# The effect of different electric vehicle proportion uptake on different intersections

By

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# ABSTRACT

Electric vehicle (EV) adoption is increasing, which presents both advantages and challenges for urban transportation systems. An important place for EV adoption in transportation networks is at intersections. This study examines how different electric vehicle (EV) usage percentages impact different intersection types while considering factors like traffic volume, congestion, energy use, and environmental effects. Investigating how different levels of EV penetration affect intersection performance and sustainability, the study combines actual research with simulation modelling with tools such as SIDRA and Aimsun.

This article highlights a variety of information on the relationship between electric vehicles (EVs) and urban transportation systems, based on a thorough literature assessment to highlight the complex connections between EV adoption rates, traffic behaviour, and infrastructure requirements. The study wants to provide important insights into the possible advantages and difficulties related to the increasing number of EVs at intersections using the analysis of data from real-world traffic scenarios and the performance of scenario-based simulations.

The results of this study add to our knowledge of how EV adoption could impact traffic patterns and urban mobility. The results indicate that increasing the percentage of electric vehicles (EVs) at intersections can result in lower emissions and energy usage, particularly when paired with renewable energy sources for the infrastructure required for charging.

The project explores various methods for optimising intersection processes in response to different levels of EV uptake using considerable analysis and different scenario. This includes evaluating how effectively traffic method, intersection design, and different phasing and timing work to accept EVs while maintaining smooth traffic flow and reducing congestion.

# DECLARATION

*I certify that this thesis 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*

Signed **Kaushik Anghan**

Date **23rd May 2024**

Supervisor - Dr. Nicholas Holyoak

Signed –

Date - 26th July 2024

# ACKNOWLEDGEMENTS

I want to start by sincerely thanking Professor Nicholas Holyoak, who is my supervisor. He has helped me navigate the research process, which presented a significant obstacle for me. Even though the paths have altered significantly, his patience and knowledge encouraged me to continue attempting the important but difficult tasks in transport planning and operation.

I am also fortunate to have Professor Branko Stazic, who taught me two transportation topics transport system engineering and transport planning and modelling; provide technical assistance in using transport planning programmes like 12D, Sidra, and Aimsun. Students frequently referred to him as their "non-official working hours professor" because of how quickly he responded to them. In the fields of using different software application and transportation planning and modelling, he is an inspiration.

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# 1. INTRODUCTION

## 1.1 Background

The integration of electric vehicles (EVs), which provide greener and more sustainable alternatives to conventional fossil fuel-powered vehicles, is causing a rapid evolution in transportation system engineering. The main benefit and considerations in adopting electric vehicles (EVs) into transportation networks are examined in this research. The design, development, and implementation of effective, secure, and environmentally friendly transportation networks are all included in the field of transportation systems engineering. In comparison to internal combustion engine vehicles, electric vehicles (EVs) offer a cleaner and more ecologically responsible way of transportation, bringing about a revolutionary transformation in the transportation sector. (United Nations, 2019)

The engineering of transportation systems has taken on a new dimension with the advent of electric vehicles. Because EVs employ electric motors driven by rechargeable batteries instead of conventional internal combustion engines, they drastically reduce greenhouse gas emissions and dependency on fossil fuels. The move to electrification led to advancements in energy management systems, vehicle design, and infrastructure. (Jidi Cao, 2021)

## 1.2 Case Study

This study investigates the impact of varying proportions of electric vehicle (EV) uptake on traffic flow and intersection performance in Adelaide, South Australia. By examining one of the city's busiest corridors, we aim to provide insights into how increasing EV adoption affects urban traffic dynamics, particularly during peak hours.

For this analysis, we selected four of the busiest intersections in the city, specifically focusing on peak morning and evening hours. These intersections were chosen based on vehicle volume data and peak time considerations, ensuring a comprehensive understanding of traffic flow during critical periods. The selected intersections are located along a key route that connects the city centre to the Northeast residential area, a vital corridor for daily commuters traveling from outer suburbs to the city for work in the morning and returning in the evening.

Figure 1 shows the study route between the four intersections from TS078 to TS075, and Figure 2 shows the study route location from the city centre in Adelaide city.

Here the intersections are following with the intersection id and road name:

- TS075 – (North Terrace - Payneham Road)
- TS076 – (Payneham Road)
- TS077 – (Payneham Road)
- TS078 – (Payneham Road – Lower Northeast Road)

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**Figure 1 Intersection route details for the case study.**

The study focuses on morning peak hours from 8 AM to 9 AM, with variations depending on specific intersection dynamics. This timeframe is critical as it represents the influx of vehicles into the city for business and work, and the evening peak when commuters return to their residential suburbs.

**Study Route:**

- **Morning Peak:** In the morning, vehicles travel from outer suburbs into the city, contributing to significant congestion along Payneham Road and intersecting routes.
- **Evening Peak:** In the evening, the traffic flow reverses as commuters leave the city centre and head towards Northeast and nearby suburban areas.

The primary objective is to assess how different levels of EV adoption impact these intersection's performance. By analysing traffic data and using simulations, the study aims to provide recommendations for optimizing traffic management and infrastructure to support increasing EV proportions, ultimately contributing to a more sustainable urban transport system in Adelaide.

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**Figure 2 Highlighted study route in the Adelaide city, this route connects the city centre and Northeast area of city**

## 1.3 Study about intersection

The selection of the four intersections for this case study is based on several key traffic metrics: vehicle flow, saturation flow, queue length, and the overall busyness of the route. These metrics are crucial for evaluating the effectiveness of different EV uptake levels on traffic management and sustainability. The goal is to identify ways to reduce queue lengths and promote a more sustainable urban environment. The study focuses on the morning peak hours from 8 AM to 9 AM, which is the busiest time as people commute to the city centre for work. During this period, Payneham Road from TS078 to TS075 experiences significant traffic congestion. The data for each intersection is collected in real-time from the actual site using the JCT application, which calculates saturation flow and queue length for each approach at every intersection.

**Detailed Route Analysis:**

- **TS078 to TS077:** Vehicles enter from TS078, and the traffic continues towards TS077. At TS077, vehicles either proceed straight towards TS076 or turn right onto Lower Portrush Road.
- **TS076 to TS075:** At TS076, most vehicles head straight towards TS075. This flow primarily consists of vehicles from TS077, but also includes additional vehicles entering from Stephen Terrace, all moving towards TS075.

### 1.4 Purpose of study

This research aims to compare the results between internal combustion engine and electric vehicle for fuel and emissions.

There for the objective of the research is,

- Research about the transportation planning.
- Research about fuel and emissions data for the Internal combustion engine and electric vehicle.
- Research about the vehicle data of the selected intersection.
- Calculate the saturation flow and queue length.
- Investigate SIDRA model for the desired output.
- Combine the output and assess the outcomes.
- Restriction on this research project.
- Recommend future study.

# 2. LITERATURE REVIEW

It's widely accepted that sales of electric vehicles are rising rapidly. Multiple studies, such as the Global EV Outlook from the International Energy Agency, indicate that there are more electric vehicles on the road. (IEA, 2020). The growth of electric vehicles has increased demand for EV charging facilities which is frequently placed carefully close to urban intersections to maximise accessibility. (Axsen, 2014). In urban crossings, traffic regulation requires extra consideration due to the increasing number of electric vehicles. One of the features that defines electric vehicles (EVs) apart from other kinds of vehicles is their less disruptive operation when compared to vehicles with internal combustion engines. Many research investigations have investigated how electric cars (EVs) impact the acoustics of intersections. (Kaar, 2013). The necessity of visible traffic signals and pedestrian safety may be impacted by this influence. According to research, there will be more than 10 million electric cars on the road worldwide in 2020, which will result in a significant change in the transportation sector (IEA, 2020).

Electric vehicle (EV) microsimulation at intersections has become an important tool for assessing how electric mobility may affect infrastructure and traffic patterns. The integration of electric cars (EVs) into microscopic traffic simulation models is the subject of research by (Ahn, 2019), which considers several variables such vehicle features, charging behaviour, and interaction with conventional vehicles. Their research shows how important it is to accurately model features unusual to electric vehicles (EVs), such as energy consumption patterns and acceleration profiles, to fully represent the different characteristics of electric transportation at intersections. Similarly, (Wang, 2021) Wang et al. research how to evaluate EV performance at signalised crossings using microsimulation, highlighting how EVs can impact intersection ability, energy demand, and delay. Research may learn more about how electric and conventional vehicles collaborate, influence infrastructure planning, and facilitate the move to electric transportation in cities by including EV-specific factors to microsimulation models. Governments and transportation experts can use the insights acquired from microsimulation-based research to plan for sustainable urban mobility and build infrastructure. These studies also offer important information about the complex interactions of EVs at crossings. Electric vehicles (EVs) produce zero tailpipe emissions, reducing air pollution and reliance on fossil fuels. Their fuel consumption depends on the source of electricity, but overall, EVs are more energy-efficient and environmentally friendly compared to traditional internal combustion engine vehicles.

The Impact of Intersection Control on Battery Electric Vehicle Energy Consumption study examined the way various intersection monitors, like a stop sign, traffic signal, and roundabout, impacted the energy and fuel consumption of internal combustion engine vehicles (ICEVs) and electric vehicles (EVs). The second-by-second speed profiles of every vehicle were supplied by a traffic simulation model, and these were utilised as inputs to estimate the energy and fuel consumption of ICEVs and EVs using microscopic fuel and energy models. The ICEVs' higher fuel consumption levels at roundabouts were brought on by their acceleration as they exited the roundabout, since acceleration rate is a significant determinant in vehicle fuel consumption. Compared to ICEVs, electric vehicles' energy use was less impacted by the intersection's control system. This makes sense because electric vehicles regenerated energy when they decelerated; at the roundabout, travelling at 88 km/h, they did so by regenerating 32.9% of their total energy, improving overall energy efficiency. (Kyoungho Ahn, 2020).

In transportation management, conventional signal-controlled intersections have been essential. Alternative designs for intersections, however, are becoming more popular. For example, roundabouts have proven to have the ability to optimise traffic flow, lower accident rates, and raise general safety (Davies, 2018). Advanced traffic management technologies at smart intersections allow for flexibility in response to changing traffic conditions (Xu, 2016). According to research by Monigl, Keegan, and Obrecht (Monigl, 2018), smart intersections adaptability and flexibility can be especially helpful for meeting the special requirements of electric vehicles. Case studies from different places offer useful information about how EVs and intersection layouts interact. For example, a trial project in Oslo, Norway, that combined adaptive traffic management systems and infrastructure for charging electric vehicles with the goal of reducing traffic congestion, showed potential in improving traffic flow (Shaheen, 2019). The implementation of electric vehicle charging facilities in roundabouts in London has transformed the operation of these crossroads, demonstrating the combination of traffic management and sustainability (Karamanis, 2019).

The uptake of electric vehicles (EVs) in Australia has gained momentum in recent years, driven by various factors including government policies, consumer incentives, and growing environmental awareness. Australian customers' increasing interest in electric vehicles (EVs) is highlighted by research by (Stephens, 2020), which has been prompted by concerns about air quality and climate change. The study also highlights how government initiatives, such tax incentives, and rebates, can encourage the use of electric vehicles. (Burke, 2019) study additionally investigates at how state-level policies impact the use of EVs in Australia, highlighting the importance of infrastructure development and supporting regulatory frameworks. But challenges including a poor infrastructure for charging and concerns about range remain to keep EV adoption from being widely accepted in the nation. The body of research indicates that so as to accelerate the adoption of electric vehicles in Australia, a combination of public education initiatives, infrastructure investment, and regulatory support is required.

To learn more about the complex connection between electric vehicles and intersections, researchers have started a few studies. Chen and Chan's (Chen, 2002) An analysis of how electric vehicles (EVs) impact traffic flow indicates that EVs have the potential to reduce traffic congestion and support improved traffic flow. Their results show that a range of vehicle characteristics, including as speeds and acceleration patterns, must be supported by crossings. These studies highlight the need for an integrated strategy that incorporates the development of charging infrastructure and intersection design. When it comes to EV adoption and intersection design, sustainability and environmental factors are important. According to research by Fulton, Liimatainen, and (Steenis, 2016), the environmental advantages of electric vehicles (EVs)—such as lower emissions and better air quality—align with metropolitan regions' more general sustainability goals. To fully achieve these advantages, intersection designs must take electric vehicle requirements into account. This includes installing charging stations that run on renewable energy. Providing renewable energy-powered charging stations is part of this. Policies and regulations have a significant influence on how electric cars (EVs) and urban intersections connect. Governments all around the world have put laws into place to promote the use of electric cars (EVs) and integrate electric mobility-friendly urban planning ideas. The Zero Emission Vehicle (ZEV) programme in California is one such initiative that aims to encourage automakers to produce more electric vehicles. (Sperling, 2009).

Urban transportation networks depend significantly on a number of traffic intersection types, each of which offers particular advantages and drawbacks for optimising transportation. The study conducted by (Akçelik, 2014) offers a thorough analysis of several intersection types, such as signalised, roundabout, and unsignalized intersections, highlighting their unique features and operational features. For example, traffic signals are used at signalised intersections to control vehicle flow, while roundabouts offer continuous flow with a smaller number of conflicts. In addition, studies conducted by (Li, 2020) and (Wu, 2017)) investigate innovative intersection designs and show how they could improve safety and traffic efficiency, such as diverging diamond interchanges and relocated left-turn crossings. To effectively construct and operate urban road networks, transportation planners and engineers must have a thorough understanding of the features and operational characteristics of various types of intersections. Cities can increase mobility, reduce traffic, and improve the overall performance of their transportation systems by optimising intersection layouts, signal timings, and traffic control methods.

Both SIDRA and AIMSUN are widely used software tools in transportation engineering for traffic analysis and simulation. There are some considerations to choose SIDRA for the transportation design and AIMSUN for the Simulation visualize.

Traffic signal optimisation and intersection analysis are the two main applications of SIDRA. Its main objective is to evaluate the operation of roundabouts, networks of intersections, and signalised and unsignalized intersections. By using defined input factors including traffic volumes, lane configurations, signal timings, and intersection geometry features, SIDRA analyses traffic flow in a systematic method. Roundabouts, unsignalized intersections, and signalised intersections are among the many of the intersection types that SIDRA can model in extensive detail. It provides analysis tools for Lane capacity, delay, queue lengths, level of service, cost, fuel, and emissions. SIDRA provides comprehensive reports and graphical outputs detailing intersection performance measures. It provides information on the effectiveness and operational efficiency of geometric design and signal timings. SIDRA's simplified procedure and user-friendly interface have made it suitable for transportation professionals of different skill levels. It provides users with thorough documentation and support resources. SIDRA is frequently used for intersection design optimisation, traffic effect studies, signal timing analysis, and intersection-level transportation planning. (SIDRA, 2020)

A software called AIMSUN is used to simulate traffic in small areas and is useful for modelling complicated transportation networks in detail. It enables the simulation of individual cars, people, and the ways in which they interact with a network. Using a microscopic simulation technique, AIMSUN simulates how individual cars and people would behave in a virtual setting. It takes into consideration factors like how drivers behave, how other cars interact, how to change lanes, and which route to take. In-depth traffic flow visualisations, such as vehicle routes, speed characteristics, queue dynamics, and congestion patterns, are produced by AIMSUN. For transportation planning and design, it makes extensive analysis of traffic operations, safety evaluations, and scenario testing simpler. Because of its complex characteristics and extensive modelling capabilities, AIMSUN is an useful instrument with a higher learning curve. It might call for more in-depth instruction and knowledge of the fundamentals of traffic simulation. Urban mobility planning, traffic management, intelligent transportation systems (ITS), public transportation operations, and urban development projects are just a few of the many uses for AIMSUN. To multimodal transportation planning and analysis, AIMSUN facilitates integration with geographic information systems (GIS), traffic data sources, and simulation models. (aimsun, 2021)

# 3. METHODOLOGY

## 3.1Study area

This study has the potential to significantly transform transportation infrastructure and sustainable urban development by offering new perspectives on the evolving relationships between electric vehicles and intersection designs. Through intensive data collection, analysis, and modelling, this project seeks to provide meaningful information that resonates with the evolving transportation context and impacts the future of urban mobility. Future research will focus on optimizing the travel time, reduce queue length, and preventing crash, increase the safety of pedestrians and drivers, and economical better. Also, this research will be helpful to the environmental sustainability to use renewable energy and decrease the fossil fuel uses.

## 3.2Model Building

To perform SIDRA modelling, we have a few steps to perform to complete the model building of each intersection. The Signal Control and Traffic Analysis Toolbox part, which makes it easier to analyse and optimise signalised intersections, is known to as SCATS data in SIDRA. Users can create and evaluate different signal control instances with the help of SCATS data, which contains parameters like signal timings, phasing, cycle lengths, and coordination strategies. Transportation experts can evaluate junction performance parameters like capacity, delay, queue lengths, and level of service by entering SCATS data into SIDRA. For safer and more effective urban mobility, this research helps optimise signal control methods, improve overall intersection operations, and increase traffic flow efficiency. (Manager Traffic Integrity, 2023)

### 3.2.1 Data collection:

Collect necessary details about the intersections according to research, including traffic volume, vehicle types, intersection geometry, lane configurations, signal timings, and any other relevant data. We can get the vehicle volume data from the SCATS count and there are some data like saturation flow and queue length are finding from the field visit. For the saturation flow we make a video of moving vehicle and after that we can calculate the saturation flow with help of JCT application and during the site visit we can calculate the queue length.

### 3.2.2 Intersection Details:

entering the geometric features, like the number of lanes, their widths, their turning radius, and any other features like bicycle paths or crossings for pedestrians, but here we have bus lane on intersection TS077, and we consider that no pedestrian during the phasing.

### 3.2.3 Traffic data input:

For each approach to the intersection, enter the traffic volumes, being specific about the number of vehicles, the kinds of vehicles (light vehicle, heavy vehicle, etc.), and the directions of the movements (left turns, through movements, right turn etc.). Depending on the needs of the analysis, I have entered hourly or daily traffic distributions or peak-hour traffic volumes. After adding the vehicle data, we need to set the priorities to vehicle movement to which vehicles needs to give away and which vehicles can be move first.

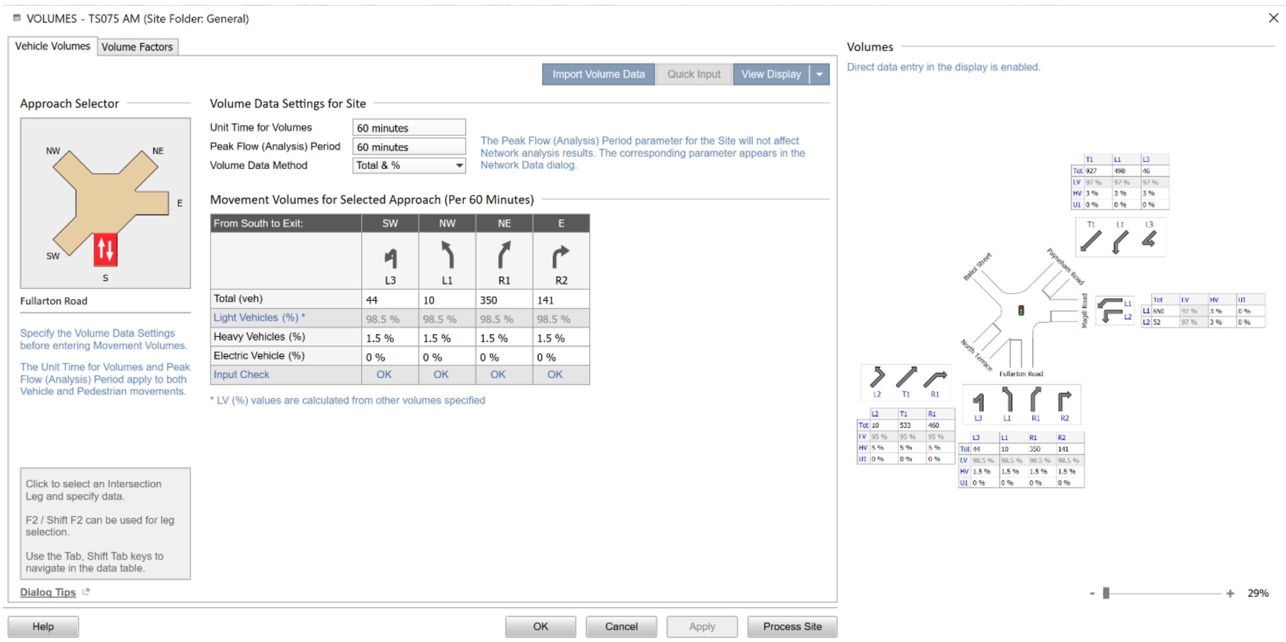



**Figure 3 Traffic intersection vehicle volume data**

### 3.2.4 Phasing and timing:

Phasing and timing are used for the design and optimize signal control for the intersection. It has the features of set the timing for the green, yellow, and red light to move traffic for time. In phasing and timing, we can set our timing in User given cycle time for signal timing based on traffic demand, peak hour patterns, and requirements of the intersection to minimize the delay and reduce the traffic flow and queue length.

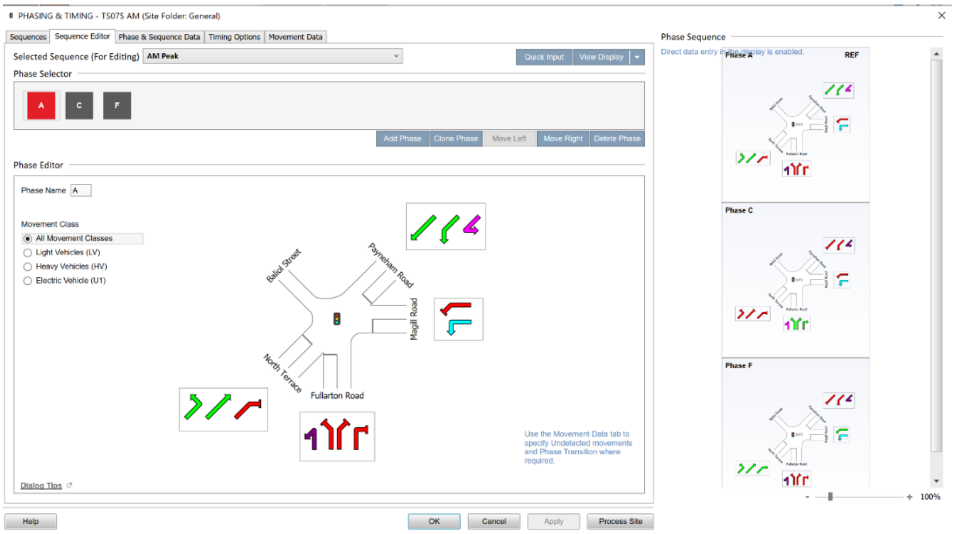



**Figure 4 Intersection phasing and timing**

### 3.2.5 Parameter setting:

Parameter setting is allowed to make changes in Model Parameters, Efficiency & Cost, and Fuel & Emissions to get results as per project requirements. Here, in the model parameters SIDRA give the default value of passenger car equivalent (pcu/veh) 1.0 as per shown Figure 5, but for the electric vehicle we are using 0.8 pcu/veh because electric vehicle has better acceleration power as compared to internal combustion engine vehicle. So, electric vehicle can pass through quicker than ICEVs.

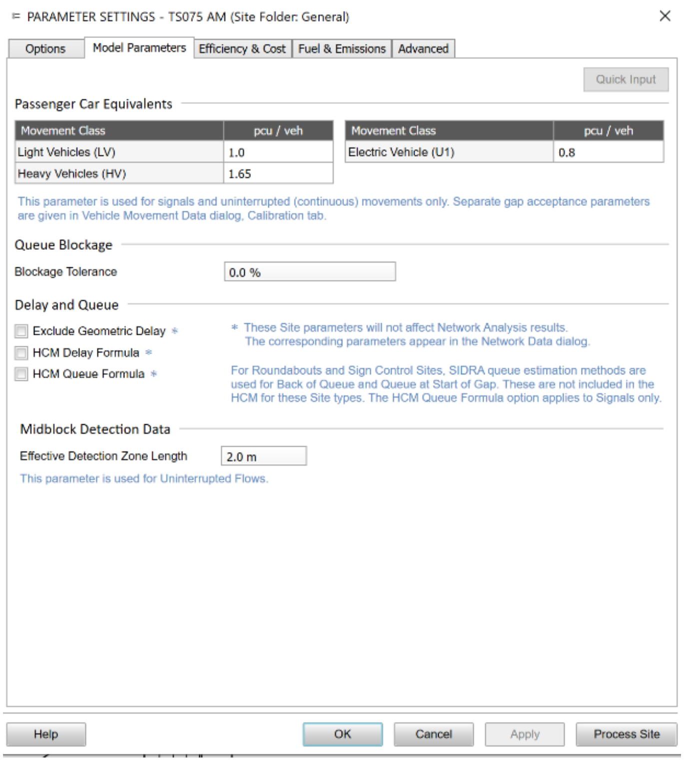



**Figure 5 Parameter setting of intersection**

After that need to change other value like Efficiency & Cost, but electric vehicles charging cost is cheaper than the fuel vehicle. There are so many ways to charge the electric vehicle and this cost are vary from the different method to charge the vehicle. Here, consider that there is no cost for the charge the electric vehicle, but from the green vehicle data of Australin Government there are different ways using for the generate the energy, this is given in Figure 28 in Appendices.

Electric vehicles (EVs) produce zero tailpipe emissions, reducing air pollution and reliance on fossil fuels. Their fuel consumption depends on the source of electricity, but overall, EVs are more energy-efficient and environmentally friendly compared to traditional internal combustion engine vehicles.

### 3.2.6 Calibration

To verify that the base case that is, the most recent valid data representing the current intersections properly represented in the model, calibration for SIDRA models requires verifying the input data. Surveys and site reports, plus additional sources of traffic data, could act as the foundation for the calibration process. The main components of this traffic signal data will include the following: traffic flow, saturation flow, phase sequences, green time splits, timing settings for all red, yellow, and pedestrian phases, as well as geometric factors.

### 3.2.7 Validation

Another evaluation that is separate from the calibration is provided by validation. To verify that the findings are accurate of the observed scenario, validation will use the calculated parameters in the base case model. The Degree of Saturation (DoS), delay, and the 95th percentile queue length on the methods are the primary metrics that need to be utilised. It shouldn't be required to conduct site surveys to determine the measured DoS values when approaches are known to be over-saturated during peak periods and the models represent this by calculating values above 0.9 DoS. On-site measurements of levels of saturation may be required for unsaturated sites to validate the model. The same JCT Traffic Tools application will also calculate DoS values from on-site measurements having established a valid saturation flow from measured data.

## 3.3 SIDRA model of intersections

SIDRA models of intersection are using for the evaluating traffic flow and performance. For the final intersection design need to be add all the data like as intersection geometry, traffic volume, vehicle movement, phasing, and timing. After adding all the data, the results are generating in SIDRA intersection outputs. Here below in Figure 6 to Figure 9, are shown that all four-intersection geometry design. In Figure 8, intersection TS077 have a bus lane on Payneham Road, and it is indicated as bus lane and this lane is different from another lane, red colour of the lane indicate that the bus lane in this intersection geometry drawing, and intersection TS078 have a two left turn road from the Payneham Road to lower northeast road. After completing the geometry design, we added the vehicle volume data and phasing details and select the practical cycle time for the model simulation.

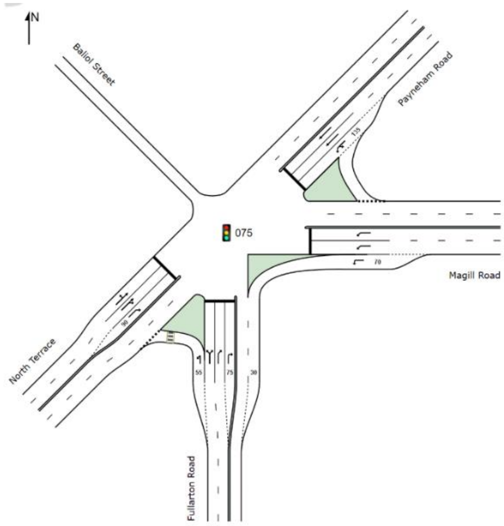



**Figure 6 Geometry of Intersection TS075**

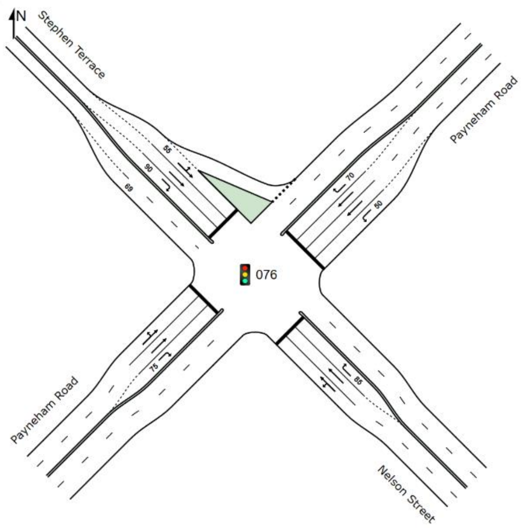



**Figure 7 Geometry of Intersection TS076**

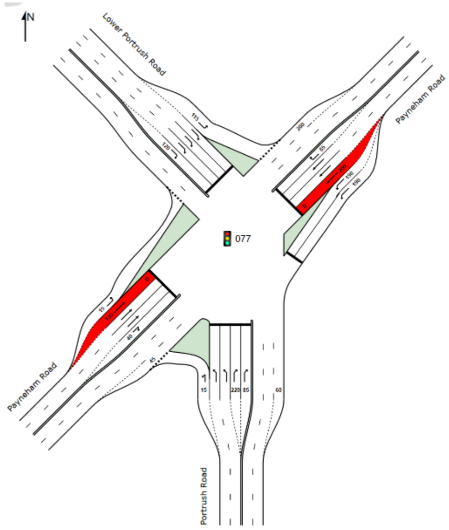



**Figure 8 Geometry of Intersection TS077**

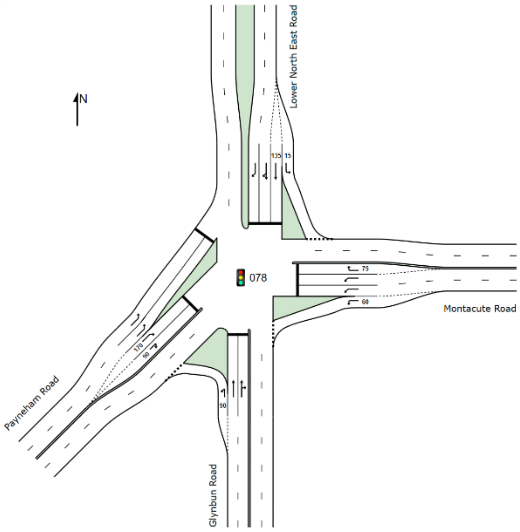



**Figure 9 Geometry of Intersection TS078**

## 3.4 Modelling Results

SIDRA modelling results provide comprehensive data about the intersection performance. It is providing crucial information for transportation planning, design, and optimisation. In the SIDRA modelling results below result are review, and in this research the main key results are control delay, queue length, total cost, fuel consumption and emissions:

- Travel Speed (km/h)
- Travel Time (veh-h/h)
- Control Delay (sec)
- Intersection Level of service (LOS)
- Queue Length (m)
- Total Cost ($/h)
- Fuel Consumption (L/h)
- Emissions (kg/h)

Data Review in SIDRA allows examining various inputs, parameters, and outputs to ensure the accuracy of the results, and reliability of each intersection modelling results. Reviewing the input data is crucial to ensure that all the information, such as intersection geometry, vehicle volume data, vehicle type, phasing and timing are entered accurately in the intersection data. Also, there are some changed the parameter setting when assessing the electric vehicle performance during the data review.

Review the results like average delay, fuel consumption, carbon emissions, and total cost. A comparison of all data with each intersection when 0% electric vehicle passing through the intersection is performed.

### 3.4.1 Control Delay (Average)

Control Delay in SIDRA is measured that vehicle spend time at a signalized intersection due to traffic control measure such as phasing, vehicle queue length and cycle time of the phasing. SIDRA calculates control delay based on various factors like as vehicle volume, signal cycle time, intersection geometry design, and vehicle movement. Here, in Figure 7 show that the average control delay of each intersection.

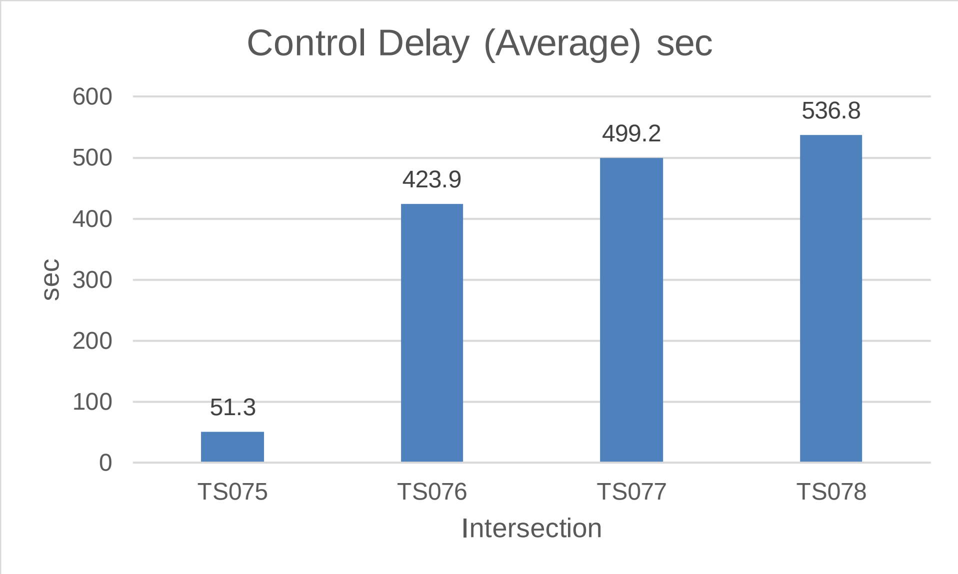



**Figure 10 Intersections Results - Control Delay (Average)**

### 3.4.2 Total Cost ($/h)

In SIDRA, total cost indicates the overall evaluation of intersection-related costs, including construction, operating, maintenance, and user costs. SIDRA determines the overall cost using consideration of a few parameters, including vehicle volumes, intersection design, signal timings, and delays. The total cost count per hour in the intersection results, below is the graphical data of all the intersections in Figure 8.

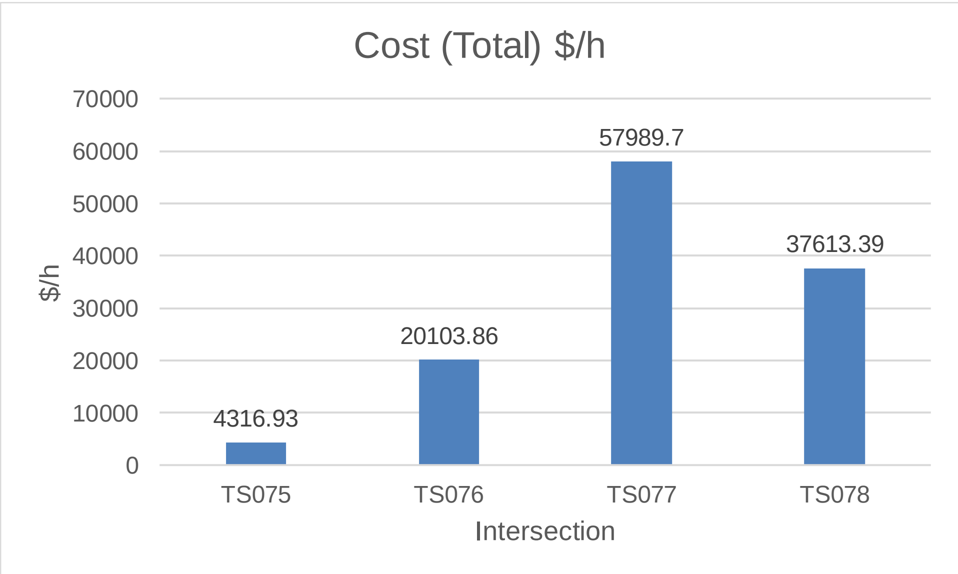



**Figure 11 Intersections Results - Total Cost**

### 3.4.3 Fuel Consumption (L/h)

SIDRA is mainly focused on the traffic data analysis and intersection performance, but it is also evaluating the fuel consumption. However, SIDRA indirectly impact on fuel consumption by evaluating traffic flow, delay, and queue length at the intersections. By optimizing the signal and phasing, geometry design of intersections, and traffic management method SIDRA can reduce the delay time and traffic congestion, and it can be helpful to reduce the travel time and improve the fuel efficiency. The overall fuel consumption of all intersections is show in Figure 9.

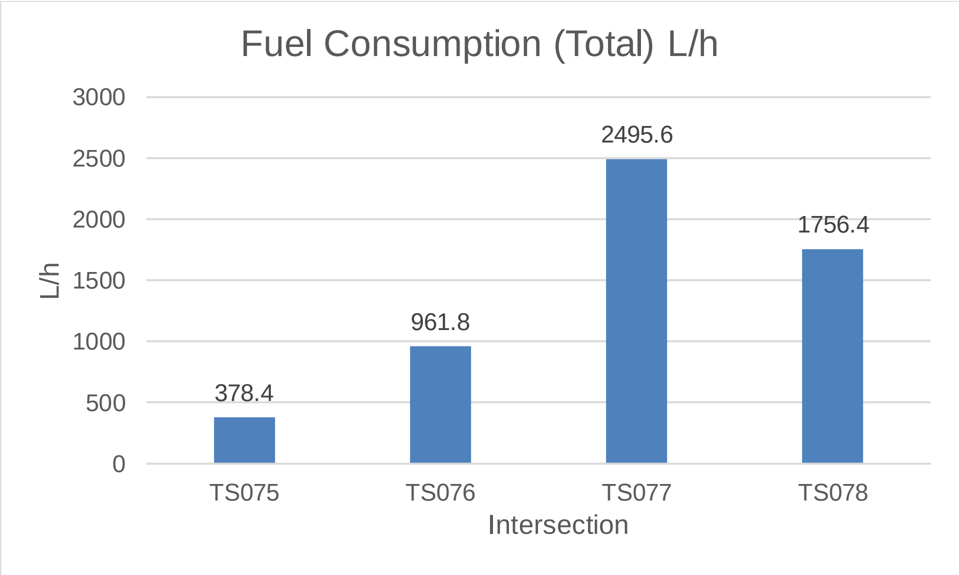



**Figure 12 Intersections Results - Fuel Consumption (Total)**

### 3.4.4 Emissions (kg/h)

SIDRA primarily focuses on intersection analysis and traffic performance; emissions are not directly calculated in the SIDRA. During the assessment of traffic flow, delays, and queue length at intersections SIDRA impact the emissions. SIDRA can minimize average delays and traffic congestion by optimizing signal timings, intersection design, and traffic management method which can reduce vehicle stopping time and emissions. Here, the shown graphical data of emissions like Carbon Dioxide, Hydrocarbons, Carbon Monoxide, and NOX in Figure 13 and Figure 14. These are the main aspect for sustainable environment, and electric vehicle (EV) have zero emission. So, electric vehicle can more impact on the future transportation model to improve the urban mobility and help to reduce such type of emissions in environment.

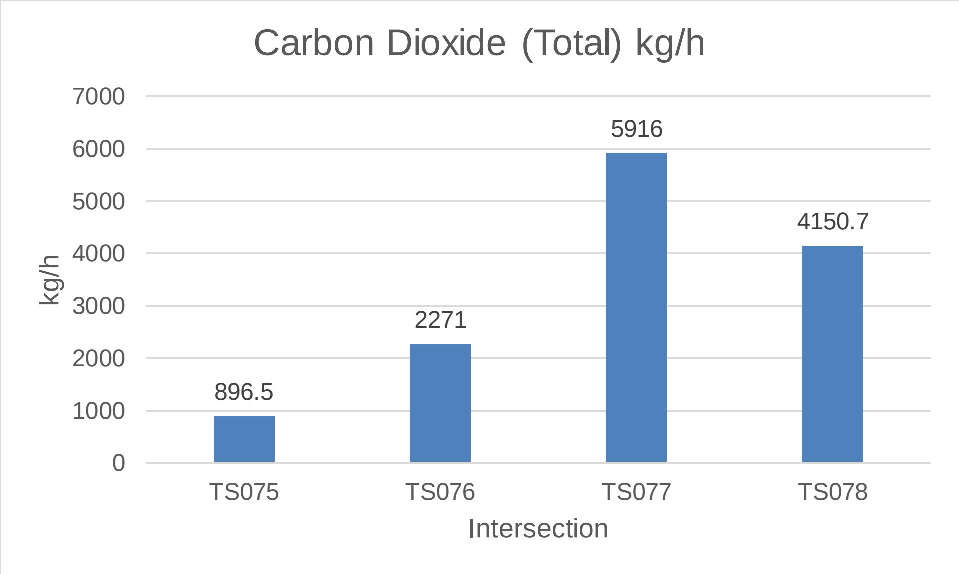



**Figure 13 Intersections Results - Carbon Dioxide (Total)**

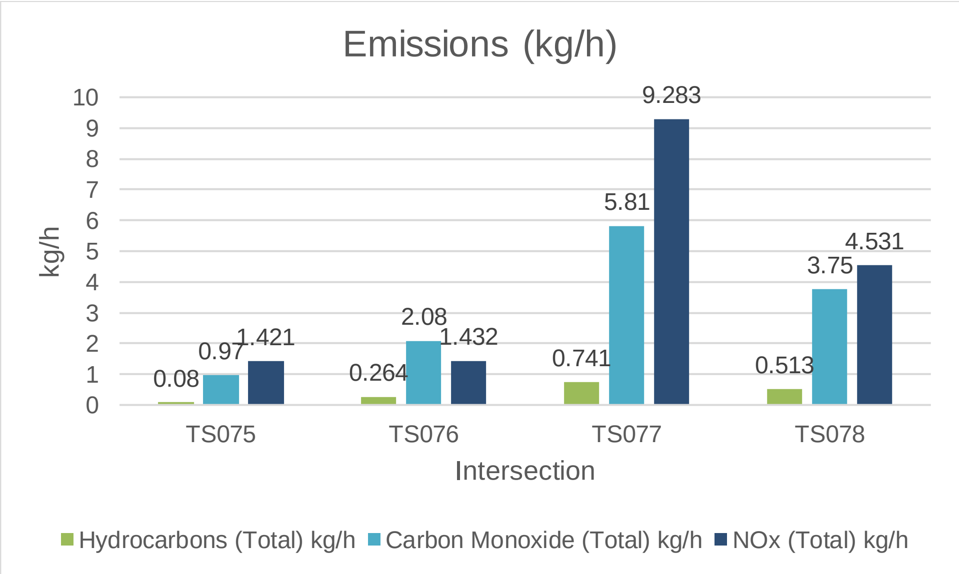



**Figure 14 Intersections Results - Emissions (kg/h)**

### 3.4.5 Level of Service (LOS)

Level of service is primarily used as a limit control for proposed scenarios to ensure that the scenario represents a practical proposal. As a performance measure the minimum requirement is LoS D for intersections in project scenarios for the future design year. Level of service can however also be used to demonstrate a coarse comparison between the base case and the scenarios. It is not useful for verifying base case models. (SIDRA, 2020)

**Table 1 Total result of all the intersections**

| Performance Measure | Vehicles | Intersections | | | |
|---|---|---|---|---|---|
| | | TS075 | TS076 | TS077 | TS078 |
| Travel Speed (Average) | km/h | 37.6 | 8.6 | 9 | 7.7 |
| Travel Time (Total) | veh-h/h | 95.3 | 506.6 | 1220.1 | 951.1 |
| Control Delay (Total) | veh-h/h | 53.07 | 446.04 | 1074.2 | 853.97 |
| Control Delay (Average) | sec | 51.3 | 423.9 | 499.2 | 536.8 |
| Intersection Level of Service (LOS) | | D | F | F | F |
| Queue Length (Worst Lane) | m | 172.4 | 846.7 | 2488.6 | 2213.4 |
| Cost (Total) | $/h | 4316.93 | 20103.86 | 57989.7 | 37613.39 |
| Fuel Consumption (Total) | L/h | 378.4 | 961.8 | 2495.6 | 1756.4 |
| Carbon Dioxide (Total) | kg/h | 896.5 | 2271 | 5916 | 4150.7 |
| Hydrocarbons (Total) | kg/h | 0.08 | 0.264 | 0.741 | 0.513 |
| Carbon Monoxide (Total) | kg/h | 0.97 | 2.08 | 5.81 | 3.75 |
| NOx (Total) | kg/h | 1.421 | 1.432 | 9.283 | 4.531 |

## 3.6 Network model of all intersections

In SIDRA intersection network is used for the evaluation of interconnected intersections and road that are analysed together to evaluate traffic flow on this network because of intersection, and this can calculate the traffic congestion, travel time and average delay of the route performance across the network. SIDRA can make complex model using multiple intersections and road liking in the network. In SIDRA network change of intersection design is possible, and it is allowed to change in vehicle volume, phasing, and other parameters at each intersection. A selected intersections are aligning with each other, so it is easy to make a network as shown in Figure 15. Intersection TS075 is nearest intersection towards city centre and TS078 is the first intersection in our study from the North direction.

After analysed the morning peak period, traffic flow from the TS078 to TS075, the peak route are created from the intersection TS078 to intersection TS075. Route analysis is used for the evaluating traffic flow, and performance along the define route within the network.

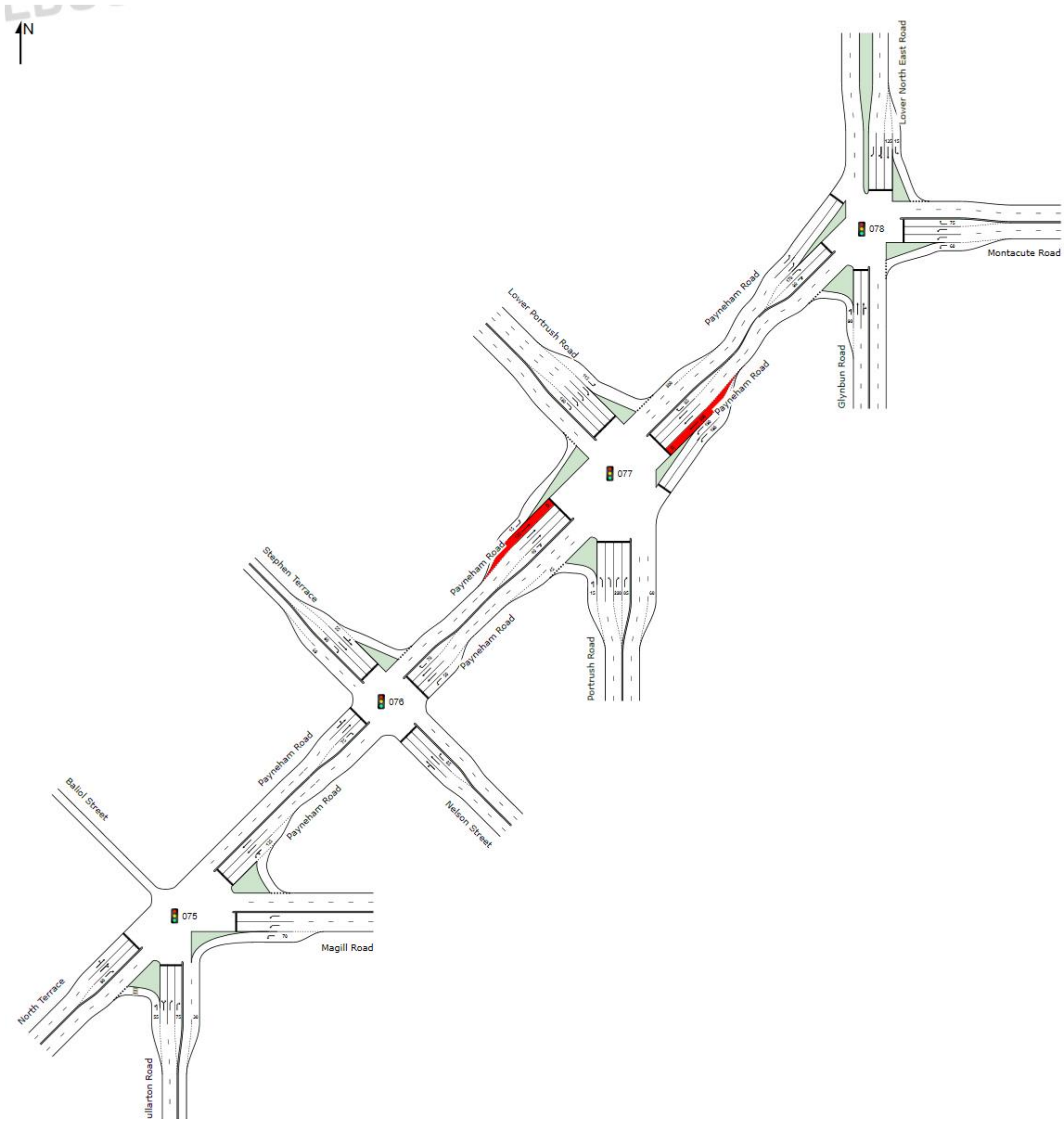



**Figure 15 Network Model**

## 3.7 Compare with electric vehicle data passing through intersection

In SIDRA intersection results for light vehicles and heavy vehicles typically includes capacity, delay, queue length, and level of service, which are assessed based on traffic volume, signal timing, intersection design, and other parameter settings. These results are providing the intersection performance of petrol and diesel vehicles. When these results are compared with electric vehicles passing through the intersection results data, some of the details should be considered like as fuel consumption, traffic flow efficiency, energy consumption. In the results fuel consumption and environmental impacts of the intersection performance are the mainly focused aspects.

Electric vehicles produce zero emissions and have lower fuel consumption as compared to internal combustion engines. Therefore, the maximum number of electric vehicles can reduce the fuel consumption and emissions at each intersection. Electric vehicles have great acceleration power as compared to petrol and diesel vehicles. This can impact on queue length and delay of the vehicle on every intersection.

## 3.8Network model data review

SIDRA can give us the network results as same as the intersection results. Here, this are the analysed travel time, queue length, total cost, fuel & emissions of the network model. In below graph are represent the results after simulating the SIDRA network model of the four intersections. An examine the results of all intersection geometry, traffic volume, signal timing, and other output but ensure that this model is aligned with the real-time data that has been collected from the during the examine of each intersection. Here from the Figure 16 to Figure 20 show that the all the graphical output of the network model. The average control delay is the reduce from each intersection result, because in this network SIDRA calculate the whole route. After using the electric vehicle control delay will be reduce as shown in graph, and this impact also shown in fuel consumption and emissions of the whole network.

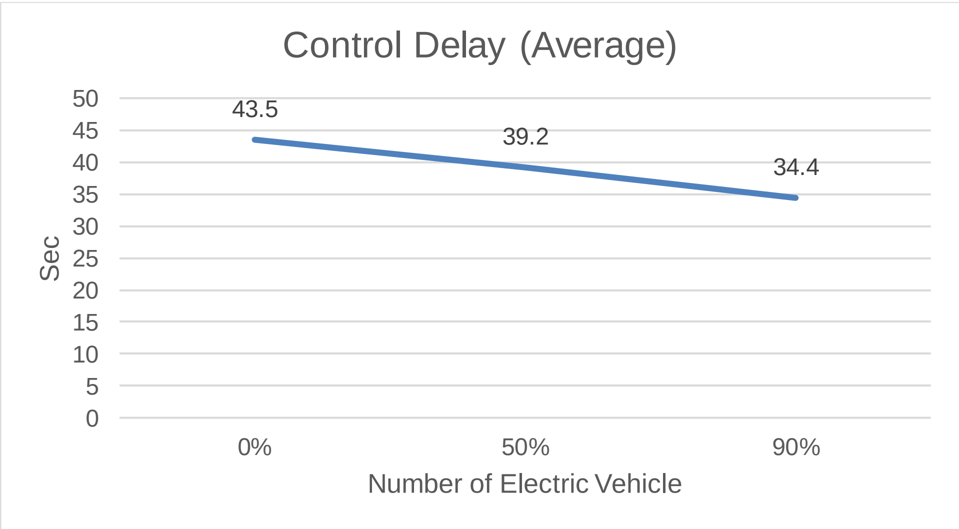



**Figure 16 Network Result - Control Delay (Average)**

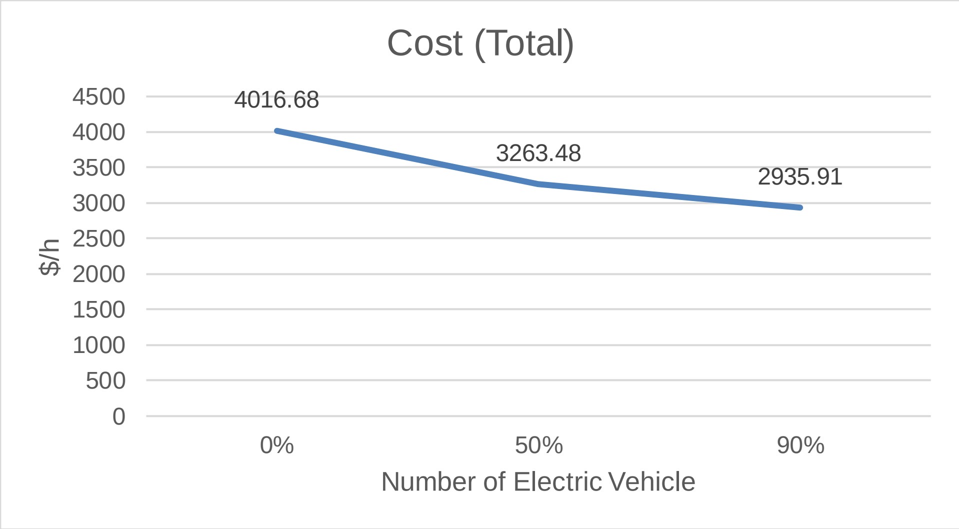



**Figure 17 Network Result - Total Cost**

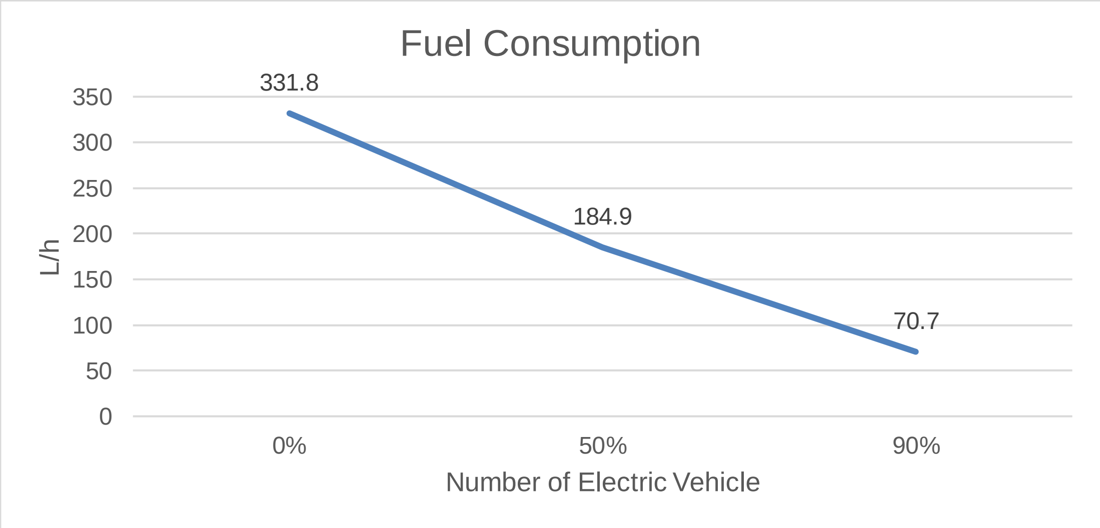



**Figure 18 Network Result - Fuel Consumption**

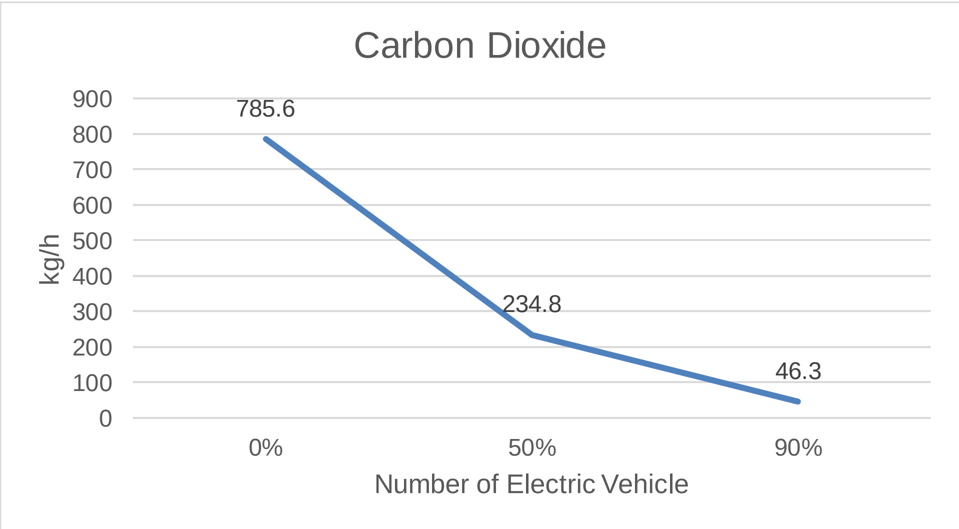



**Figure 19 Network Result -Carbon Dioxide**

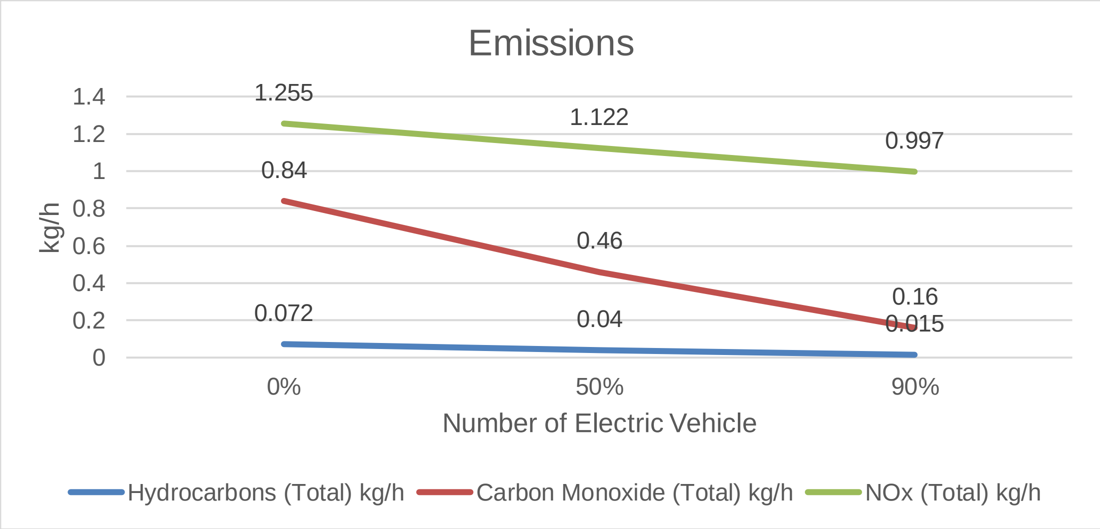



**Figure 20 Network Result - Emissions**

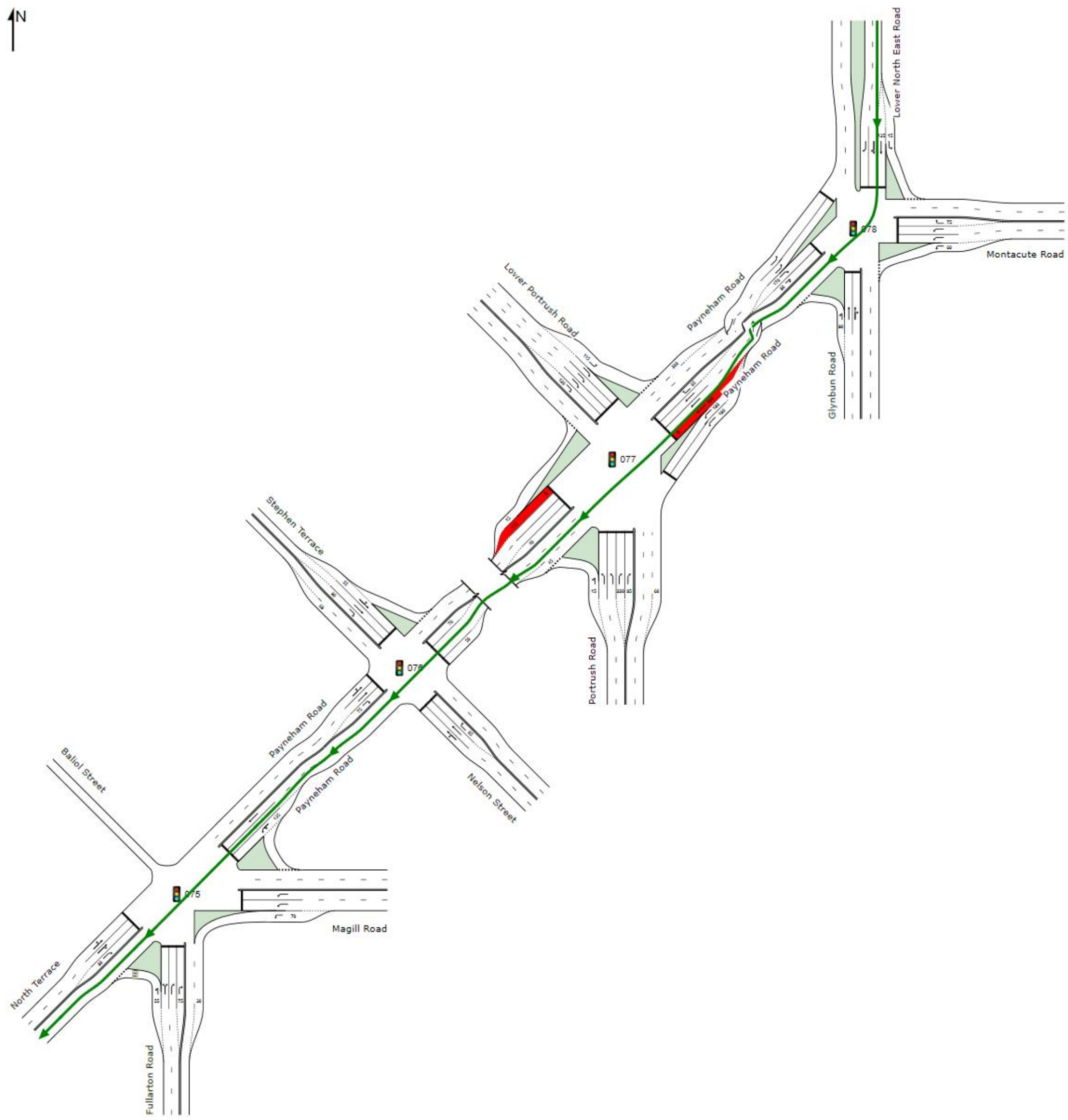



**Figure 21 AM Peak route from intersection TS078 to intersection TS075**

# 4. RESULTS AND DISCUSSION

After getting the results of each individual intersection as describe in graph. Now, these are the analysed data using the electric vehicle volume in the vehicle volume. Every year the electric vehicles are increase in daily transportation. So, there are the different scenario to review the results at intersection with different percentages of electric vehicles moves with other vehicles at intersection. Here, assumed that 0% electric vehicles are move on road present time (this is the base model and results), after that 10%, 25%, 50%, 75% and 90% electric vehicles are passing through each intersection, and review the results. Table 1 shows that the results of the TS075 intersection.

**Table 2 Intersection TS075 results with electric vehicle scenario from 0% to 90%**

| TS075 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Performance Measure** | **Vehicles** | **All MCs** | | | | | |
| | | **Number of Electric Vehicle** | | | | | |
| | | **0%** | **10%** | **25%** | **50%** | **75%** | **90%** |
| Travel Speed (Average) | km/h | 37.6 | 38.1 | 38.5 | 39.7 | 40.7 | 41.2 |
| Travel Time (Total) | veh-h/h | 95.3 | 94.1 | 92.9 | 90.3 | 88.1 | 87 |
| Control Delay (Total) | veh-h/h | 53.07 | 51.14 | 47.83 | 44.5 | 40.18 | 39.03 |
| Control Delay (Average) | sec | 51.3 | 49.5 | 46.3 | 43 | 38.9 | 37.8 |
| Intersection Level of Service (LOS) | | D | D | D | D | D | D |
| Queue Length (Worst Lane) | m | 172.4 | 165.3 | 153.2 | 138.6 | 123.9 | 117.5 |
| Cost (Total) | $/h | 4316.93 | 4088.24 | 3811.22 | 3407.31 | 3134.71 | 3028.44 |
| Fuel Consumption (Total) | L/h | 378.4 | 343.7 | 295.9 | 212 | 132.2 | 84.1 |
| Carbon Dioxide (Total) | kg/h | 896.5 | 737.1 | 536.6 | 273.2 | 111.7 | 60.3 |
| Hydrocarbons (Total) | kg/h | 0.08 | 0.072 | 0.062 | 0.044 | 0.027 | 0.017 |
| Carbon Monoxide (Total) | kg/h | 0.97 | 0.88 | 0.75 | 0.53 | 0.32 | 0.19 |
| NOx (Total) | kg/h | 1.421 | 1.391 | 1.373 | 1.299 | 1.249 | 1.207 |

In Table 2 results is when 0% electric vehicle are considered on intersection, and after that the average control delay was 51.3 seconds and after assumed that if number of electric vehicles are increase in road and supposed to be 50% riders are used the electric vehicles then average delay is 43 seconds. Now, after maximizing the efficiency of electric vehicles up to 90%, the result of average delay is 37.8 seconds, and it is much better than the 50% and 0% of electric vehicle are approach at intersection. From the drastic reduction in average delay also there is cut off in total cost of the traffic management and development from $4316.93/h to $3028.44/h when the vehicle volume are upgrading in electric vehicle from 0% to 90%.

**Table 3 Intersection TS076 results with electric vehicle scenario from 0% to 90%**

| TS076 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Performance Measure** | **Vehicles** | **All MCs** | | | | | |
| | | **Number of Electric Vehicle** | | | | | |
| | | **0%** | **10%** | **25%** | **50%** | **75%** | **90%** |
| Travel Speed (Average) | km/h | 8.6 | 9 | 8.3 | 10.5 | 11.4 | 12.9 |
| Travel Time (Total) | veh-h/h | 506.6 | 482.7 | 527.3 | 415.3 | 381.6 | 337.2 |
| Control Delay (Total) | veh-h/h | 446.04 | 421.99 | 471.16 | 357.43 | 324.3 | 279.15 |
| Control Delay (Average) | sec | 423.9 | 401 | 447.8 | 339.7 | 308.2 | 265.3 |
| Intersection Level of Service (LOS) | | F | F | F | F | F | F |
| Queue Length (Worst Lane) | m | 846.7 | 835.4 | 1032.8 | 875.4 | 922.4 | 849.9 |
| Cost (Total) | $/h | 20103.86 | 18733.6 | 19780.57 | 14970.72 | 13358.87 | 11688.8 |
| Fuel Consumption (Total) | L/h | 961.8 | 843.5 | 769.7 | 458.4 | 250.9 | 131.4 |
| Carbon Dioxide (Total) | kg/h | 2271 | 1797.2 | 1374.4 | 563.2 | 180.5 | 69.6 |
| Hydrocarbons (Total) | kg/h | 0.264 | 0.232 | 0.218 | 0.13 | 0.076 | 0.044 |
| Carbon Monoxide (Total) | kg/h | 2.08 | 1.86 | 1.71 | 1.1 | 0.67 | 0.4 |
| NOx (Total) | kg/h | 1.432 | 1.387 | 1.445 | 1.292 | 1.212 | 1.14 |

As review the intersection TS075 data, same as the result of intersection TS076 are shown in Table 3. Intersection TS076 is the quite busy intersection as compared to TS075, this result was depend on the SCATS data and the input data that is manually collect from the JCT application during the survey and study from the site. Other intersection results are shown in Table 4 and Table 5.

**Table 4 Intersection TS077 results with electric vehicle scenario from 0% to 90%**

| TS077 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Performance Measure** | **Vehicles** | **All MCs** | | | | | |
| | | **Number of Electric Vehicle** | | | | | |
| | | **0%** | **10%** | **25%** | **50%** | **75%** | **90%** |
| Travel Speed (Average) | km/h | 9 | 9.5 | 10.3 | 12 | 14.3 | 15.9 |
| Travel Time (Total) | veh-h/h | 1220.1 | 1158.4 | 1066 | 915.5 | 767.1 | 689.7 |
| Control Delay (Total) | veh-h/h | 1074.2 | 1011.74 | 918.4 | 766.09 | 616.05 | 537.92 |
| Control Delay (Average) | sec | 499.2 | 470.2 | 426.8 | 356 | 286.3 | 250 |
| Intersection Level of Service (LOS) | | F | F | F | F | F | F |
| Queue Length (Worst Lane) | m | 2488.6 | 2410.1 | 2286.3 | 2062.9 | 1815.8 | 1655.6 |
| Cost (Total) | $/h | 57989.7 | 53947.82 | 48245.67 | 39752.94 | 32246.7 | 28825.13 |
| Fuel Consumption (Total) | L/h | 2495.6 | 2199.5 | 1778.6 | 1172.1 | 664.2 | 408.1 |
| Carbon Dioxide (Total) | kg/h | 5916 | 4709.8 | 3205.9 | 1479.5 | 532.6 | 266 |
| Hydrocarbons (Total) | kg/h | 0.741 | 0.657 | 0.537 | 0.365 | 0.221 | 0.15 |
| Carbon Monoxide (Total) | kg/h | 5.81 | 5.23 | 4.39 | 3.12 | 1.99 | 1.38 |
| NOx (Total) | kg/h | 9.283 | 8.94 | 8.417 | 7.595 | 6.791 | 6.347 |

**Table 5 Intersection TS078 results with electric vehicle scenario from 0% to 90%**

| TS078 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Performance Measure** | **Vehicles** | **All MCs** | | | | | | |
| | | **Number of Electric Vehicle** | | | | | | |
| | | **0%** | **10%** | **25%** | **50%** | **75%** | **90%** |
| Travel Speed (Average) | km/h | 7.7 | 8 | 8.8 | 10.3 | 11.8 | 13.3 |
| Travel Time (Total) | veh-h/h | 951.1 | 907.8 | 832 | 707.4 | 616.5 | 548.7 |
| Control Delay (Total) | veh-h/h | 853.97 | 810.91 | 734.27 | 608.36 | 518.55 | 449.7 |
| Control Delay (Average) | sec | 536.8 | 509.7 | 461.6 | 382.4 | 326 | 282.7 |
| Intersection Level of Service (LOS) | | F | F | F | F | F | F |
| Queue Length (Worst Lane) | m | 2213.4 | 2155.7 | 2063.9 | 1895.4 | 1705.2 | 1579.7 |
| Cost (Total) | $/h | 37613.39 | 35120.34 | 31222.88 | 25485.01 | 21583.9 | 19024.19 |
| Fuel Consumption (Total) | L/h | 1756.4 | 1541.9 | 1219.8 | 768.5 | 409.9 | 221.6 |
| Carbon Dioxide (Total) | kg/h | 4150.7 | 3286.9 | 2180.5 | 943.7 | 294.3 | 114.4 |
| Hydrocarbons (Total) | kg/h | 0.513 | 0.454 | 0.362 | 0.235 | 0.137 | 0.085 |
| Carbon Monoxide (Total) | kg/h | 3.75 | 3.36 | 2.76 | 1.9 | 1.17 | 0.76 |
| NOx (Total) | kg/h | 4.531 | 4.342 | 4.018 | 3.531 | 3.129 | 2.876 |

After getting all the intersection results using the electric vehicle data, results are compared in Table 2 to Table 5. Now, connect all the intersection TS075 to TS078, and making a peak time route. Here, the peak route time taken between 800 AM to 900 AM. Below table 6 is shown the network analysis data with 0%, 50% and 90% electric vehicle.

**Table 6 Intersection results with electric vehicle scenario from 0%, 50% and 90%**

| Network Output | | | | |
|---|---|---|---|---|
| **Performance Measure** | **Vehicles** | **All MCs** | | |
| | | **Number of Electric Vehicle** | | |
| | | **0%** | **50%** | **90%** |
| Travel Speed (Average) | km/h | 32.6 | 34.2 | 36 |
| Travel Time (Total) | veh-h/h | 90.3 | 87.2 | 84.4 |
| Control Delay (Total) | veh-h/h | 41.2 | 37.54 | 33.58 |
| Control Delay (Average) | sec | 43.5 | 39.2 | 34.4 |
| Intersection Level of Service (LOS) | | D | D | C |
| Queue Length (Worst Lane) | m | 106.5 | 93.7 | 89.1 |
| Cost (Total) | $/h | 4016.68 | 3263.48 | 2935.91 |
| Fuel Consumption (Total) | L/h | 331.8 | 184.9 | 70.7 |
| Carbon Dioxide (Total) | kg/h | 785.6 | 234.8 | 46.3 |
| Hydrocarbons (Total) | kg/h | 0.072 | 0.04 | 0.015 |
| Carbon Monoxide (Total) | kg/h | 0.84 | 0.46 | 0.16 |
| NOx (Total) | kg/h | 1.255 | 1.122 | 0.997 |

In Table 6, result is when 0 percentage electric vehicle runs through the intersection and get the level of service D for the whole network, while 90 percentage vehicles are run through the intersection with the others vehicle the level of service is C for the whole network model. From the network results this can be evaluate that total cost reduce by 30% in network route when the electric vehicle increases from 0% to 90%, and carbon dioxide can reduce up 80% in the environment from the vehicle. These are the results are varying from the intersection wise and depend on vehicle volume and time. These intersections are busy intersections during the morning peak time and the vehicle data is the real time data, so assume that if electric vehicles demand is increasing in upcoming year and that will around 90% electric vehicle drive by people after 10 years, so there has been drastic change in the transportation model and results.

# 5. CONCLUSION

The people are accepting electric vehicle, and this change are effective for the infrastructure and transportation system development. In which the better intersection design for the urban development and that impact can be shown on the complex design of the new transportation design because of electric vehicles are rapidly growing on road. The conclusion of this project is that the using the electric vehicle to reduce the delay time, traffic volume, reduce the emissions, and sustainable for environmental. This significant change highlights how important it is to deal with the opportunities and issues caused by an increase in the use of electric vehicles at urban intersections. This study has a great possibility to evaluate the modern transportation infrastructure and sustainable urban development by contributing to new perspective between the relationships of electric vehicles and intersection designs. Currently the intersection is developed for the light vehicles, heavy vehicles, and electric vehicles but from the performance review intersection, roundabout and unsignalized turn can be improved to support the electric vehicles can move smoothly and reduce the fuel consumption and improve the environment.

Analysis of all the results is concluded that the uptake of 90% of electric vehicle would be reduce delay up to 50% and cost reduce by 50%. Other benefit of the upgradation of vehicle in future is electric vehicle can be reducing carbon dioxide up to 80%. This is beneficial for the sustainable urban development.

From the data collection and analysis of the model, and modelling this project gain the useful results for the transportation context and impacts the future of urban mobility. In the project future research will focus on optimizing the travel time, reduce the average delay, reduce queue length, crash safety, improve the pedestrian safety, and better for the sustainable environment. Also, this research will be helpful to the environmental sustainability to use renewable energy and decrease the fossil fuel uses.

# 6. FUTURE WORK

Aimsun is a microscopic traffic simulation software that offers detailed visualization of vehicle movements, allowing transportation professionals to observe traffic flow patterns, congestion dynamics, and intersection operations. By comparing Aimsun simulations with SIDRA results, analysts can verify the accuracy and reliability of intersection performance assessments conducted using SIDRA. (aimsun, 2021)

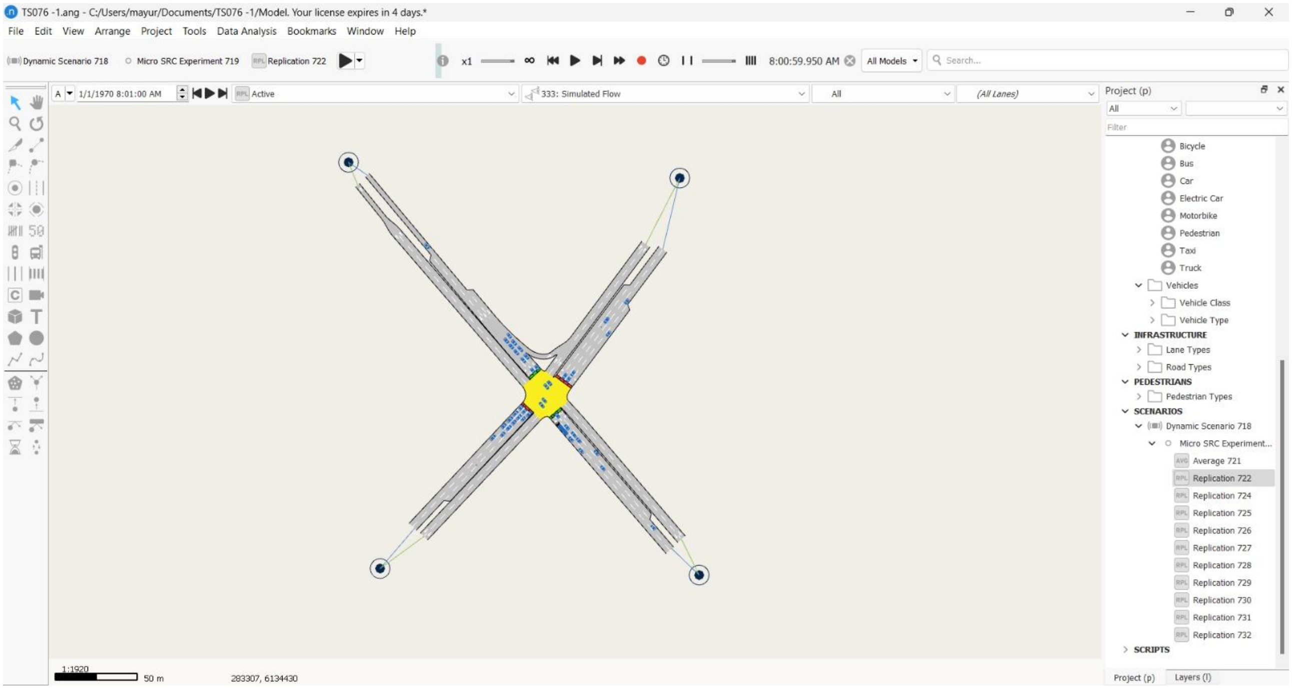
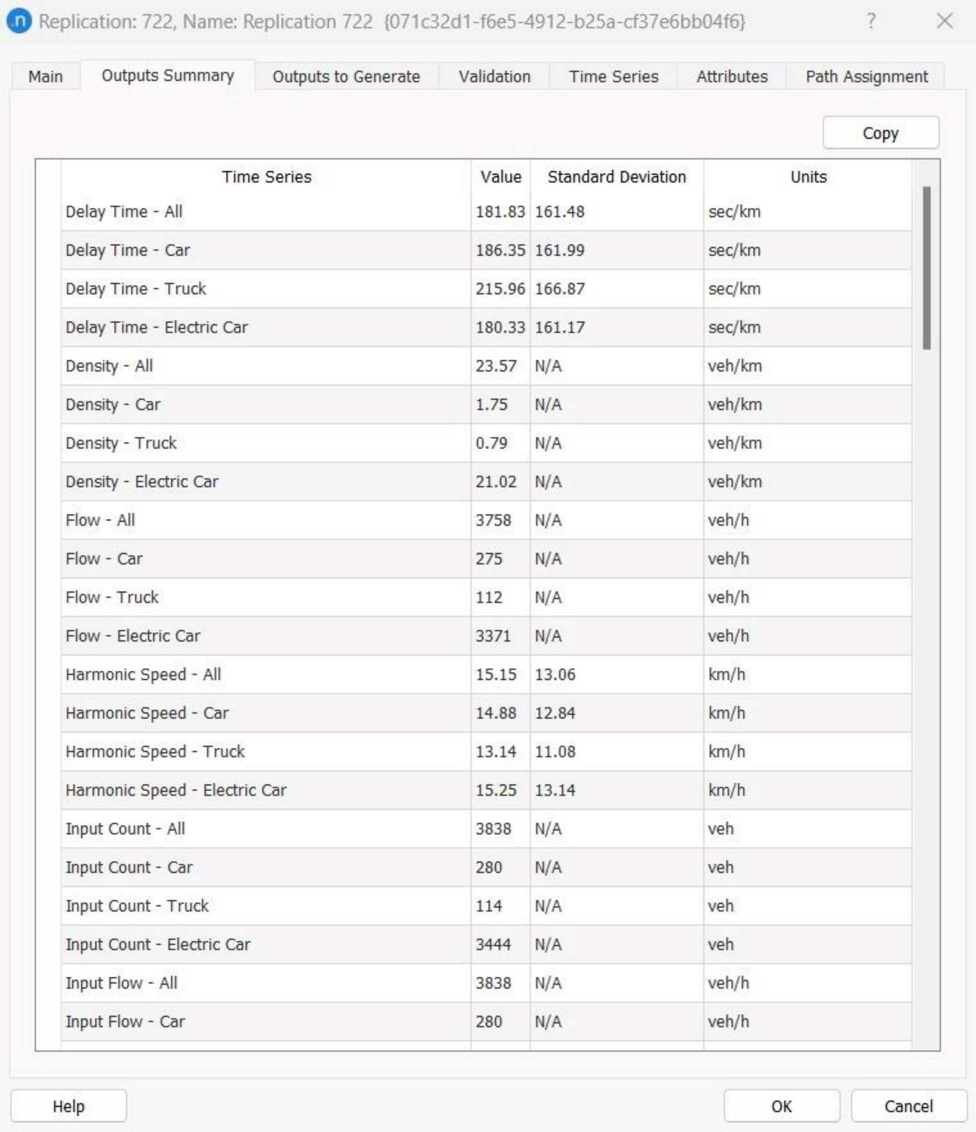



**Figure 22 Aimsun simulation model of intersection TS076**

Intersection TS076 simulation model is shown in Figure 22, this is the feature model of the intersection. In Aimsun, the intersection geometry required and vehicle data from as per the SACTS counts and data acquired from the site visit using JCT application. This Aimsun model is created with the using of 90% of electric vehicle and after the simulation the model, control delay is 181 seconds, and as compared to SIDRA results this is the nearest value of the Aimsun results. This result is shown in Figure 23.




| Time Series | Value | Standard Deviation | Units |
|---|---|---|---|
| Delay Time - All | 181.83 | 161.48 | sec/km |
| Delay Time - Car | 186.35 | 161.99 | sec/km |
| Delay Time - Truck | 215.96 | 166.87 | sec/km |
| Delay Time - Electric Car | 180.33 | 161.17 | sec/km |
| Density - All | 23.57 | N/A | veh/km |
| Density - Car | 1.75 | N/A | veh/km |
| Density - Truck | 0.79 | N/A | veh/km |
| Density - Electric Car | 21.02 | N/A | veh/km |
| Flow - All | 3758 | N/A | veh/h |
| Flow - Car | 275 | N/A | veh/h |
| Flow - Truck | 112 | N/A | veh/h |
| Flow - Electric Car | 3371 | N/A | veh/h |
| Harmonic Speed - All | 15.15 | 13.06 | km/h |
| Harmonic Speed - Car | 14.88 | 12.84 | km/h |
| Harmonic Speed - Truck | 13.14 | 11.08 | km/h |
| Harmonic Speed - Electric Car | 15.25 | 13.14 | km/h |
| Input Count - All | 3838 | N/A | veh |
| Input Count - Car | 280 | N/A | veh |
| Input Count - Truck | 114 | N/A | veh |
| Input Count - Electric Car | 3444 | N/A | veh |
| Input Flow - All | 3838 | N/A | veh/h |
| Input Flow - Car | 280 | N/A | veh/h |

**Figure 23 Aimsun simulation results of intersection TS076**

SIDRA modelling is used to project intersection performance in the future while considering expected increases in traffic in the coming years. Transportation planners can evaluate an intersection's capacity, delay, and level of service under future traffic conditions by adding growth predictions and traffic forecasts into SIDRA simulations. By taking a proactive approach, planners can identify possible delays, estimate infrastructure demands, and develop plans for effectively managing the increasing demands on transportation. (SIDRA, 2020)

In conclusion, further research study about Aimsun simulation analysis for the compare the results of SIDRA intersection and Visualization analysis of Aimsun to know better electric vehicle behaviour at intersection and using this real time data to reduce the travel time, queue length and emissions from the vehicle for the better transportation development and sustainable environment.

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# APPENDICES

Figure 24 is shown that the real time data collection situation, during the calculation of saturation flow and queue length this image was captured of intersection TS077.

**Table 7 Real-time data collection of each intersection using JCT application for saturation flow**

| Intersection | Approach | Turn Movement | Saturation Flow | Queue Length (metre) |
|---|---|---|---|---|
| TS075 | North East | Through | 1689 | 165 |
| TS075 | North East | Left | 1756 | 130 |
| TS075 | East | Through | 1615 | 98 |
| TS075 | East | Left | 1567 | 35 |
| TS075 | South | Through | 1734 | 65 |
| TS075 | South | Right | 1432 | 35 |
| TS075 | West | Through | 1678 | 72 |
| TS075 | West | Right | 1534 | 52 |
| | | | | |
| TS076 | North East | Right | 1567 | 47 |
| TS076 | North East | Through | 1645 | 134 |
| TS076 | North East | Left | 1435 | 23 |
| TS076 | South East | Right | 1589 | 43 |
| TS076 | South East | Through | 1688 | 113 |
| TS076 | South West | Right | 1587 | 38 |
| TS076 | South West | Through | 1602 | 131 |
| TS076 | North West | Right | 1501 | 56 |
| TS076 | North West | Through | 1583 | 108 |
| | | | | |
| TS077 | North East | Right | 1654 | 65 |
| TS077 | North East | Through | 1818 | 146 |
| TS077 | North East | Left | 1545 | 48 |
| TS077 | South | Right | 1674 | 63 |
| TS077 | South | Through | 1713 | 105 |
| TS077 | South West | Right | 1612 | 30 |
| TS077 | South West | Through | 1598 | 98 |
| TS077 | North West | Right | 1634 | 48 |
| TS077 | North West | Through | 1703 | 118 |
| TS077 | North West | Left | 1512 | 67 |
| | | | | |
| TS078 | North East | Right | 1809 | 132 |
| TS078 | North East | Through | 1612 | 146 |
| TS078 | East | Right | 1511 | 58 |
| TS078 | East | Through | 1699 | 102 |
| TS078 | East | Left | 1503 | 23 |
| TS078 | South | Right | 1544 | 48 |
| TS078 | South | Through | 1678 | 98 |
| TS078 | South West | Right | 1533 | 59 |
| TS078 | South West | Through | 1601 | 81 |

| | | | | |
|---|---|---|---|---|
| TS078 | South West | Left | 1569 | 92 |

**Figure 24 Intersection during real time data collection**

When SIDRA network software initializes, this application home screen shows the different kind of option to build up the intersection, roundabout, stop-giveaway signal, and freeway. Here, intersection module is perfect for the design all the intersection.

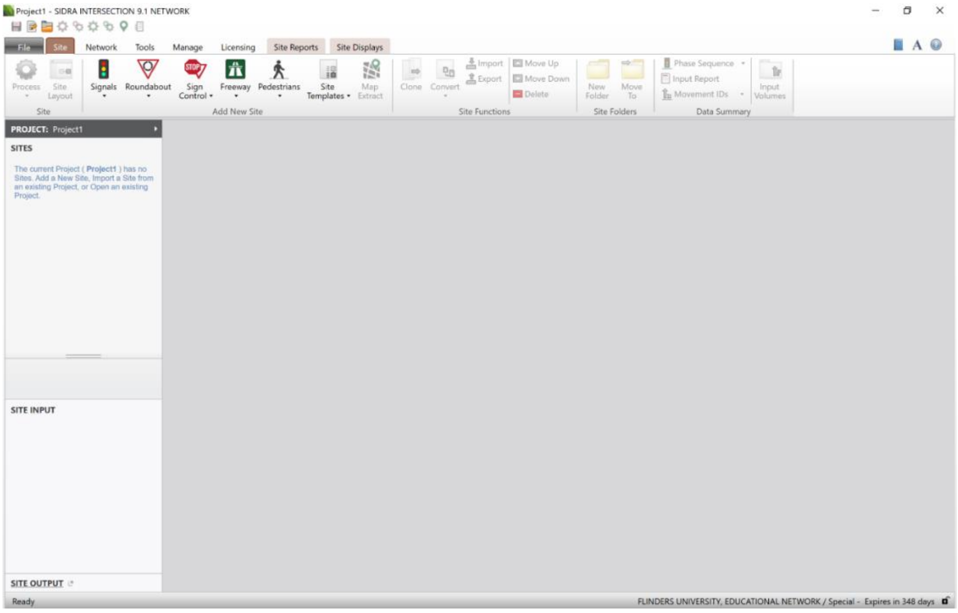


**Figure 25 SIDRA Intersection Software**

This module is using for the intersection geometry design, this tool has different features to build up right intersection design with suitable direction and length of the road. This intersection can identify with site id and name. In this design the approach length also can be adjusted during the design of the intersection, it is used when one intersection relates to other intersection.

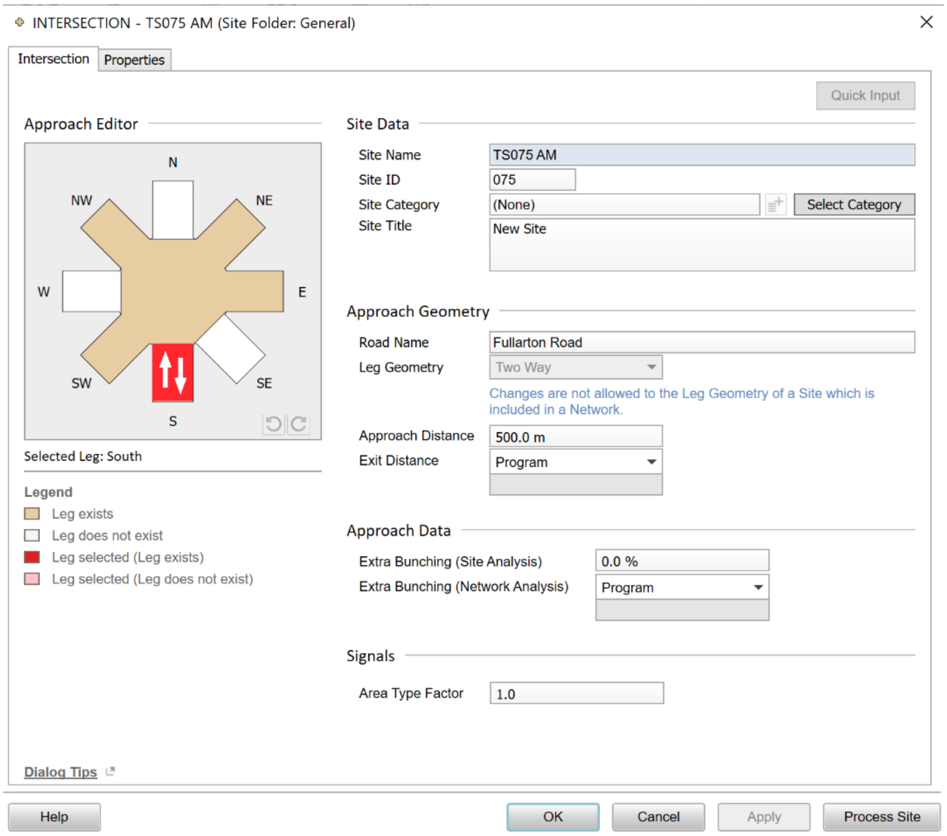


**Figure 26 Geometry Design for Intersection**

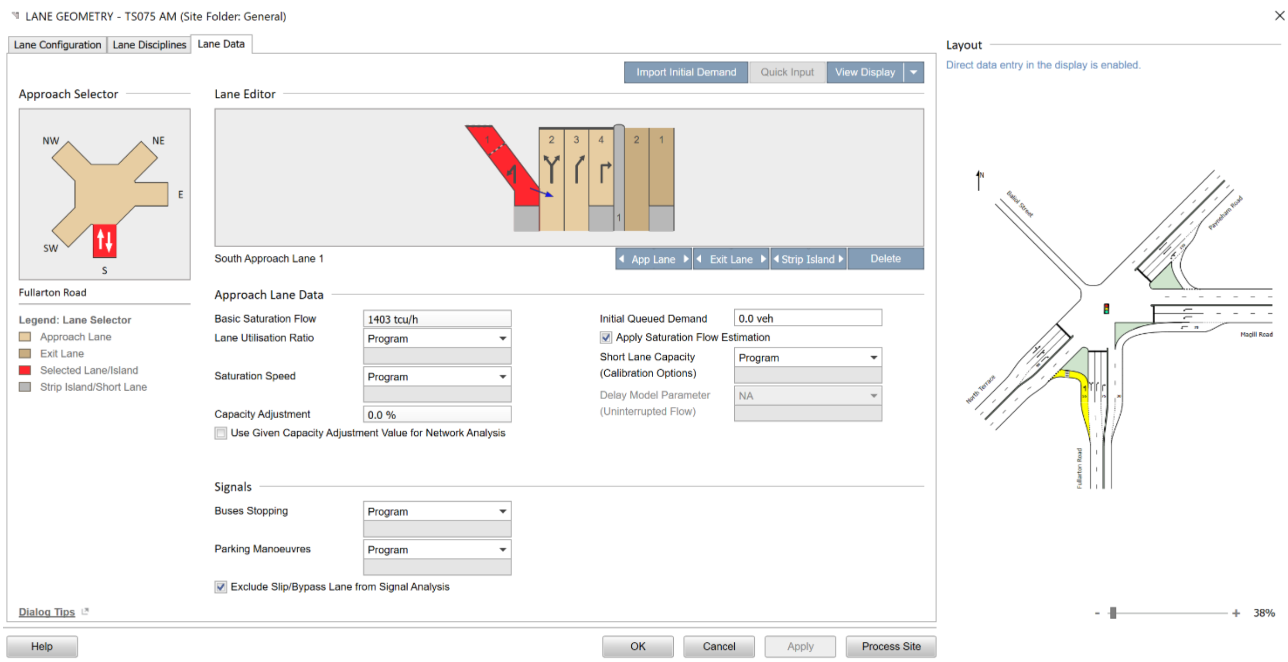


**Figure 27 Lane data in Lane geometry**

Figure 27 represents the lane data option in lane geometry, it is used to change the lane geometry of the intersection, lane discipline and lane data. In the lane data, saturation flow is the main aspect of the model data this has been collected from site survey with help of JCT application to find out saturation flow and queue length.

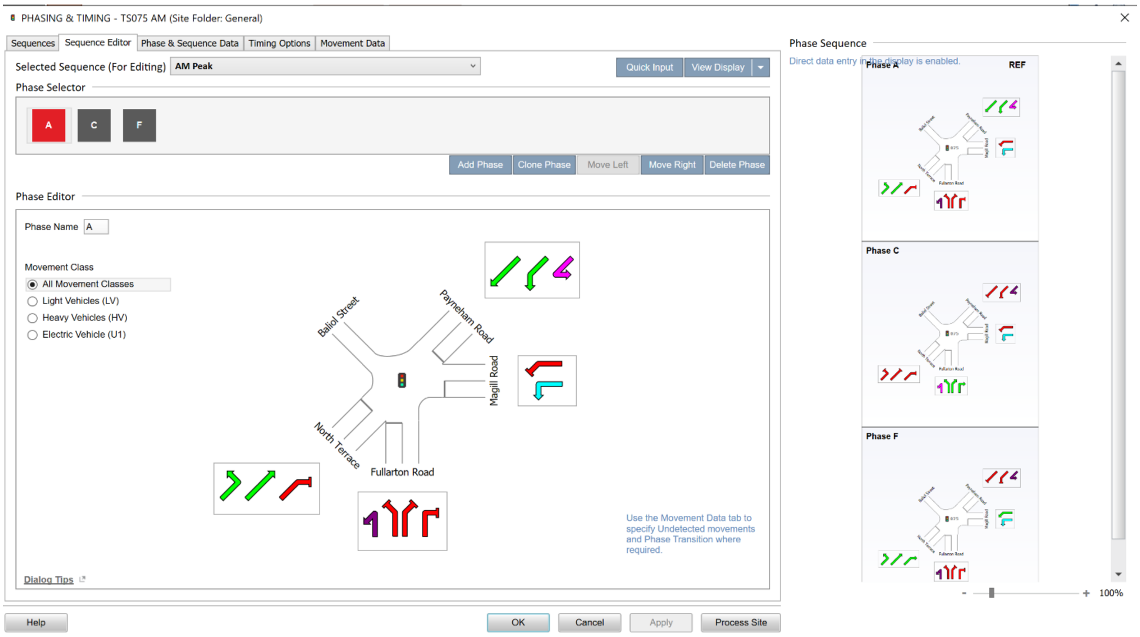


**Figure 28 Phasing and timing**

Phasing and timing module shows in Figure 28, and this is used for the change the signal phasing data and phasing time of the intersection. In the signal phasing practical cycle time also can be used to optimize the intersection results.

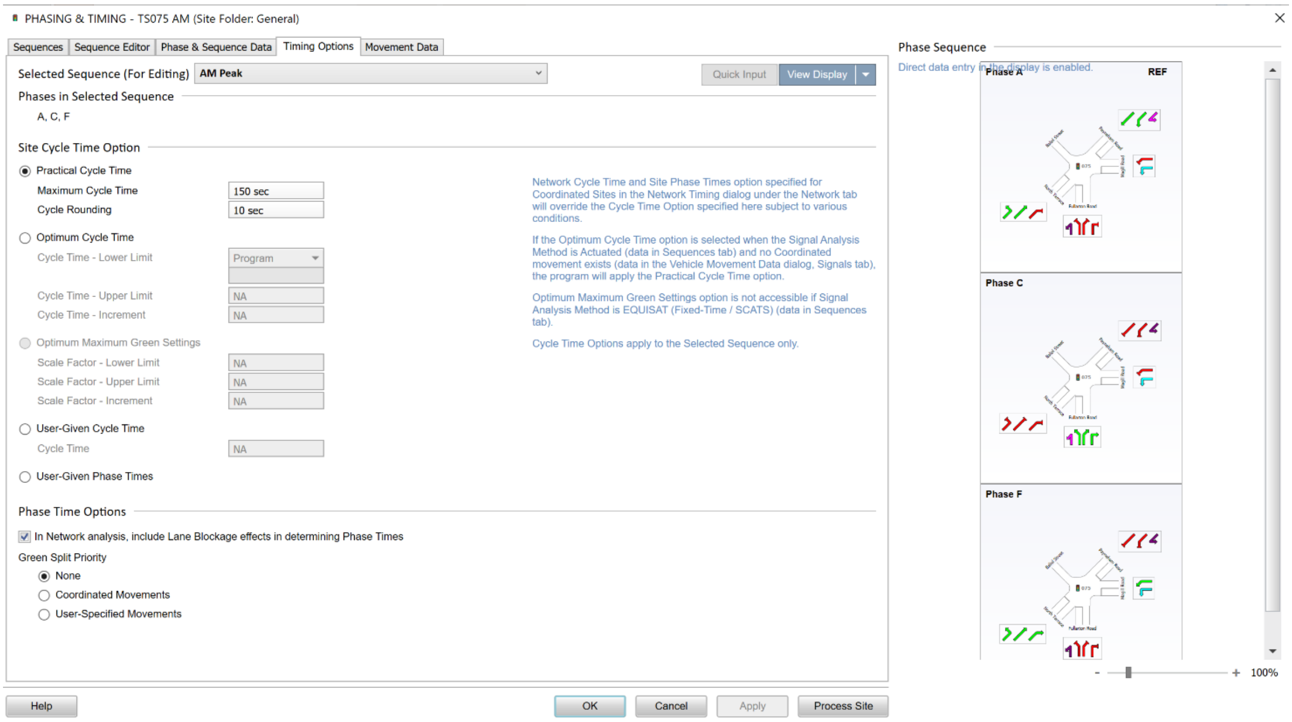


**Figure 29 Timing option during the phasing and timing**

Figure 29 shows cycle time option, in the cycle time that options are like practical cycle time, optimum cycle time, user given cycle time and user given phase time. Here, the best option is practical cycle time, and this has been used to get the all the intersections output in SIDRA. The practical cycle time is 150 seconds, and this is for all of the four intersections.

| | | Choose a vehicle: Toyota Camry Ascent Sport Sedan CVT (released 2022) | Choose a vehicle: Tesla Model Y LongRange (LY5LD) SUV Auto (released 202 |
|---|---|---|---|
| **Details** ⓘ | Body | 4 door, 5 seat Sedan | 4 door, 5 seat SUV |
| | Engine | 2.5L 4cyl Electric/Petrol 95RON, | Pure Electric |
| | Transmission | 1 spd CVT | 1 spd Auto |
| | Drivetrain | 2WD | 4WD |
| **Tailpipe $CO_2$ (g/km)** ⓘ | Comb | 96 [Better than average] | N/A [Better than average] |
| | Urban | 98 [Better than average] | N/A [Better than average] |
| | Extra | 96 [Better than average] | N/A [Better than average] |
| **Annual fuel cost** ⓘ | ($AUD) | $1252 | $776 |
| **Fuel consumption (L/100km)** ⓘ | Comb | 4.2 | N/A |
| | Urban | 4.3 | N/A |
| | Extra | 4.2 | N/A |
| **Energy consumption** ⓘ | (Wh/km) | N/A | 154 |
| **Electric range** ⓘ | (Km) | N/A | 612 |
| **Air pollution standard** ⓘ | (Emissions) | Euro 6 | Pure EV |

**Figure 30 Comparison between electric vehicle and fuel vehicle**

Figure 30 is showing the comparison between fuel economy vehicle Toyota Camry Ascent Sport Sedan CVT and Tesla Model Y Long Range. In this chart some of the parameters like fuel consumption, energy consumption and tailpipe carbon dioxide are compared and used to evaluate the results at different intersections.

Figure 31 is the shows the data of the electric vehicle energy consumption and fuel emissions, in this table there is no carbon dioxide release from the electric vehicle, and this prove that the electric vehicle has zero emissions during the driving. Figure 32 is real data from the Tesla Model Y, this is also show that the electric vehicle has zero fuel emissions and zero carbon emissions.

| | mg/km | | | | |
|---|---|---|---|---|---|
| | $PM_{2.5}$ | $NO_x$ + HC | $NO_x$ | $SO_2$ | CO |
| *Vehicle standards (test cycle)* | | | | | |
| US Tier 3 | 2 | 53 | | 0.6[a] | 1057 |
| Euro 6 (gasoline) | 0.3[b] | 170 | 60 | | 500 |
| Euro 6 (diesel) | 0.3[b] | | 80 | | |
| *US 2017 ICE* | | | | | |
| Best-in-class (HEV) (test cycle)[42] | 0.06[c] | 2 | 0.3 | | 31 |
| 2016 fleet average[d] (on-road)[10] | | 66 | 28 | | 231 |
| *EU ICE* | | | | | |
| Average Euro 6 gasoline DI ICE (RDE)[43,44] | 0.2–0.4[b] | | 12–20 | | 17–100 |
| *Typical 2017 BEV electricity emissions* | | | | | |
| 2014 US elec. grid[45,46,47] | 7 | 71 | 70 | 123 | |
| 2016 US elec. grid[41] | | | 37 | 41 | |
| 2030 US elec. grid[41] | | | 30 | 32 | |
| *Brake and Tire Wear* [50,51–52] | | | | | |
| Brake wear | 2–6 | | | | |
| Tire wear | 1–5 ($PM_{2.5}$) | | | | |
| | 4–13 ($PM_{10}$) | | | | |

**Figure 31 Energy consumption and emissions of vehicle**

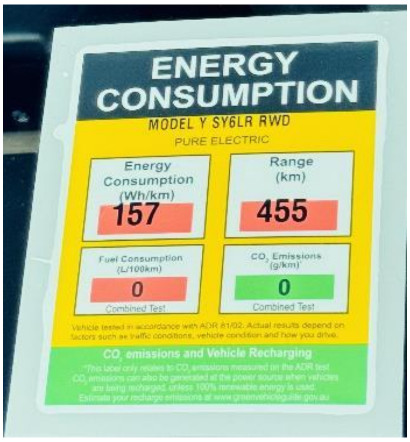


**Figure 32 Tesla energy consumption data**