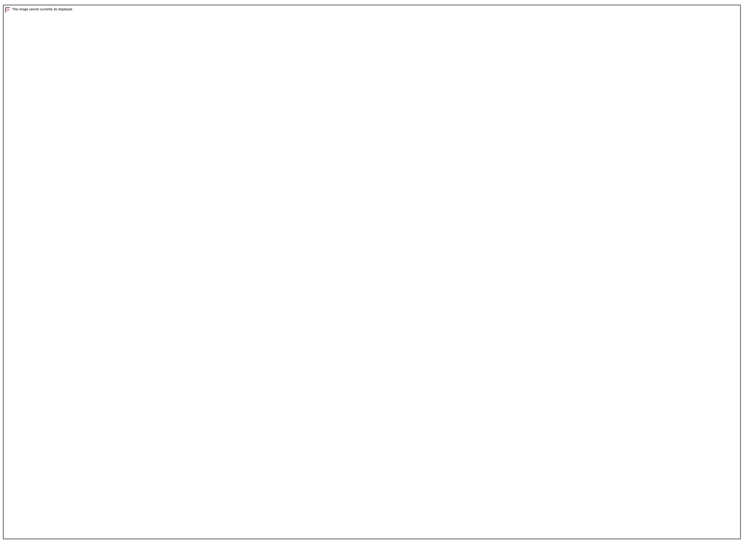
Infraworks 360 is one of these software programs. It is used in a case study in Gothenburg for building models and simulating traffic (Samantha & Emelie 2017). This study area has 2 main roads and 4 intersections. Infraworks can setup the road network, non-signalised and signalised intersections, traffic analyse, vehicle demand and simulation output such as departures, drive distance, drive time, delay, maximum queues etc.

To setup the model, first step is to collect data. The volume of light vehicles, heavy vehicles, buses is collected. Then use Infraworks 360 to setup road network. The model can be set up by import elevation, road layers and buildings in model builder, then delete all imported roads and manually rebuilt new road network.

After the model is built, then the calibration is managed. Simulation will run and check is the model built correct or not. To make the vehicle behaviour more realistic, it can check if and how every change will affect the vehicle behaviour. If there is no improvement after changes, it does not mean the parameters does not affect result, it means they did not improve the issue in visual.

The simulation output then can be exported in Microsoft Excel, the data will have the information for whole road network, such as total travel time, total amount of vehicles, number of stops and average speed. The delay and queue for each intersection can be obtained.

Using 3D models can also improve road safety (Eliseev, Tomchinskaya, Lipenkov & Blinov 2016). The road traffic accident can be visualised by simulate on Infraworks. It can show where the driver's blind point exists, vehicle movement in a complex terrain. Figure 5 shows an example of intersection between Gagarin Ave and Beketov St. In this case, this intersection has some safety hazard. When vehicle goes in d2 direction, a collision may happen with the vehicle in d3 direction.



(Eliseev, Tomchinskaya, Lipenkov & Blinov 2016,'Using 3D-modelling Technologies to Increase Road Safety')

Figure 5. Traffic Diagram on the Gagarin Avenue and Beketov Street crossing

Arliansyah and Bawono (2014) studied the grade separation performance by using a micro simulation program. The study area is at the intersection of Palembang City. The micro simulation program used is called VISSIM 8.00 Program. Data collection and modelling traffic conditions is including in this program. For data collection, traffic volume, flow speed and road geometric is required. Then queue length and delay time can be estimated. There are few different scenarios and each scenario have different queue length and delay time. The different scenarios include existing, geometric change, installation of traffic light, geometric change combine with traffic light installation, etc. Compared the queue length and delay time, the best scenario is selected, which is geometric change.

To sum up, existing issues for Oaklands Crossing include traffic delay, business concerns and safety issues. To address these issues, grade separation is a good option based on similar examples for other cities in Australia and other countries. The railway underpass roadway design to be used needs to be decided. Some software will be used to build traffic models and evaluated in both economic and environmental concerns. The suitable software package for this project will be Nano-scaled traffic modelling, also intersection focused modelling. Therefore, the software SIDRA and Infraworks are selected to build traffic models and do analysis on Oaklands Crossing. SIDRA is more focused on intersection and Infraworks focused on Nano-scale modelling and analysis.

5. Methodology

After literature review, the methodology for this project is clear. The data of traffic volume for Oaklands Crossing intersection will be collected, the data will be analysed and the peak hour and peak volume will be calculated to create the worst case scenario. Then the existing models and future models will be built in SIDRA and Infraworks. The models will be validated and collaborated to match the real traffic situation, then they will be simulated and the results will be given through software. The result will be analysed.

3.1 Data Collection & Analysis

To analysis the traffic situation in Oaklands Crossing, the traffic volume data is needed. The traffic volume data is from SCATS database. Figure 6 shows the Oaklands Crossing intersections in database. There are two intersections involved. TS284 is the intersection between northern Morphett Road, Diagonal Road and Seaford Railway. TS117 is the intersection between southern Morphett Road and Diagonal Road. These two intersections are main signalised intersections in Oaklands Crossing area. The exported data is saved as excel form. There are two years data exported, which are traffic volume of 2016 and 2017.

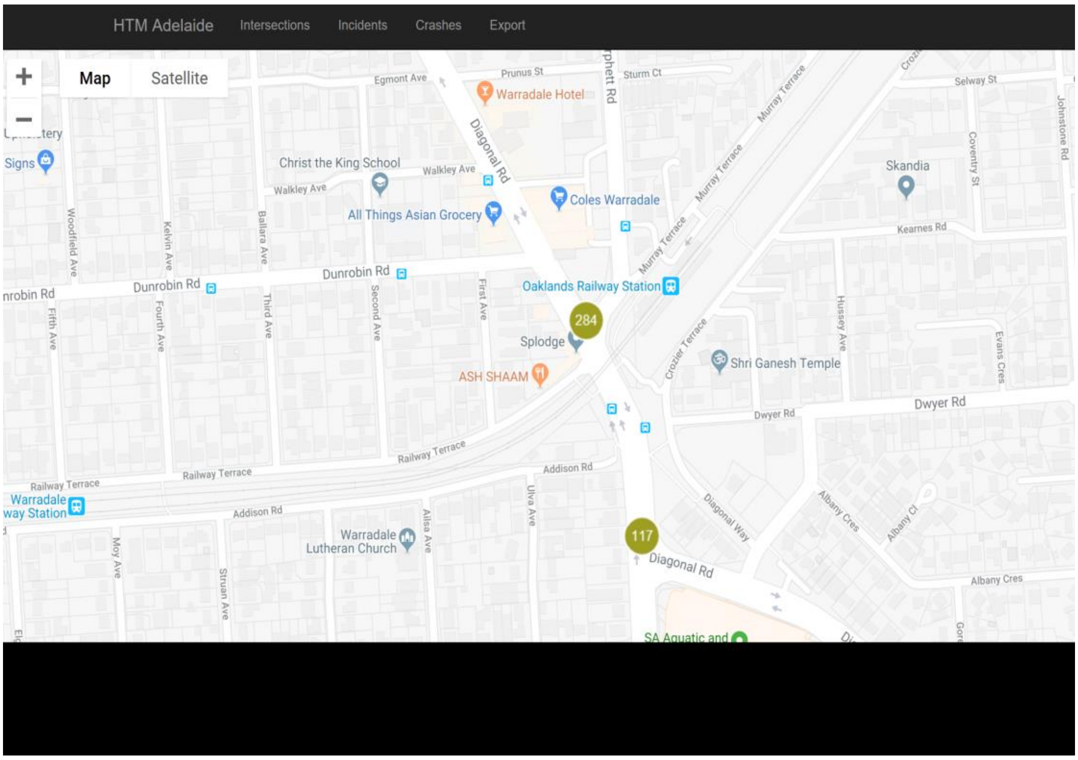


Figure 6. Oaklands Crossing in SCATS database

(https://scatsviewer.flinders.edu.au/)

The exported traffic volume table is shown in Table 4. Date time shows traffic volume data is collected every 5 minutes. The site number is the number of the intersection. In data collection, there are 2 site numbers which are TS284 and TS117. The number from 1-10 in first row is the lane number. This table only shows a small part of the whole table. The whole table show the volume of 24 lanes for whole year from 1st of January to 12th of December. The data after 12th of December is not in data sheet for 2017, therefore, the traffic volume data from 13th to 31st of December is filled with data sheet for 2016.

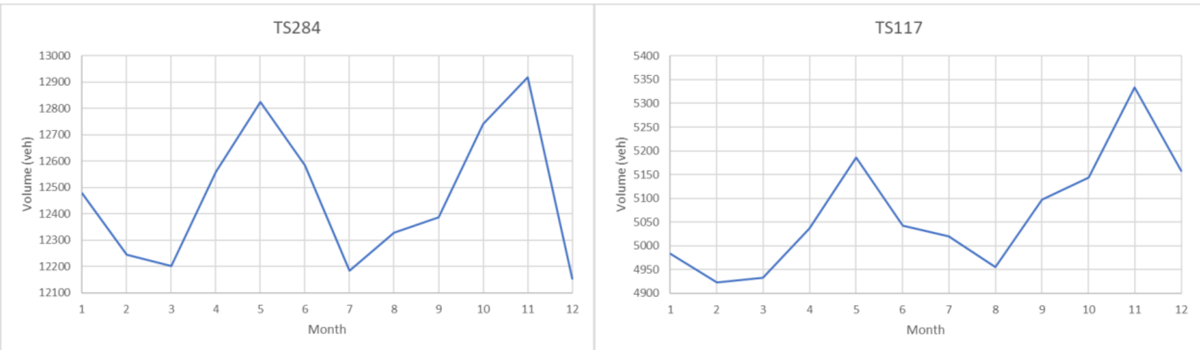
The first step of data analysis is to determine the total volume for all lanes in 5 minutes. The function sum up is used in excel. Based on the data size is enormously large, which includes 28 columns and 104,848 rows (recorded every 5 minutes for whole year), sort data is necessary to increase analysis speed. The whole data is separated by month and it is easier to read and do analysis on different months. During the total volume for every 5 minutes calculation, it is noticed that some total volume is dramatically high. When checking through the volume for each lane, there are few lanes present number '2046'. This appears even at 2 am in the morning. It is due to detector error, the data need to be replaced by previous year to make sure the data is reasonable and hence can be used in further modelling and analysis.

Table 4. Traffic volume data

datetime	site_no	0	1	2	3	4	5	6	7	8	9	10
2017-01-01T00:00:00	284		6	2	2	0	2	5	4	4	2	5
2017-01-01T00:05:00	284		6	1	3	2	2	6	4	2	5	7
2017-01-01T00:10:00	284		13	6	1	1	0	2	7	9	7	2
2017-01-01T00:15:00	284		18	9	2	4	1	12	16	11	11	12
2017-01-01T00:20:00	284		18	8	6	4	3	16	15	15	5	16
2017-01-01T00:25:00	284		49	17	5	2	4	43	23	15	15	42
2017-01-01T00:30:00	284		33	14	9	7	4	30	29	19	16	30
2017-01-01T00:35:00	284		35	11	4	3	6	23	25	19	13	21
2017-01-01T00:40:00	284		44	20	11	6	13	37	30	31	24	37
2017-01-01T00:45:00	284		56	16	8	3	7	33	37	25	20	33
2017-01-01T00:50:00	284		40	10	11	4	7	35	30	21	16	35
2017-01-01T00:55:00	284		12	5	8	6	4	14	9	10	5	14
2017-01-01T01:00:00	284		38	16	14	6	5	41	27	23	17	42
2017-01-01T01:05:00	284		30	13	5	9	14	17	23	24	20	16
2017-01-01T01:10:00	284		22	13	9	2	9	20	21	11	20	21
2017-01-01T01:15:00	284		25	10	10	4	9	25	21	13	18	25
2017-01-01T01:20:00	284		29	9	5	10	10	20	24	22	20	21
2017-01-01T01:25:00	284		24	13	6	4	6	23	17	12	12	23
2017-01-01T01:30:00	284		29	10	8	1	6	31	16	10	14	30

As far as all the total volume per 5 minutes is calculated, the volume per hour is required. To calculate the volume for every hour, the 12 total volume data for every 5 minutes in this hour is summed up. This step is required to be done in a separate data sheet because the peak volume for each month can be determined. Table 5 indicates the peak volume and time for every month for TS284 and TS117.

Table 5. Peak time and volume for TS284 and TS117



The morning peak volume for TS284 is 12,919 vehicles from 11:00 am to 12:00 pm in 25th of November, the afternoon peak volume is 12,825 vehicles from 15:15 pm to 16:15 pm in 9th of July. The morning peak volume for TS117 is 5,333 vehicles from 11:00 am to 12:00 pm in 25th of November, the afternoon peak volume is 5,186 vehicles from 13th of May. The peak traffic volume for TS284 is nearly twice bigger than TS117 due to the railway on TS284. The morning peak time is 11:00 am to 12:00 pm may due to a large amount of people going to Marion shopping centre to have lunch or go shopping. It may also because it is in exam period for Flinders University and that is the time that students finish exams and go to Marion shopping centre or go back home. The afternoon peak time is about 3pm in the afternoon. There can be few factors effect the peak time, such as people finishing work and go back home, students finishing exams, etc. The purpose of finding out peak time and volume for morning and afternoon is critical because the worst scenario case is needed to build models on SIDRA or Infraworks.

3.2 SIDRA Modelling

Once the data collection and analysis is finished, next step is to build existing model and future model on SIDRA. There are two intersections need to be built which are TS284 and TS117. For site input, intersection information is needed such as site name, site number, the length of the roads. Figure 7 shows the layout of existing model for TS284. The layout has a slight difference compare with the real map, this due to the limitation of lane type, it cannot create rail and road at same direction. When set up movement definitions, it need to be made sure that vehicle on the road cannot drive into railway and the train on the railway can only go straight. For lane geometry, the lane width, short lane length and lane type all can be measured in Google Earth. The bus lane is coloured in yellow and the railway is coloured in red. Then the pedestrian crossing is added.

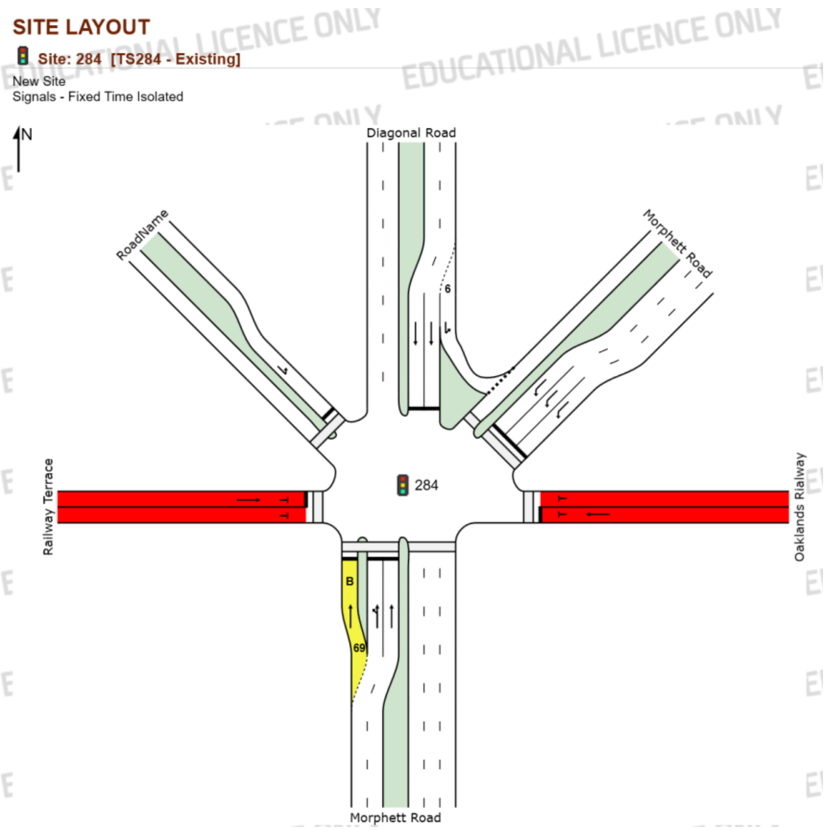


Figure 7. Existing Model for TS284 on SIDRA

To input data for volumes, the peak hour volume data is required to fill in. For TS284, the peak hour in the morning is 11:00 am to 12:00 pm. The 12 groups of 5 minutes volume data are found out at the morning peak hour. Figure 8 shows the lane number for different direction. Lane 1 and 2 is northwest direction, lane 3, 4 and 5 is northeast direction and lane 17, 18 is from south direction. All the other lanes as shown in figure have vehicles come out of intersection so it is not counted. Sum up the volume for each direction in peak hour, then it will give the total vehicle volume from different directions. As SIDRA requires not only total volume, but also traffic volume of light vehicles, heavy vehicles, buses and bicycles. The number of heavy vehicles is assumed as 2% of total vehicles. The number of buses depends on bus route and timetable. Therefore, the website Adelaidemetro is viewed to calculate how many buses pass through stops that are close to this two intersections. The bus stops involved are Stop 29 Morphett Road at west side and east side, Stop 28C Diagonal Road at both sides and Stop 28A Morphett Road at East side. The bus which passed these stops from 11:00 am to 12:00 pm is counted hence the bus traffic volume is calculated for each direction.

To calculate the amount of bicycles trains, it needs site observation. To simplify the situation, the traffic volume of trains and bicycles is observed in 15 minutes then the number multiply by 4 to get the traffic volume of trains and bicycles for different directions in an hour.

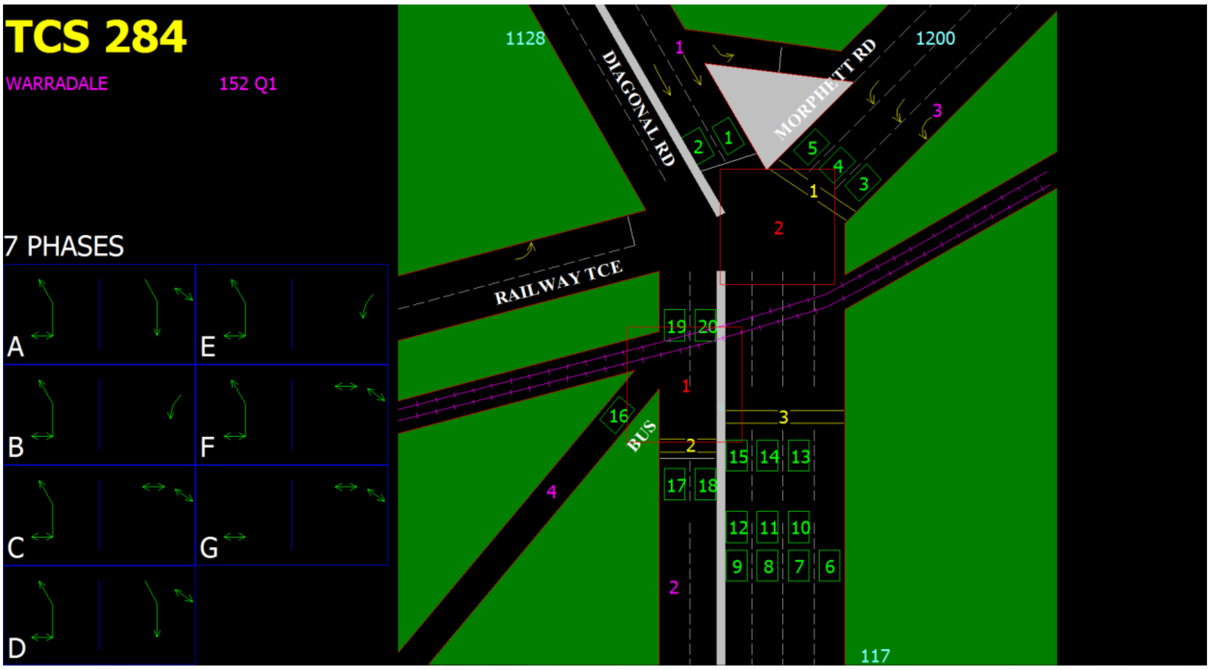


Figure 8. Phasing and lane number for TS284

For phasing and timing input, the SCATS operation sheet and original SCATS files are reviewed. The Figure 8 shows different phases for TS284. The repeated phases is not needed. For TS284, there are 4 phases which are A, B, C and G. As mentioned in phasing operation sheet, phase C is only for pedestrians and phase G is for trains only. The total cycle time is 120 seconds. Phasing time for every 2 minutes from 11:00 am to 12:00 pm is in the SCATS files, then the average phasing time for different phases are calculated. However, the average phasing time only include phase A, B and C. To make phase G in and keep total cycle time, it requires to reduce few seconds phasing time from phase A, B and C and hence phase G can have time to run through.

As the site input is finished, then the intersection TS284 and TS117 can be processed and SIDRA will give the results. Then use network to connect two intersection together. The cycle time need to be set as 120 seconds then process the network.

After the existing model for TS284 and TS117 is built, next step is to build a future model. Based on DPTI design, in the future the train will go underpass the intersection. TS284 need to be changed to match the future DPTI design. Because SIDRA is a 2D software, once the train go underpass the intersection, it no longer belongs to TS284, therefore the railway can be removed. For phasing and timing, phase G can be deleted, the timing is modified to match the SCATS files. TS117 did not change in the future so for the future network just connect future TS284 and existing TS117 together.

3.3 SIDRA Analysis

After the existing and future network are processed, Level of service (LOS) for network sites is checked. Level of service is related to the quality level of traffic performance, such as vehicle delay time, vehicle speed, etc. Figure 9 shows the LOS approach for existing and future network. For existing network, the average LOS is D, the worst roads are north Morphett Road, Railway Terrace and south Morphett Road which LOS of these roads all reached E. After move railway underpass the intersection, the LOS of Railway Terrace significantly increased from E to A because it changed from signalized to unsignalized. The LOS for railway is E because the real timetable for train cannot put in so SIDRA estimated the model time and it may affect the LOS of train and the train stopped until Phase G, but in real life the train will go through the intersection without stopping.

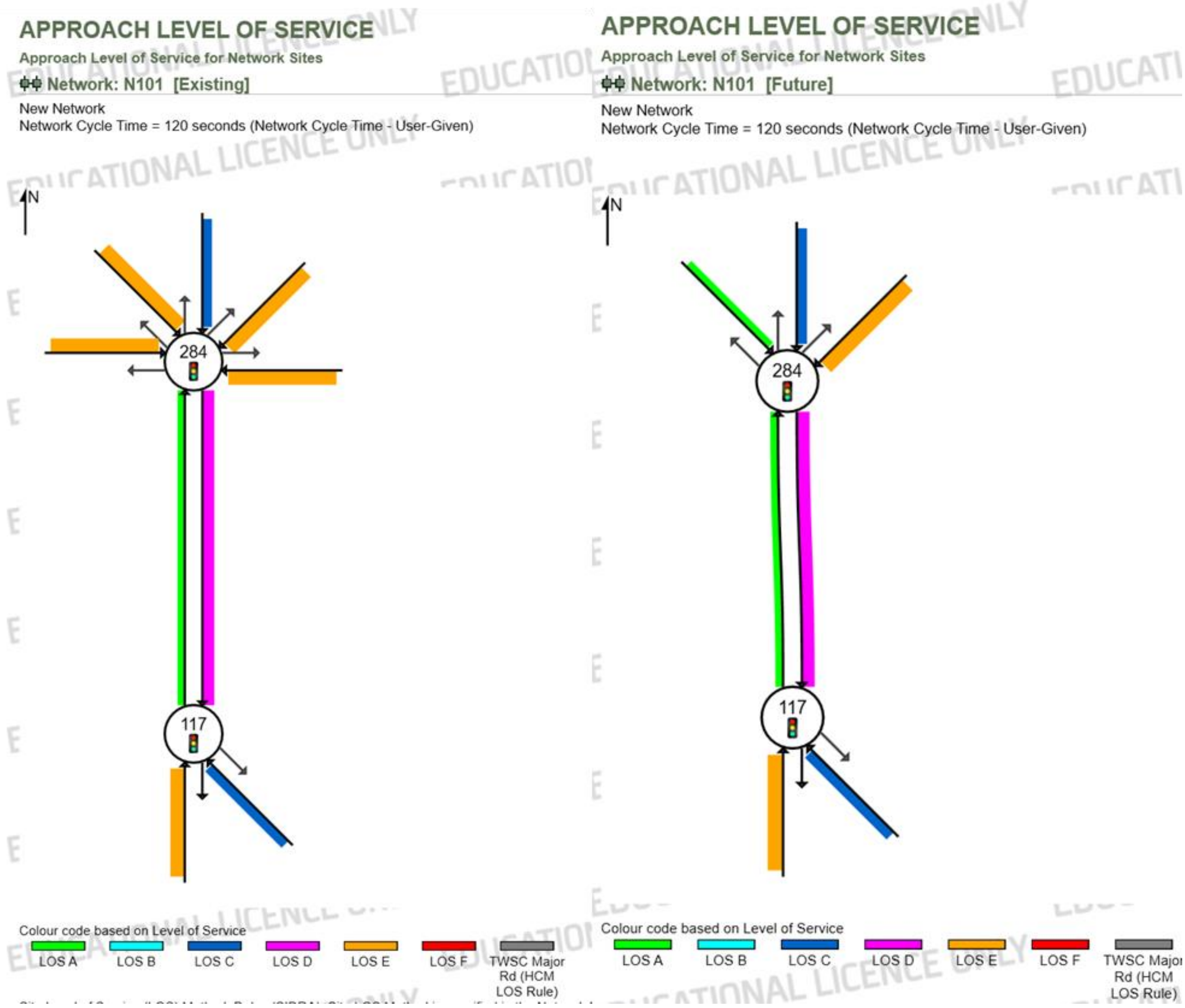


Figure 9. LOS for existing model and future model

Compare with the future DPTI model and existing model on SIDRA, the average LOS is D for both. The travel speed slightly increased from 30.7 km/h to 31 km/h due to railway go underpass the intersection and no more phase for railway, therefore more time for phase A, B and C to run. The total delay time reduced from 91 veh-h/h to 88 veh-h/h. The future model is more environmental as well. The carbon dioxide dropped from 1598 kg/h to 1568 kg/h.

3.4 Infraworks Modelling

To make a more detailed analysis on Oaklands Crossing, the software Infraworks is chosen. The reason why Infraworks is chosen is because it is a 3-D software which when building railway underpass the intersection in the future, it is easy to be visualized. Another factor that has been considered is Infraworks is able to simulate traffic in Nano-scale, which is detailed in every vehicle, train and pedestrian, this will help to avoid safety hazards and hence increase the safety for all road users. Meanwhile, network from Infraworks can include more roads and intersections around hence make the result closer to real life.

To build model for Oaklands Crossing, the model builder is used. The model builder provides the base data such as road, buildings, imagery and elevation. After the base model is created, then the function mobility simulation is used for further detailed traffic analysis. Mobility simulation is used to simulate the movement of all vehicles, trains and pedestrians and it gives economic and environmental assessment in the report.

On the base model, the road information is not always correct. For Oaklands Crossing, the base model as shown in Figure 10 does not have railway. For Diagonal Road, there are 2 separate roads which each of them have a in-way and out-way. Some intersections is shown as a continuous road and there are some irrelevant road in selected area as well. To modify the base model, one of the Diagonal Road need to be deleted, the lane number and speed limit on the other Diagonal Road need to be changed to match the image. The train railway need to be added. All intersections need to be checked and some of them need to be redesigned. The irrelevant road can be deleted.

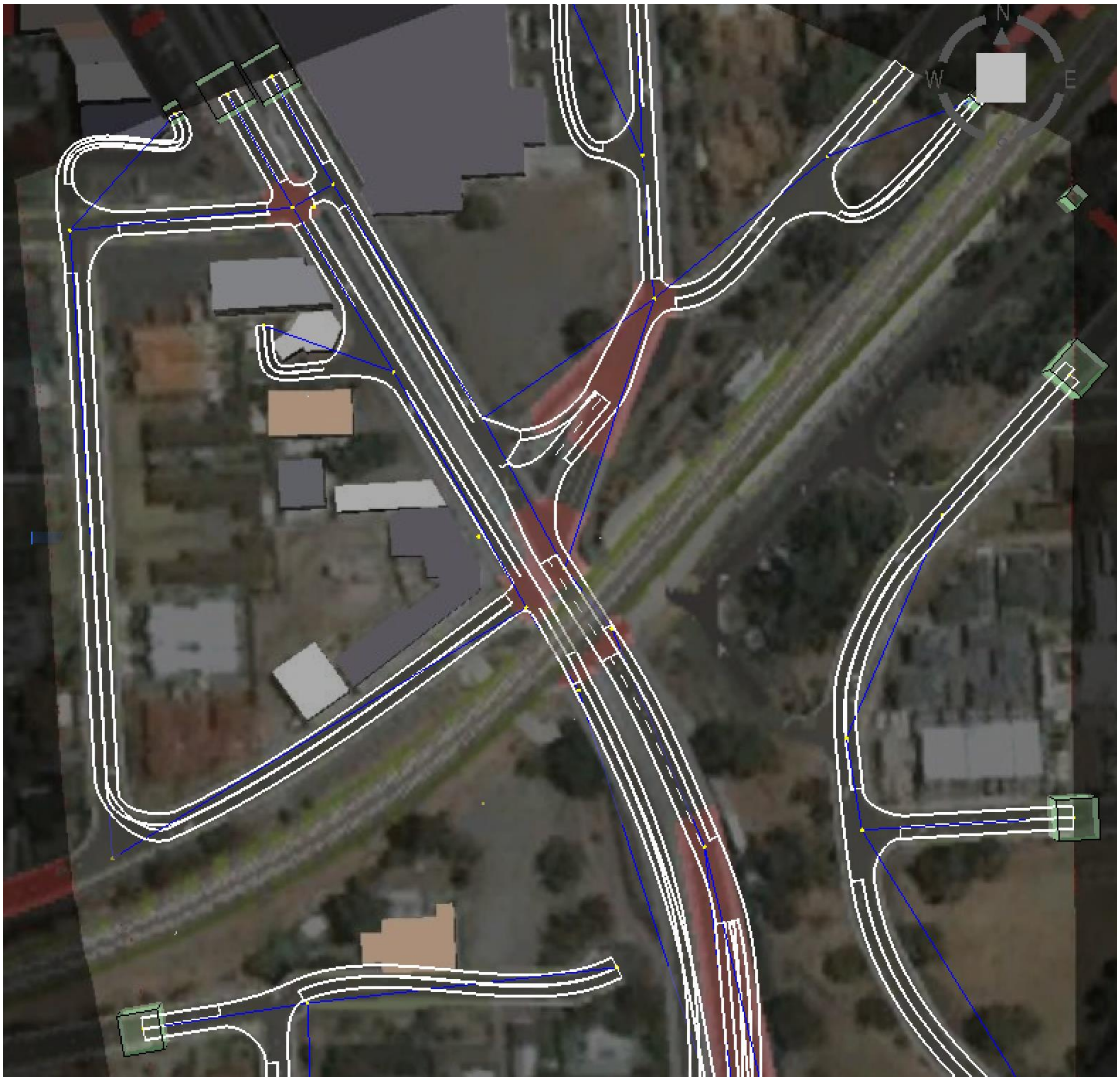


Figure 10. Base model for Oaklands Crossing

The railway is created first with the same elevation the Oaklands Crossing intersection. One of the Diagonal Road is deleted and another one changed from 1 lane to 2 lanes from north to south, 1 lane to 2 lanes from south to north. Depending on the image, the short lane and merge lane need to be added as well. The lane number needs to match the real world. For the connection between road and railway, the road needs to be bisected otherwise it will be overlapped. Then the streamline between two bisected roads is connected therefore when train come through the vehicles will stop and other time vehicles can still go through. There are few streamline missed so all streamline need to be added based on the traffic rules.

For intersections, there are unsignalized and signalized intersections. Unsignalized intersection has no traffic light, only give way or stop sign. Signalized intersection has traffic light and vehicles travel follow the light. After all the intersections are designed correctly, then use intersection control to identify unsignalized and signalized intersections. For example, Figure 11 shows the intersection between Egmont Ave and Diagonal Road and this is an unsignalized intersection. The gray continuing arrow is free flow, which means the vehicles go without stopping. The dark blue dotted line is give way which indicates the vehicle should give way to free flow. The light green dotted line is yield, which show the vehicle cannot go until no vehicle on free flow or give way.

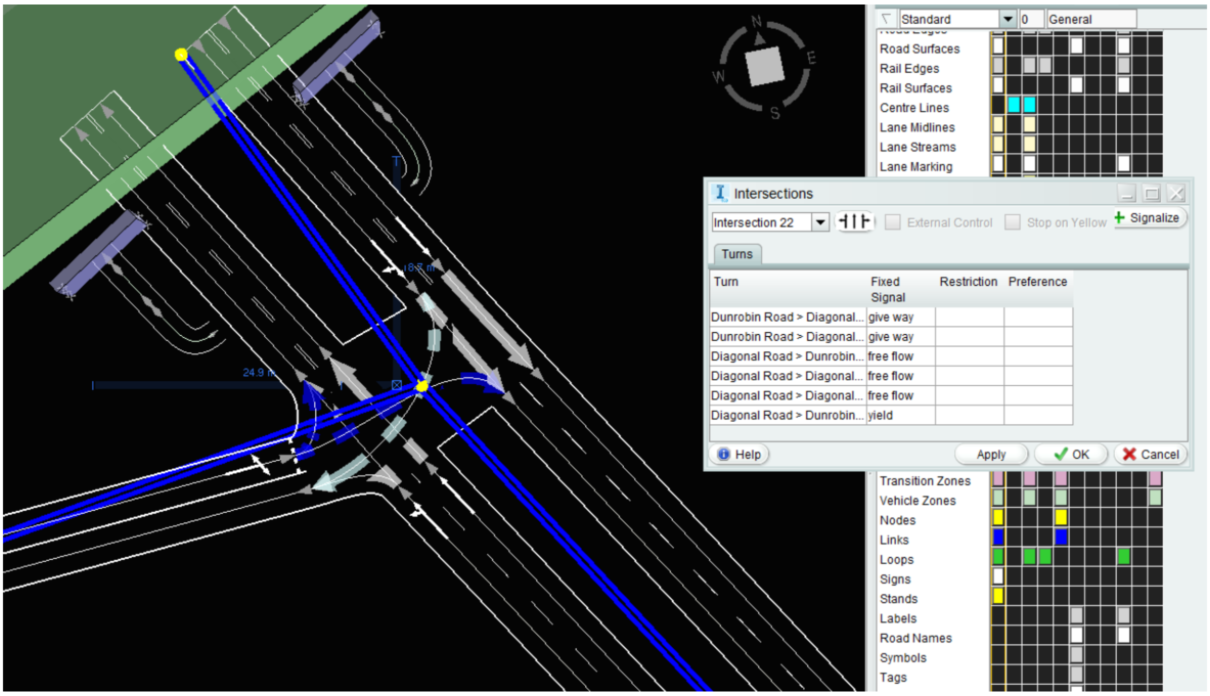


Figure 11. Intersection between Egmont Ave and Diagonal Road

For signalized intersection, TS117 is a good example as shown in Figure 12. On the base model, this intersection is an unsignalized intersection. To modify this intersection, the signalized option is selected. The group of vehicle is identified and phases and timing can be put in based on SIDRA phasing and timing. In the timing option, the stretch phase is the reference phase in SIDRA. The stretch phase is also shown in SCATS operation sheet as well.

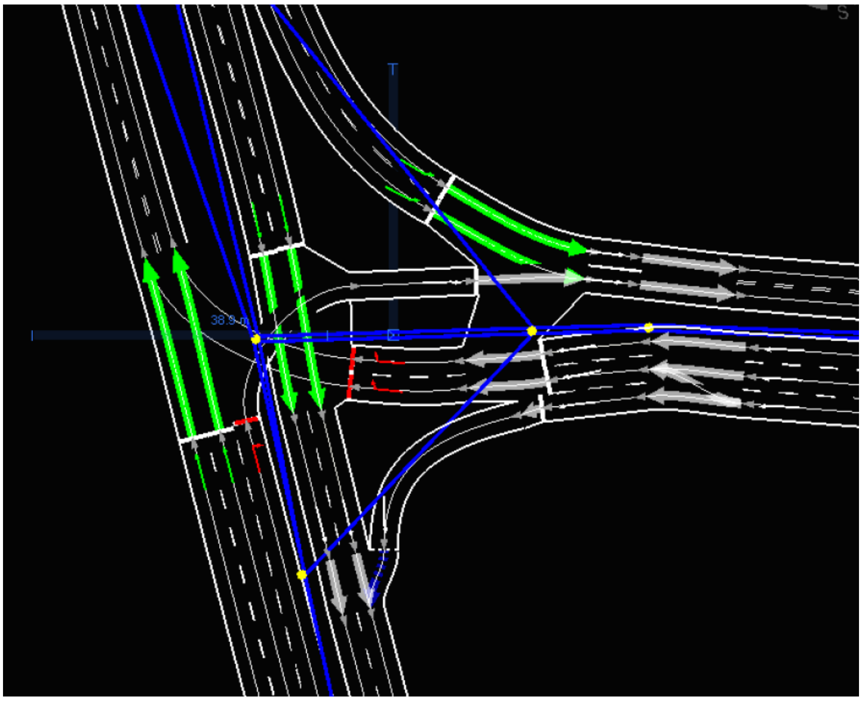


Figure 12. Signalized intersection TS117

After the unsignalized and signalized intersections have been modified, the detail for trains, bus and pedestrians need to be considered. For train, the rail stands, trails and services and boom gates are added in the model. For trails and services, it need to be adjusted to match real life. Adelaidemetro is reviewed to find out the timetable for train between 11:00 am to 12:00 pm then it is put in service. For buses and routes, the bus stands are added based on the map, the routes are created and service is based on the Adelaidemetro timetable. For pedestrians, the walkway is added.

Zones and areas are added then. Zones are added at the end of each road, areas are added at the end of each walkway. The Origin Destination (OD) matrix is then built for vehicles, buses and pedestrians. This is a part of trip distribution. It connect trip productions at the origin to trip attractions at the destination (Week 5 Trip Distribution). The OD matrix is shown in Figure 13. Each zone indicates a different road. For example, zone 4 to 11 is from north of Diagonal Road to south of Diagonal Road, which is the main road and the volume is high. Zone 11 to 10 is from south of Morphett Road to north of Morphett Road through Diagonal Road, there is no value there means vehicles cannot go from zone 11 to 10 due to traffic rules. There are many small volumes, such as zone 4 to zone 2. This is because the main focus will be on the volume through two intersections, so all the other around intersections and road will set as 2 vehicles go from one zone to the other zone in an hour. The busiest area is around TS284 and

TS117 so it is easier to set small value for vehicles that passed other unsignalized intersection. To fill the OD matrix, network flows on SIDRA is processed to get the result. The flows is shown in Figure 14. From north to south, the difference between the volume of vehicles out of TS284 and into TS117 is 22 vehicles, which is a very small difference. From south to north, the difference between the volume of vehicles out of TS117 and go into TS284 is 404 vehicles, which is significantly high. The reason of why the difference is huge may because the bus went into bus lane and waited for a while so the camera did count the bus at TS117 but not TS284. To remove the significant difference, 404 is divided by three, it gives 135 vehicles for each road. For south of Morphett Road to north of Morphett Road and south Diagonal Road to north Morphett Road add 135 vehicles, for north Morphett Road remove 135 vehicles to make the huge difference to 0. Hence the traffic volume for two intersections matched.

Mode Private Vehicles Profile Simulation Division Division Furness...

	Profile	2	4	10	13	14	1	3	7	9	11	12	15	Total
2				2	2	2				2	10	2	5	25
4		2		2	2	2	2	2	2	2	616	2	515	1149
10		2			2	2				2	455	2	461	926
13			2			2	2	2	2	2	2	2	5	21
14			2		2		2	2	2	2	2	2	5	21
1		2	2	2				2	2					10
3		2	2	2	2	2	2		2	2	2	2	5	25
7		2	2	2	2	2	2	2		2	2	2	5	25
9		2	2	2	2	2	2	2	2		2	2	5	25
11			921		2	2	2	2	2	2		2	85	1020
12			2		2	2	2	2	2	2	2		5	21
15			687		2	2	2	2	2	2	482	2		1183
Total		12	1622	12	20	20	18	18	18	20	1575	20	1096	4451

Figure 13. OD Matrix for vehicles

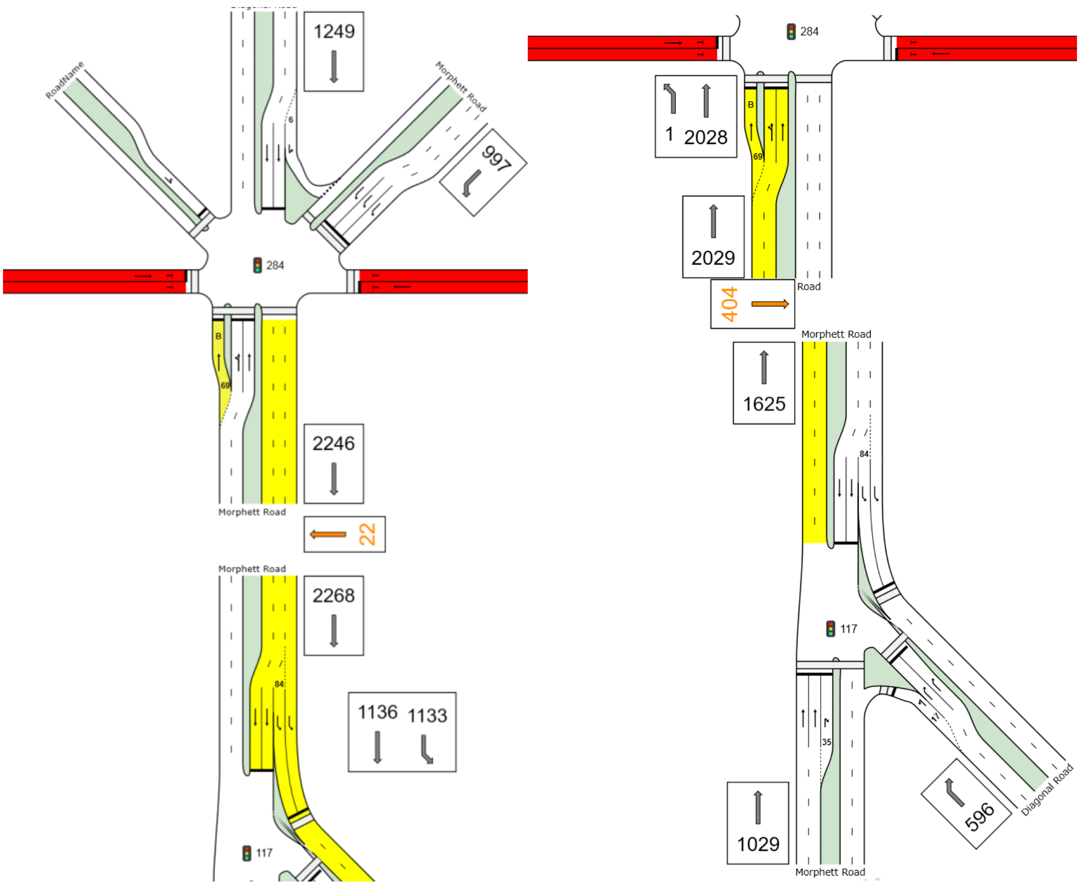


Figure 14. Network flow from SIDRA

3.5 Infraworks Analysis

3.5.1 Calibration and validation

After the existing model is built, next step is calibration and validation to check if the model time will match real time or not, the standards parameters have been changed from default values or not. For calibration, validator is used and turn counts is checked. Two intersection TS284 and TS117 is added to validator. This is shown in Figure 15. The purpose to run validator is to check GEH. Normally GEH is used for traffic engineering, traffic forecasting and traffic modelling. (Week 8) The equation of GEH is show in Equation 1, where M is modelled hourly traffic volume and C is real-world hourly traffic volume. GEH stands for Geoffrey E. Havers.

$$GEH = \sqrt{\frac{2(M-C)^2}{M+C}} \qquad \textbf{Equation 1}$$

If GEH is less than 5, that means the modelled traffic volume is very close to real-world traffic volume (Model Calibration Criteria). During calibration, GEH from south Morphett Road to north Diagonal Road is always a bit higher than 5. Therefore, the phase timing slightly changed a bit. 1 more second added on phased B and phase C, 2 seconds reduced on phase A for TS117.

Then all GEH blow 5 and the calibration is finished.

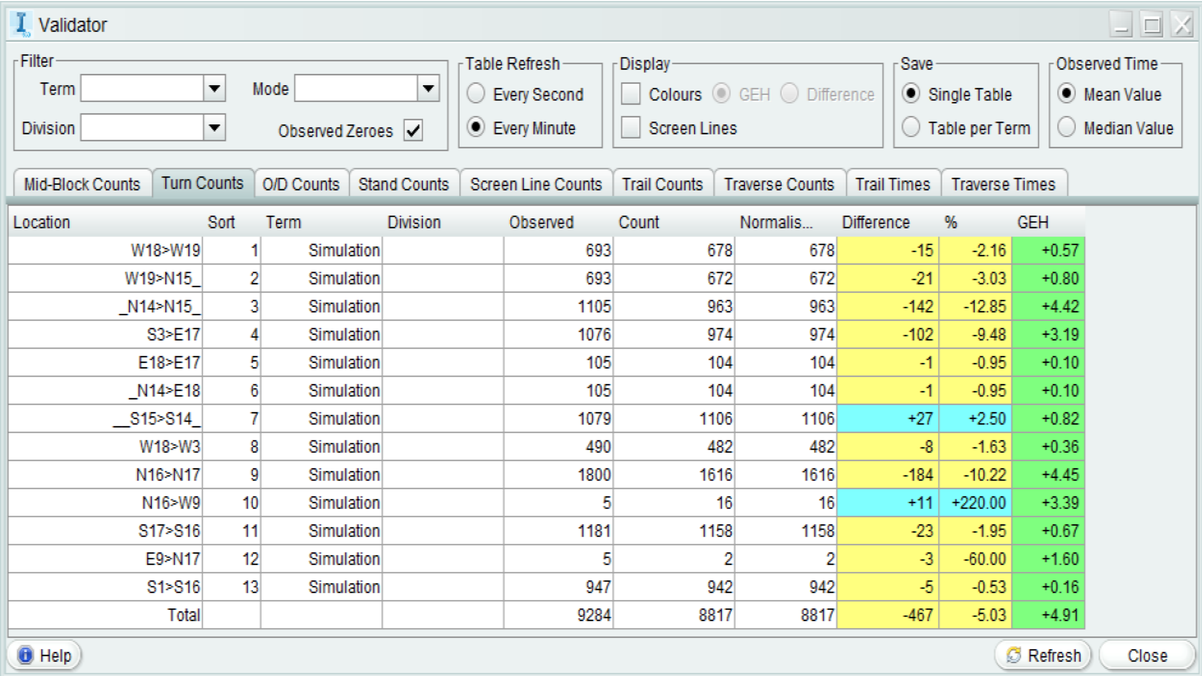


Figure 15. Validator – Turn Counts

Next step is to do validation. The model auditor is used to check the standards parameters. Figure 16 shows the parameters that model auditor checked. During the parameters checking, there is an empty area found out and fixed.

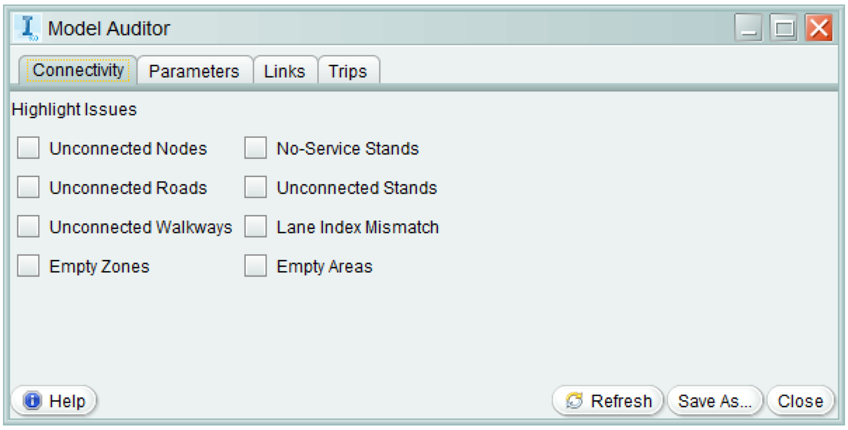


Figure 16. Model Auditor

Then Record of Lost & Obstructing Agents is processed during simulation to check is there any road have vehicle delays more than 5 minutes. As the result, vehicle delay on all road is less than 5 minutes. Calibration and Validation is a crucial part in Infraworks modelling to make sure the model situation is very close to real-world situation.

3.5.2 Simulation

After the existing model is built, next step is to run simulation and get results. Before simulating the model, the economic evaluation report need to be added in the output.

The simulation time should be set up between 11:00 am to 12:00 pm and this can be changed in terms. During simulation, an observed problem is when vehicles wait for boom gate up on north Diagonal Road, cars would not wait behind the stop line there for all vehicles at TS284 overlayed and crashed into others. This is because when the traffic is very busy and vehicles move slowly, they still want to go into the intersection and hence jammed the traffic. This affected traffic on north Morphett Road badly, vehicles become blocked and cannot turn left to go south to Diagonal Road. To solve this problem, box speed is set up as 30 km/h at this intersection. In this case, vehicles will not go into intersection if the speed is equal or less than 30 km/h, which in other words, vehicles will not pass through until the traffic conditions are good.

3.5.3 LOS Analysis

The output result is exported to excel file. The Table 6 shows the LOS for the existing model. In this table, control delay is the total delay time for all the vehicles. Queue delay is for the vehicles less than queue threshold speed. Queue max is the counted number of vehicles that drive less than queue threshold speed. Stops is how many times did vehicles stopped in total. In existing model, the worst LOS is E, which is located from north Morphett Road to south Diagonal Road.

Table 6. LOS for existing model on Infraworks

Approach	Exit	Intersection	LoS	Control Delay	Approach Delay	Acceleration Delay	Queue Delay	Queue Size	Queue Max	Stops	Turned	Approaching	Total	People	Vehicle Delay	Person Delay
S	S	I	S	S	S	S	S	S	D	I	I	I	I	I	S	S
W1		3	B	18.6	15.83	2.77	17.25	0.02	1	4	4	0	4	23	00:01:14	00:07:09
E2		3	C	29.38	27.77	1.61	25	0.03	1	4	4	0	4	18	00:01:57	00:12:45
S1		4	E	41.38	40.16	1.22	33.21	8.7	35	941	938	5	943	938	10:46:59	10:46:59
S2		4	A	0	0	0	0	0	0	0	0	0	0	0	00:00:00	00:00:00
E10		23	A	2.26	0	2.26	0	0	0	0	10	0	10	10	00:00:22	00:00:22
S3		34	A	11.82	10.66	1.16	5.21	1.42	16	284	976	8	984	1004	03:12:16	03:14:34
W3		10	B	10.35	7.12	3.23	4.88	0.65	5	160	482	0	482	482	01:23:07	01:23:07

The LOS for DPTI model is determined as well and it is shown in Figure 17. Compared with the existing model, the LOS from north Morphett Road to south Diagonal Road increased from E to D. Control delay time decreased from 41 seconds to 31 seconds. The Queue maximum size decreased from 35 vehicles to 24 vehicles. Stops decreased from 943 to 760. This indicates with the grade separation, the traffic for Oaklands crossing intersection has less delay time, less queue, less stops for vehicles. It in many ways significantly enriched people’s life.

Compare with the LOS analysis in SIDRA, LOS analysis in Infraworks more focus on whole network but not only intersections. The advantage of Infraworks is after grade separation, SIDRA cannot do LOS of railway but Infraworks can still analysis LOS of railway, hence the LOS of railway can be further analysed.

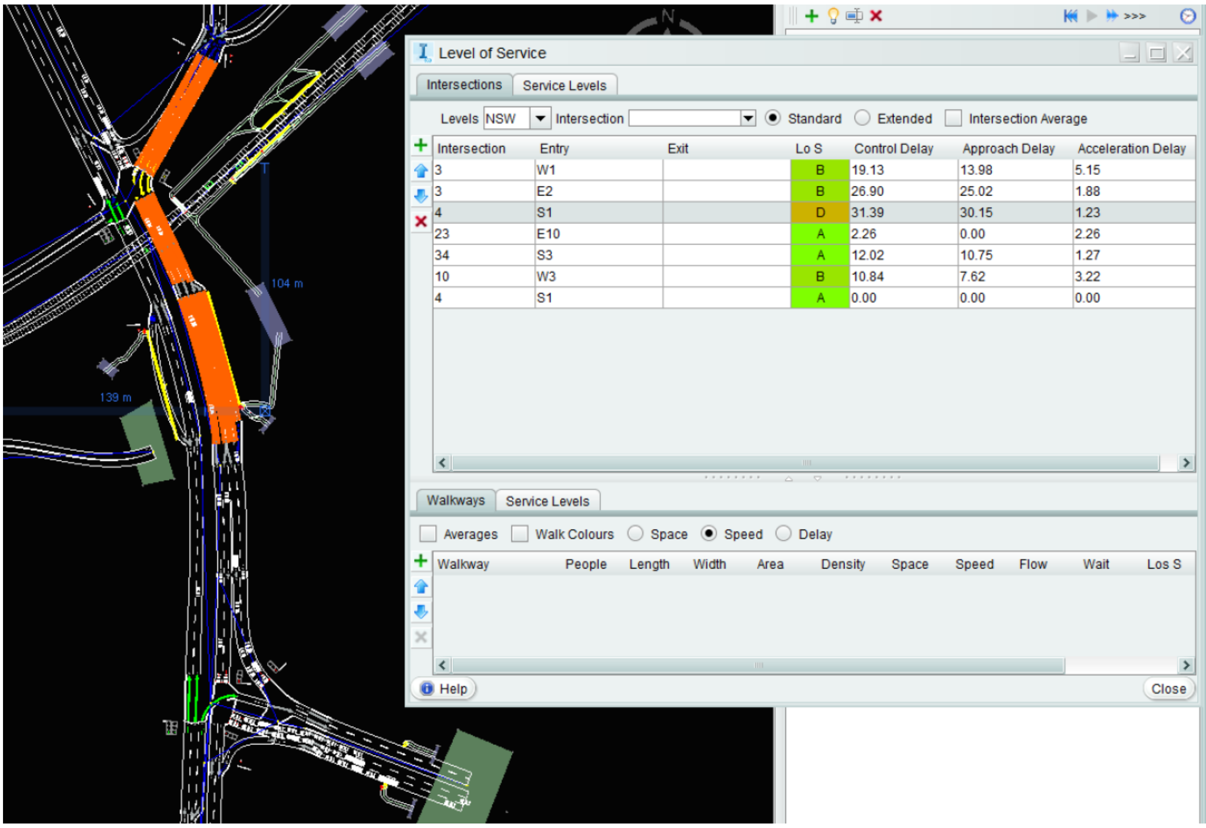


Figure 17. LOS for future DPTI model

3.5.4 Economic Evaluation

To evaluate whether this project is economic or not, economic evaluation report is reviewed from the output of Infraworks. The excel document is under results, quick simulation folder. There are many economic measure reports for different kind of vehicles. The report used to evaluate in this project is the summary report. Table 7 shows the report for existing model. In report, it shows all trips normalised trips. To compare with future model, normalised data will be reviewed and analysed in this project. The evaluation report gives the result about how many vehicles pass through in peak hour, what is the total count and distance of stops, queue time, travel speed, delay time and cost. To evaluate whether the project is economical or not and how does the performance improve, count of vehicle, distance, time, speed, delay and total cost will be considered.

Table 7. Economic Evaluation report for existing model

Commuter - Economic Evaluation											
Title	Economic Evaluation Report										
Subtitle	Design Option / Date / Time										
Simulation file	C:/Users/mephisto/Desktop/C										
Model run at	Fri Sep 07 08:24:10 ACST 201										
Simulation date	25 / 06 / 2016				Last Clear:		11:00:00.000		Version:		6.00.006
Simulation duration	11:00 to 12:00				This Save:		12:00:00.000				
		Count	Distance (km)	Time (h:m:s)	Speed (km/h)	Stops	Delay (h:m:s)	Distance Cost ($)	Time Cost ($)	Stops Cost ($)	Total Cost ($)
Complete Trips	Total	4475	2004.413	105.291	19.037	4594	74.42	501.103	2632.281	574.25	3707.634
	Mean		0.448	00:01:24		1.027	00:00:59	0.112	0.588	0.128	0.829
	Std Dev		0.112	00:02:22		0.878	00:02:20	0.028031	0.992	0.11	1.003
All Trips	Total	4581	2049.518	111.34	18.408	4713.937	80.107	512.38	2783.504	589.242	3885.125
	Mean		0.447	00:01:27		1.029	00:01:02	0.112	0.608	0.129	0.848
	Std Dev		0.112	00:02:30		0.881	00:02:28	0.028103	1.045	0.11	1.053
All (Normalised)	Total	1000	447.395	24.305	18.408	1029.019	17.487	111.849	607.619	128.627	848.096

3.6 Different Scenarios

The existing model has been built and simulated, all issues have been picked out and solved. The next step is to build future model and later obtain the results from different scenarios which can be compared and the best scenario for economic and environmental purposes can be found out.

3.6.1 Scenario 1 – DPTI Model

The first scenario is followed by the DPTI design, which is to reconstruct railway underpass at the intersection. Figure 18 shows the design in Infraworks. In this model, the railway's elevation is reduced by 10 meters. The boom gates are removed. Pedestrian walkway will still be on the same level as the intersection. The walkway goes down to the train station. All the other traffic rules will not change. Compared with SIDRA future model building, build future model on Infraworks is easier and quicker. All input data does not require to change, the only changed parameter is railway geometry.

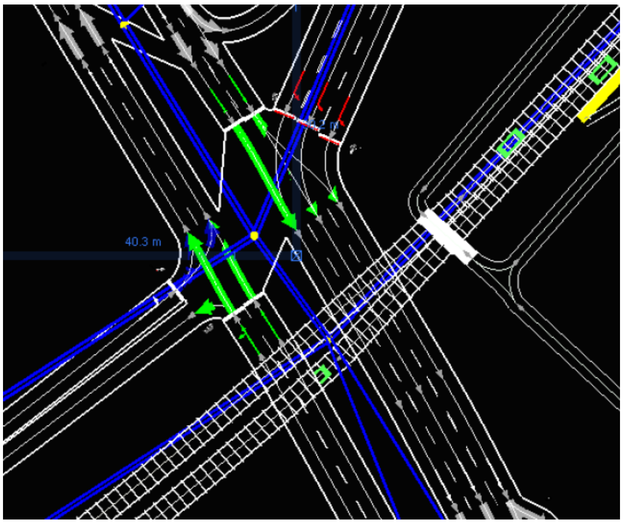


Figure 18. Scenario 1 – DPTI Model

3.6.2 Scenario 2 – Additional lane on north Morphett Road Model

The DPTI future model showed that from north Morphett Road to south Diagonal Road the level of service is still the worst. The idea is to improve the LOS for this section of road. Because the delay time and queue size is still quite large compare with other roads, so an additional lane was added on the kerb side and this additional lane extended to the south of Diagonal Road to make the traffic flow faster. For intersection 117 in the future, there will be no change. This scenario is shown in Figure 19, which shows the design in Infraworks. In SIDRA, the geometry is changed from North Morphett Road and Diagonal Road. From North Diagonal Road to South Diagonal Road, the right turn changed from a short lane to full-length lane to match the number of lanes that connect two intersections.

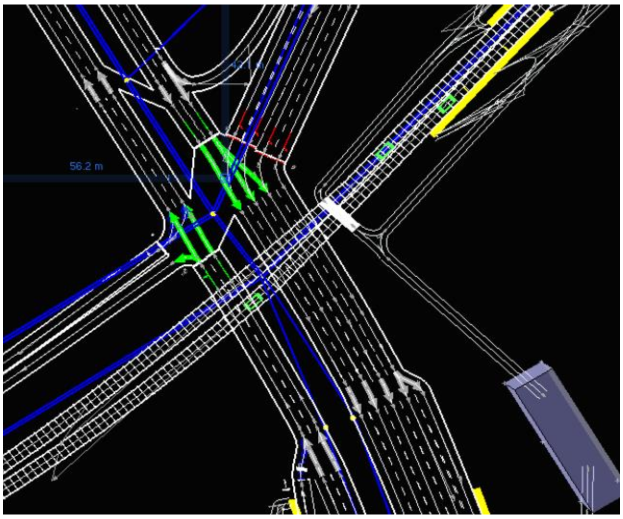


Figure 19. Scenario 2 – Additional Lane on North Morphett Road

3.6.3 Scenario 3 – Additional lane on Diagonal Road Model

Another solution to enhance the LOS for Oaklands Crossing is adding another lane on Diagonal road. The additional lane on Diagonal Road can reduce the traffic volume on each lane hence reduce the traffic delay time on Diagonal Road, it can also reduce the traffic from Morphett Road to Diagonal Road according to reduced vehicle queue. It is shown in Figure 20. In SIDRA for intersection TS117, it uses same design as scenario 3.

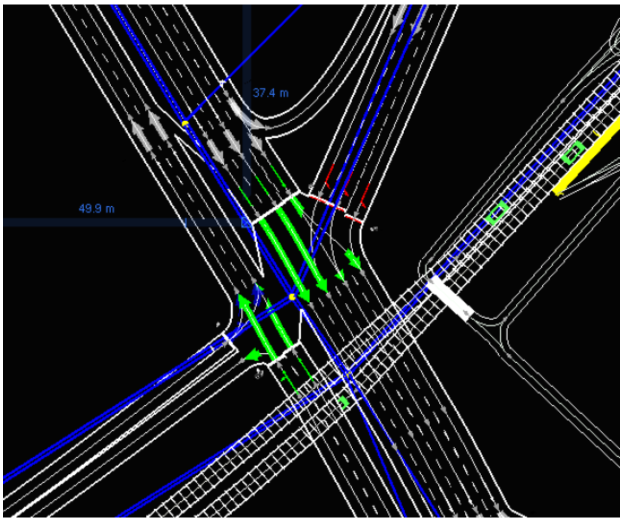


Figure 20. Additional lane on Diagonal Road Model

3.6.4 Scenario 4 – Unsignalized Model

To reduce the LOS of road, converting the intersection from signalized to unsignalized is considered, which in other words, unsignalized intersection will have less traffic delay and queue and the train will not affect intersection anymore. The intersection TS284 is selected as shown in Figure 21. To convert signalized intersection to unsignalized on Infraworks, all the phasing and timing need to be deleted. For unsignalized intersection, vehicles from North Morphett Road must give way to the vehicle from North Diagonal Road, from North Diagonal Road to South Diagonal Road it is free flow. The lane for North Morphett Road reduced from three to two because more lane for give way may cause safety hazard and more traffic delays. The number of lane on Diagonal Road set same as existing model. Intersection 117 will not be changed.

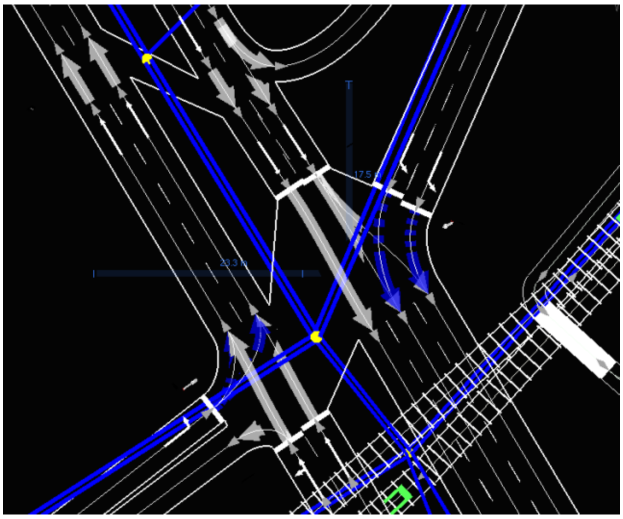


Figure 21. Unsignalized Model

6. Discussion

To find out the economic and environmental design, four different scenarios were simulated and compared with initial model in both SIDRA and Infraworks.

4.1 SIDRA model evaluation

The LOS for each road on each direction are compared in this section. For North Morphett Road, the LOS for existing model is E, which is pointed out as an issue of Oaklands Crossing. After grade separation and train go underpass the intersection, for DPTI design, the LOS is not changed, which in other words, the potential negative impact must be considered. Scenario 2 and scenario 3 shows additional lane on North Morphett Road or North Diagonal Road cannot solve the problem. However, the unsignalized design made a magnificent difference, the LOS increased from C to A, which means the vehicles on North Morphett Road will not be blocked and can run very smooth. It shows that unsignalized design has a significantly influence on North Morphett Road.

For North Diagonal Road, the LOS for existing situation is C. Compare with scenario 1, the LOS is same as before which means the grade separation does not have a big impact on North Diagonal Road. For scenario 2 and 3, the additional lane on North Morphett Road and Diagonal Road improved the LOS on North Diagonal Road, it increased from C to B. This is because the additional lane gives more space to vehicles to pass through and the number of vehicles on each lane decreased hence the LOS increased. For unsignalized design, it not only has an enormous impact on North Morphett Road, but also on North Diagonal Road. The LOS increased from C to A. This indicates additional lane will have positive effect and unsignalized design is even better on North Diagonal Road.

For Railway Terrace, this road does not have a big impact on general traffic because only few cars go through this road. But the grade separation still improved the performance from South Morphett Road to Railway Terrace. For all four scenarios, the LOS increased from E to A because no railway crossover.

For South Diagonal Road, the LOS for all 4 future scenarios are same as the existing design, which is level C, this is because for all 4 scenarios, the main change is focused on Oaklands Crossing, which is TS284 not TS117.

For South Morphett Road, the LOS for existing model is E because the vehicles from southbound drive to north are delayed by Oaklands Crossing. For DPTI design, the LOS for South Morphett Road is still the same because the LOS for North Diagonal Road is the same. For scenario 2 and 3, LOS increased from E to C, which in other words, the additional lane has a large impact on South Morphett Road. Surprisingly, LOS for scenario 4 only slightly increased from E to D. LOS for all different scenarios are shown in Appendix A.

To make the situation clearer, Table 8 shows the output value for existing model and future model in 4 different scenarios in SIDRA network. As shown in the table, the average travel speed increased in all 4 scenarios. Scenario 4 has the fastest travel speed in the future. The delay time all reduced and scenario 4 has the shortest delay time. For emission, scenario 1, 2 and 3 have similar amounts whereas scenario 4 has the smallest amount of emission. Because other components of emission only have small percentage and did not change a lot in the future, so they are not counted in.

Table 8. SIDRA Evaluation

SIDRA	Existing	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Travel Speed (km/h)	30.7	31	34.6	35	37.3
Delay (veh-h/h)	91.05	88.85	69.59	67.65	57.37
Emission - CO2 (kg/h)	1598.3	1568.7	1518.9	1501.4	1364.3

To sum up, unsignalized design has the most significant impact on Oaklands Crossing, an additional lane slightly impacting the traffic around. By using unsignalized intersection, vehicles will not waiting for a long time at the intersection hence the amount of emission is less. The scenario with grade separation only has minimum influence. In this case, unsignalized design is the most suitable design for traffic concern based on SIDRA evaluation and it is the most environmentally positive design.

4.2 Infraworks Evaluation

According to SIDRA which mainly focuses on Intersection analysis to evaluate the most economic and environmental model for entire network around Oaklands Crossing, Infraworks is required. 4 scenarios were simulated and result can be found from output file. To evaluate economic model, the economic evaluation report is reviewed; to evaluate environmental model, the report for vehicle detail is reviewed, to compare existing models and 4 future models, it is easier to use the normalized data from the economic evaluation report, which is shown in Table 9. The full evaluation table for existing model and four future scenario is in Appendix B.

Table 9. Normalized economic evaluation report

Infraworks	Count	Time	Speed	Stops	Delay	Total Cost
		(h:m:s)	(km/h)		(h:m:s)	($)
Existing	1000	24.305	18.408	1029.019	17.487	848.096
Scenario 1	1000	20.945	21.346	894.37	13.89	747.184
Scenario 2	1000	20.987	21.286	912.377	14.004	750.415
Scenario 3	1000	21.068	21.203	902.945	14.071	751.231
Scenario 4	1000	19.485	22.916	838.04	12.489	703.522

The results indicate the travel time, travel speed, number of stops, delay time and total cost for every thousand vehicles. Compared with existing situation, all future models that finished grade separation use less time to travel through, vehicles can travel faster, a smaller number of stops, delay time reduced and total cost reduced. The total cost is the sum of distance cost, time cost and stops cost. Compared between 4 scenarios, add an additional lane on Diagonal Road take longest time to travel, which is 21 second. The unsignalized intersection design has less travel time, because there is no phasing and timing at that intersection, which make vehicles go continually. For DPTI design and additional lane on North Morphett Road and Diagonal Road design, the travel speed is similar whereas the DPTI design has slightly faster speed than the other two. The additional lane made road wider but also resulted in more vehicles to manage, it will affect vehicles when they change lane or indicate. This can be applied to the number of stops and delay time as well. Scenario 1 has less stops and less delay time than scenario 2 and 3, therefore, the total cost of scenario 1 is less than scenario 2 or scenario 3. On the other hand, build additional lane requires more money to construct. It will also take longer to build than just do grade separation. Scenario 4 has highest travel speed, least stops, shortest delay time and least cost. In this case, scenario 4 has the best value because it cost less than other 3 scenarios.

Compared with existing models, for every thousand vehicles, unsignalized intersection design can save 4.8 seconds on the road, it travels 4.5 km/h faster than before, reduced about 191 stops for vehicles, also saved nearly 5 seconds on delay time and it saved $145. Based on 42,000 vehicles pass through Oaklands Crossing every day, the benefit is significant. Everyday it will save nearly 200 seconds on the road, reduced around 8,000 stops totally, and reduce 210 seconds delay time. It can save $6,090.00 every day. For DPTI design, it can save about

$4,238 per day; for additional lane on North Morphett Road it can save $4,100 per day; for additional lane on Diagonal Road it can save $4,068 in a single day. Therefore, the unsignalized intersection design is the most economic model in 4 scenarios.

The increasing of traffic volume need to be considered as well. In 20 years, the traffic volume will be increased, therefore another result based on 10% increased traffic volume is reviewed. the unsignalized intersection design will use 22 seconds, speed will be 19.6 km/h, stops will be 950, delay time will be 16 seconds and total cost will be $801 per thousand vehicle. Compared with the existing design, it saved 1.8 second, 55 stops reduced, saved 2 seconds for delay time and saved $47. For 42,000 vehicles it saved 80 seconds on the road, around 2 thousand stops, saved 88 seconds and saved $1973 every day.

However, the limitation of this scenario is that unsignalized intersection is not safe for pedestrians who want to cross over or bicycles. One of the solutions is to build a footpath and cycle path underpass the intersection, which means on the side of road way, so people and bicycles can go across the intersection safely. For the other 3 future scenarios, based on they are all signalized, so there will be a phase for pedestrian and cycles to cross over and this will take less time than people go underpass. Another solution is to build the unsignalized intersection as a roundabout, it can improve the safety for pedestrians but it may increase the traffic delay time and number of vehicle stops. By time consuming and lack of time on software study, the roundabout design is not built in SIDRA or Infraworks.

For Oaklands Crossing project, DPTI website mentioned that the Australian Government invested around $95 million, the State Government invested around $74 million and the City of Marion Council invested about $5 million. If the traffic volume is stable and does not change in 20 years, by using the unsignalized intersection design, it will require 42 years to pay back for the Australian Government, 33 years for the State Government and 2 years for the City of Marion Council. If the traffic increased by 10% in 20 years, it will use 132 years to pay back for the Australian Government, 103 years for the State Government and 7 years for the City of Marion Council.

7. Conclusion

For Oaklands Crossing, the railway underpass the road design is used. By comparing and evaluating four different scenarios, which are just grade separation design, additional lane on North Morphett Road design, additional lane on Diagonal Road design and unsignalized design, the best scenario is the unsignalized design. It is the most environmentally appropriate and economic design. The carbon dioxide emission reduced 234 kg/h. By same traffic volume in the future, it saved about $6,072 per day and will pay back the Australian Government, the State Government and the City of Marion Council in 50 years. If the traffic volume increases by 10% in future, it will pay back the Australian Government and the State Government around 100 years and will pay back the City of Marion Council in less than 10 years. This project will create lots of job opportunities and when it is finished, it will enormously enriched local resident's life and attract the attention from the public to invest on local business. The Oaklands Crossing grade separation will also make an easier way to go to Marion Shopping Centre.

In conclusion, the Oaklands Crossing grade separation project will be more environmentally responsible than before and cost less on the road. It can also stimulate the economy around, local business such as Westfield Hotel, Marion Shopping centre will have great benefit. The railway and footpath go underpass the Oaklands intersection will improve safety level for pedestrians and drivers and avoid safety hazards. Therefore, the solution of the traffic delay issue, business concern and safety hazard issue can be solved economically and environmentally.

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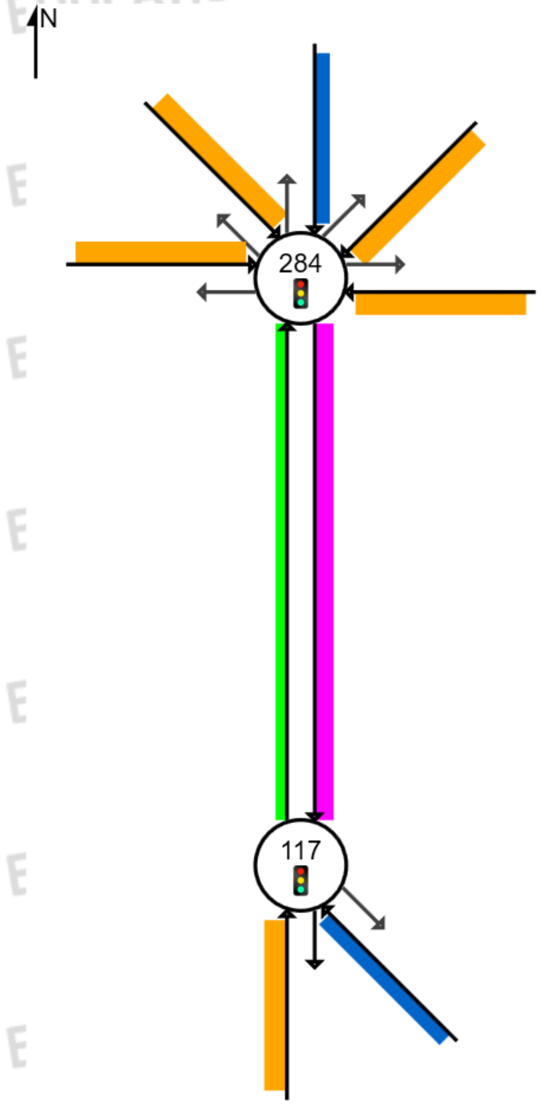
Appendix A

Level Of Service for Existing Model and 4 Future Model

Approach Level of Service for Network Sites

Network: N101 [Existing]

New Network
Network Cycle Time = 120 seconds (Network Cycle Time - User-Given)



Colour code based on Level of Service

LOS A | LOS B | LOS C | LOS D | LOS E | LOS F | TWSC Major Rd (HCM LOS Rule)

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Network tab).

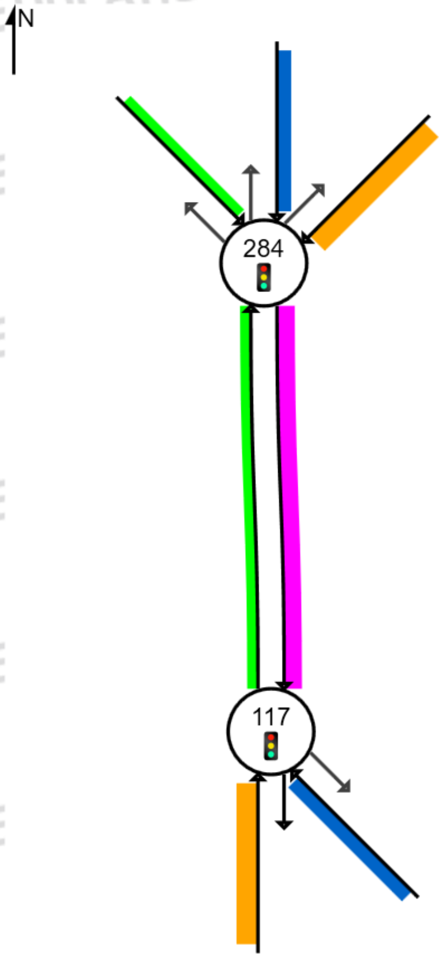
Figure A1. LOS for existing model

APPROACH LEVEL OF SERVICE

Approach Level of Service for Network Sites

Network: N101 [Future 1]

New Network
Network Cycle Time = 120 seconds (Network Cycle Time - User-Given)



Colour code based on Level of Service

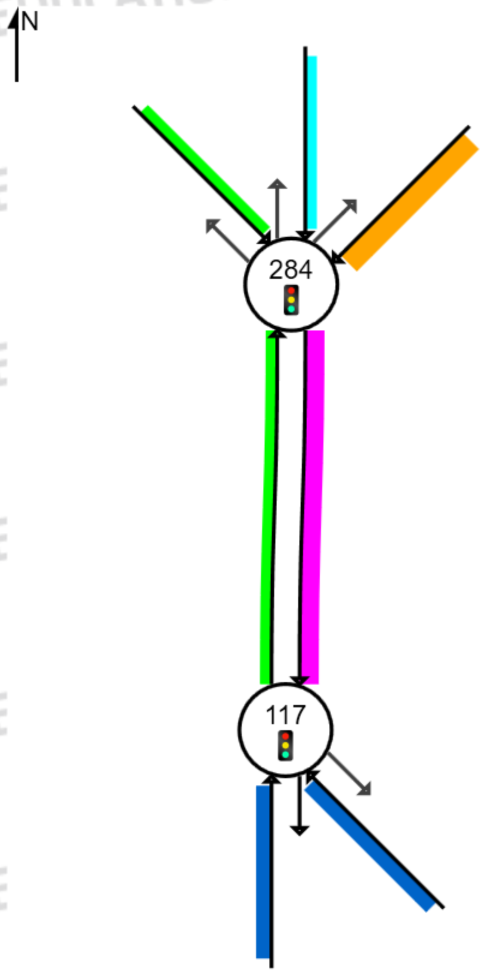
LOS A | LOS B | LOS C | LOS D | LOS E | LOS F | TWSC Major Rd (HCM LOS Rule)

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Network tab).

Figure A2. LOS for future scenario 1

Network: N101 [Future 2]

New Network
Network Cycle Time = 100 seconds (Network Cycle Time - User-Given)



Colour code based on Level of Service

LOS A | LOS B | LOS C | LOS D | LOS E | LOS F | TWSC Major Rd (HCM LOS Rule)

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Network tab).

Delay model settings are specified for individual Sites forming the Network.

Figure A3. LOS for future scenario 2

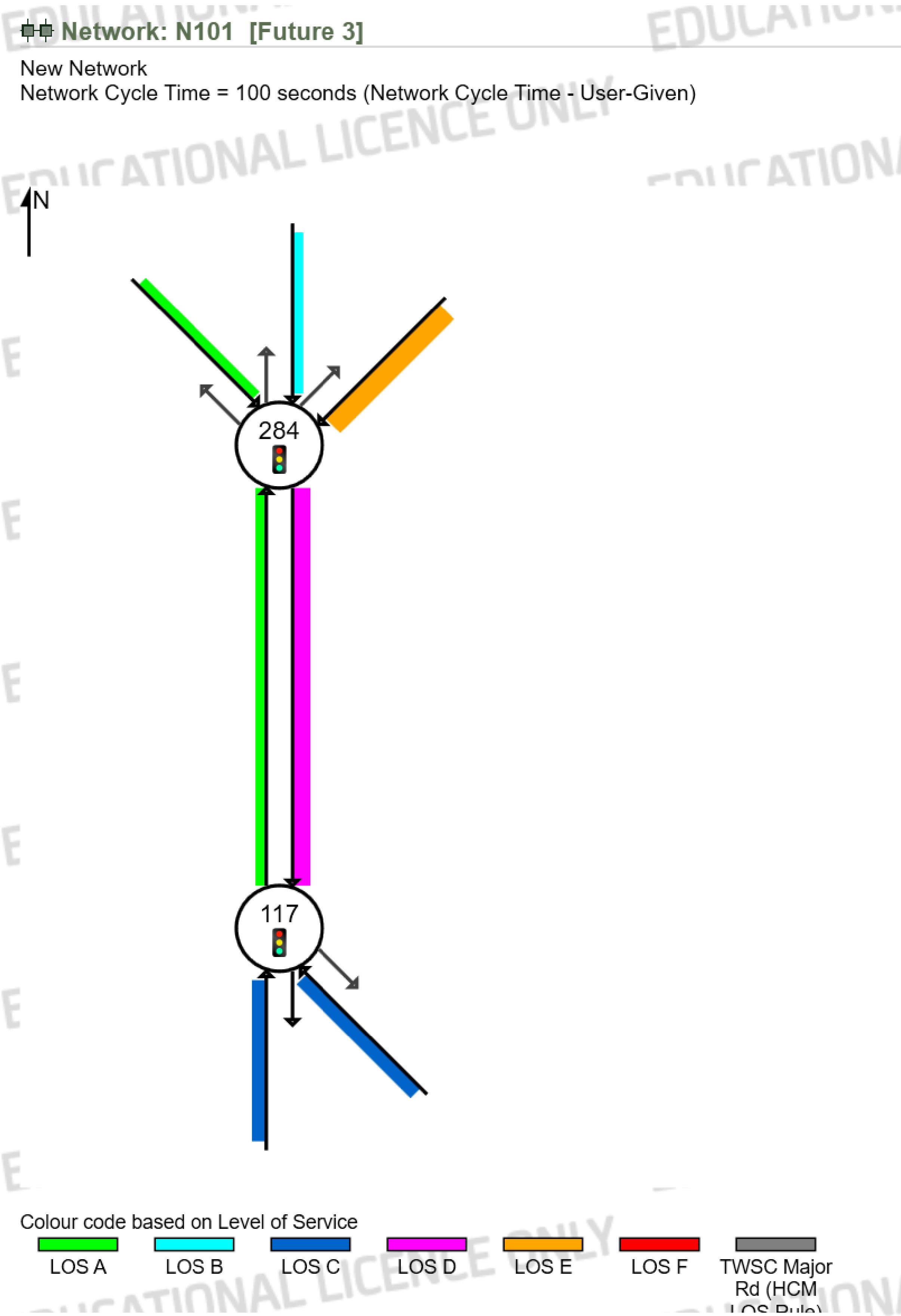
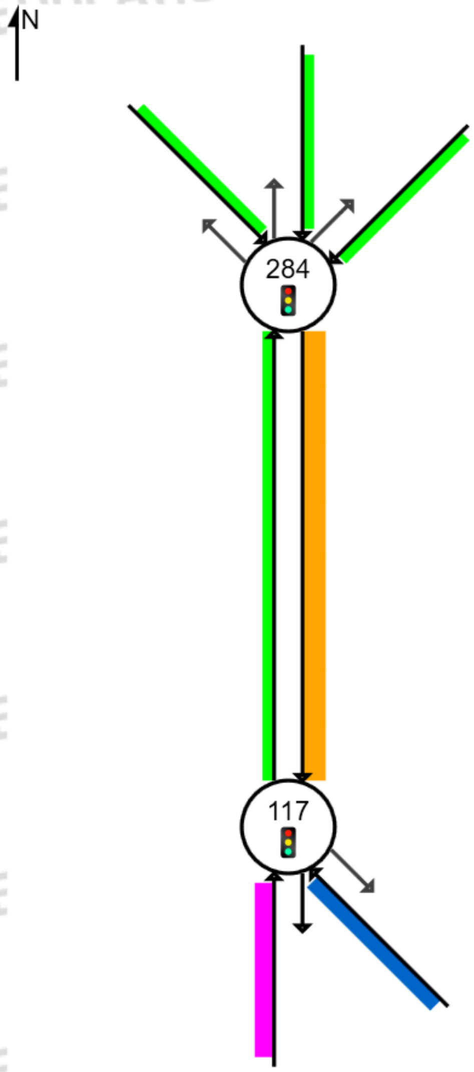


Figure A4. LOS for future scenario 3

Network: N101 [Future 4]

New Network
Network Cycle Time = 100 seconds (Network Cycle Time - User-Given)



Colour code based on Level of Service

LOS A | LOS B | LOS C | LOS D | LOS E | LOS F | TWSC Major Rd (HCM LOS Rule)

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Network Data dialog (Network tab).

Delay model settings are specified for individual Sites forming the Network.

Figure A4. LOS for future scenario 4

Appendix B

Economic Evaluation Report

Existing Model

Table B1. Economic report for existing model

Subtitle	Design Opt										
Simulation	C:/Users/n										
Model run	Fri Sep 07										
Simulation	25 / 06 / 2				Last Clear:		11:00:00.0		Version:		6.00.006
Simulation	11:00 to 1				This Save:		12:00:00.0				
		Count	Distance	Time	Speed	Stops	Delay	Distance C	Time Cost	Stops Cost	Total Cost
			(km)	(h:m:s)	(km/h)		(h:m:s)	($)	($)	($)	($)
Complete	Total	4475	2004.413	105.291	19.037	4594	74.42	501.103	2632.281	574.25	3707.634
	Mean		0.448	00:01:24		1.027	00:00:59	0.112	0.588	0.128	0.829
	Std Dev		0.112	00:02:22		0.878	00:02:20	0.028031	0.992	0.11	1.003
All Trips	Total	4581	2049.518	111.34	18.408	4713.937	80.107	512.38	2783.504	589.242	3885.125
	Mean		0.447	00:01:27		1.029	00:01:02	0.112	0.608	0.129	0.848
	Std Dev		0.112	00:02:30		0.881	00:02:28	0.028103	1.045	0.11	1.053
All (Norma	Total	1000	447.395	24.305	18.408	1029.019	17.487	111.849	607.619	128.627	848.096

Scenario 1 – DPTI design

Table B2. Economic report for future scenario 1

Title	Economic										
Subtitle	Design Opt										
Simulation	C:/Users/n										
Model run	Fri Sep 07										
Simulation	25 / 06 / 2				Last Clear:		08:00:00.0		Version:		6.00.006
Simulation	08:00 to 0				This Save:		09:00:00.0				
		Count	Distance	Time	Speed	Stops	Delay	Distance C	Time Cost	Stops Cost	Total Cost
			(km)	(h:m:s)	(km/h)		(h:m:s)	($)	($)	($)	($)
Complete	Total	4481	2005.852	92.012	21.8	3981	60.057	501.463	2300.3	497.625	3299.388
	Mean		0.448	00:01:13		0.888	00:00:48	0.112	0.513	0.111	0.736
	Std Dev		0.112	00:01:31		0.804	00:01:28	0.028057	0.638	0.1	0.659
All Trips	Total	4581	2048.07	95.948	21.346	4097.107	63.632	512.018	2398.692	512.138	3422.848
	Mean		0.447	00:01:15		0.894	00:00:50	0.112	0.524	0.112	0.747
	Std Dev		0.112	00:01:36		0.81	00:01:33	0.028084	0.668	0.101	0.686
All (Norma	Total	1000	447.079	20.945	21.346	894.37	13.89	111.77	523.618	111.796	747.184

Scenario 2 – Additional lane on North Morphett Road

Table B3. Economic report for future scenario 2

Title	Economic										
Subtitle	Design Opt										
Simulation	C:/Users/n										
Model run	Tue Oct 09										
Simulation	25 / 06 / 2				Last Clear:		08:00:00.0		Version:		6.00.006
Simulation	08:00 to 0				This Save:		09:00:00.0				
		Count	Distance	Time	Speed	Stops	Delay	Distance C	Time Cost	Stops Cost	Total Cost
			(km)	(h:m:s)	(km/h)		(h:m:s)	($)	($)	($)	($)
Complete	Total	4481	2004.9	92.208	21.743	4063	60.576	501.225	2305.188	507.875	3314.288
	Mean		0.447	00:01:14		0.907	00:00:48	0.112	0.514	0.113	0.74
	Std Dev		0.112	00:01:31		0.821	00:01:28	0.02804	0.639	0.103	0.66
All Trips	Total	4581	2046.477	96.143	21.286	4179.6	64.154	511.619	2403.582	522.45	3437.651
	Mean		0.447	00:01:15		0.912	00:00:50	0.112	0.525	0.114	0.75
	Std Dev		0.112	00:01:36		0.827	00:01:33	0.02805	0.668	0.103	0.686
All (Norma	Total	1000	446.732	20.987	21.286	912.377	14.004	111.683	524.685	114.047	750.415

Scenario 3 – Additional lane on Diagonal Road

Table B4. Economic report for future scenario 3

Title	Economic I										
Subtitle	Design Opt										
Simulation	C:/Users/n										
Model run	Tue Oct 09										
Simulation	25 / 06 / 2				Last Clear:		08:00:00.0		Version:		6.00.006
Simulation	08:00 to 0				This Save:		09:00:00.0				
		Count	Distance	Time	Speed	Stops	Delay	Distance C	Time Cost	Stops Cost	Total Cost
			(km)	(h:m:s)	(km/h)		(h:m:s)	($)	($)	($)	($)
Complete	Total	4483	2005.733	92.636	21.652	4029	60.945	501.433	2315.888	503.625	3320.946
	Mean		0.447	00:01:14		0.899	00:00:48	0.112	0.517	0.112	0.741
	Std Dev		0.112	00:01:32		0.803	00:01:28	0.028014	0.639	0.1	0.66
All Trips	Total	4581	2046.33	96.51	21.203	4136.389	64.461	511.583	2412.758	517.049	3441.389
	Mean		0.447	00:01:15		0.903	00:00:50	0.112	0.527	0.113	0.751
	Std Dev		0.112	00:01:36		0.808	00:01:33	0.02803	0.669	0.101	0.686
All (Norma	Total	1000	446.699	21.068	21.203	902.945	14.071	111.675	526.688	112.868	751.231

Scenario 4 – Unsignalized Intersection

Table B5. Economic report for future scenario 4

Title	Economic I										
Subtitle	Design Opt										
Simulation	C:/Users/n										
Model run	Fri Sep 14										
Simulation	25 / 06 / 2				Last Clear:		08:00:00.0		Version:		6.00.006
Simulation	08:00 to 0				This Save:		09:00:00.0				
		Count	Distance	Time	Speed	Stops	Delay	Distance C	Time Cost	Stops Cost	Total Cost
			(km)	(h:m:s)	(km/h)		(h:m:s)	($)	($)	($)	($)
Complete	Total	4490	2007.309	85.492	23.479	3743	53.781	501.827	2137.303	467.875	3107.005
	Mean		0.447	00:01:08		0.834	00:00:43	0.112	0.476	0.104	0.692
	Std Dev		0.112	00:01:31		0.817	00:01:28	0.028054	0.637	0.102	0.656
All Trips	Total	4581	2045.518	89.263	22.916	3839.062	57.213	511.379	2231.572	479.883	3222.834
	Mean		0.447	00:01:10		0.838	00:00:44	0.112	0.487	0.105	0.704
	Std Dev		0.112	00:01:36		0.823	00:01:33	0.028033	0.668	0.103	0.683
All (Norma	Total	1000	446.522	19.485	22.916	838.04	12.489	111.631	487.136	104.755	703.522

Unsignalized Intersection with 10% increased traffic volume in the future

Table B6. Economic report for future scenario 5

Title	Economic I										
Subtitle	Design Opt										
Simulation	C:/Users/n										
Model run	Tue Oct 09										
Simulation	25 / 06 / 2				Last Clear:		08:00:00.0		Version:		6.00.006
Simulation	08:00 to 0				This Save:		09:00:00.0				
		Count	Distance	Time	Speed	Stops	Delay	Distance C	Time Cost	Stops Cost	Total Cost
			(km)	(h:m:s)	(km/h)		(h:m:s)	($)	($)	($)	($)
Complete	Total	4771	2150.657	109.944	19.561	4469	76.039	537.664	2748.597	558.625	3844.886
	Mean		0.451	00:01:22		0.937	00:00:57	0.113	0.576	0.117	0.806
	Std Dev		0.107	00:01:38		0.899	00:01:35	0.026709	0.684	0.112	0.72
All Trips	Total	5002	2234.784	114.182	19.572	4751.39	79.927	558.696	2854.539	593.924	4007.159
	Mean		0.447	00:01:22		0.95	00:00:57	0.112	0.571	0.119	0.801
	Std Dev		0.111	00:01:40		0.895	00:01:37	0.027713	0.697	0.112	0.73
All (Norma	Total	1000	446.778	22.827	19.572	949.898	15.979	111.695	570.68	118.737	801.111