“Modelling and Evaluating Signalized Intersection Performance: “A Sidra-Based Approach Using Scat and Bluetooth Data”

By

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Submitted to the College of Science and Engineering in partial fulfillment of the requirements for the degree

Master of Engineering (Civil)

Flinders University – Adelaide Australia

23 May 2024

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ABSTRACT

Abstract - Urban traffic congestion presents significant challenges to efficient road operations and environmental sustainability. This thesis investigates how signal coordination and Bluetooth data integration affect traffic flow optimization, collision performance, and environmental sustainability along Adelaide's Green Hill Road Network and intersections.

The research project begins with a thorough literature review, which analyses signal coordination techniques, traffic management strategies, and simulation methodologies used in various urban areas, focusing on high traffic Flow and Traffic Congestion. It highlights the importance of innovative traffic management approaches while identifying gaps in current research.

The research uses Sidra Software to evaluate signal coordination strategies at three signalized intersections Network One intersection at the corner, the busiest one on Green Hill Road. Traffic performance indicators are used to evaluate the effectiveness of signal timing optimization in reducing congestion, travel delays, and environmental emissions.

Furthermore, the thesis analyses the integration of SCAT (Sydney Coordinated Adaptive Traffic System) and Bluetooth data for real-time traffic monitoring and signal optimization. By combining traditional SCAT design with Bluetooth's low-cost data collection capabilities, the study expects to increase signal timing precision and overall traffic management efficiency.

The findings highlight the benefits of modern traffic data collection methods and demonstrate the potential for data-driven urban traffic management. This research helps to reduce congestion, improve road operations, and reduce the environmental impact of urban areas by optimizing signal timing and traffic management strategies.

Keywords: Signal coordination, traffic management, SCAT, Bluetooth data integration, traffic signal optimization, traffic flow analysis, Sidra software, urban traffic congestion, collision performance, and environmental sustainability.

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: - **Mayur Vaghasiya**

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ACKACKNOWLEDGMENTS

I would like to express my heartfelt gratitude to my supervisor, Rocco Zito, for their unwavering support and invaluable guidance throughout the research process. Their expertise and encouragement have been instrumental in shaping this work. Additionally, I extend my appreciation to my co-supervisor, Golnoosh Farajollahi, for their technical assistance and support, which has contributed significantly to the development of this project.

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1 INTRODUCTION

1.1 Project Introduction

Signalized intersections are like lifelines for busy cities, keeping traffic moving effectively. As the global economy developed in the last century, more people moved to cities, causing them to expand in population and face new difficulties. One major issue is determining how to plan the transportation system in cities (Yan et al, 2016). These intersections are more than just crossroads; they are the focal points where roads come together, determining how cars, bicycles, and pedestrians move while ensuring everyone's safety and the smooth operation of our cities.

However, as urban areas expand, these critical intersections face several problems. Safety concerns, long queues, and traffic congestion are fairly common (Zhou et al., 2017). In addition to aggravating commuters, these issues increase fuel consumption and pollution (Albool et al., 2023).

This research project conducts a thorough investigation of signalized intersections to fully understand their behavior and assess how well they perform. The goal is to make these intersections more functional for everyone, which is similar to solving a large problem with a lofty goal. The key component of this mission is the use of real-time traffic data from advanced technologies such as SCATS (Leitner et al., 2022). Fine-tuning traffic signals using the Bluetooth System is a crucial strategy for improving traffic flow and reducing congestion (Celtek et al, 2020).

Imagine intersections that can change travel, reducing traffic and improving safety. The goal here is to eliminate a more sustainable and environmentally friendly urban landscape, not just to make things simple (Albool et al., 2023). We are primarily focusing on the most significant and busy intersections, which are constantly congested with various types of traffic. To understand traffic behavior and optimize intersection design and signal configurations, advanced modelling techniques and transportation specialists' expertise are required.

Throughout this journey, we search for creative solutions to make them smarter and more effective by investigating intersections with high levels of traffic network and one intersection intensity. We may face challenges along the way, but our solid goal is to create intersections that improve urban life by increasing efficiency.

1.2 Project Background

Signalized intersections are fundamental to urban transportation networks because they serve as important intersections where different roads converge. In congested cities, they control traffic flow, ensuring mobility and safety for cyclists, and pedestrians.

Several studies investigated ATSC to improve the accessibility of signalized intersections, with the primary objective of reducing traffic congestion and travel time (Reyad and Sayed, 2023)

Signal timing significantly influences the possibility of a collision at an intersection. According to (Reyad and Sayed, 2023), optimizing safety at signalized intersections requires changing key signal parameters as well as using microsimulation models and safety evaluation methods.

The background demonstrates how bad traffic is for drivers and the environment. Traditional solutions, such as developing more roads, are expensive and ineffective. There are also issues with congestion pricing. As a result, the focus is now on improving traffic signals and optimizing existing roads. (Leitner et al., 2022). The effectiveness of traffic signals is evaluated using data in this method. This study fills a gap because there is currently no best method for this evaluation, despite previous research. (Leitner et al., 2022). It aims to provide a concise framework by taking into consideration data sources, performance measures, and methodologies. The aim of addressing the difficulties in evaluating signalized intersections is to improve the performance of city transportation systems (Leitner et al., 2022).

Traffic Signal Control Systems (TSCS) are critical for reducing traffic congestion and improving transport in cities. Because signalized intersections face the majority of traffic issues, such as waiting times and congestion, effective TSCS control strategies are critical to enhancing their efficiency (Celtek et al, 2020). To model and assess signalized intersection performance, it is necessary to understand the fundamental concepts of TSCS, such as cycle length, delay time, and traffic states (Celtek et al, 2020). The overall effectiveness of urban traffic management can be improved through TSCS optimization, which is critical for reducing traffic congestion.

2 LITERATURE REVIEW

The literature review for the thesis on "Research Findings on Bluetooth Technology for Traffic Signal Monitoring and Traffic Control" can be organized around the primary contributions and findings from various studies researching the use of Bluetooth technology in traffic management systems. Here is a detailed literature review based on the available sources (Goodall et al., 2013).

2.1 Literature review for modelling

In traffic simulation, different types of simulations are used depending on the scope and detail required. Macro-simulation covers a whole city area and is used for creating large models that analyze city-wide traffic patterns, often employing tools like VISUM, CUBE, and EMME (Żak et al., 2014). Major simulation focuses on significant highways or main roads, providing insights into traffic flow on critical routes (Amini et al., 2017). Minor simulation targets small networks or individual streets, offering detailed analysis of specific streets or small areas. Microsimulation is the most detailed, concentrating on single intersections. (Abbas et al., 2013) Tools like SIDRA and AIMSUN are used to examine traffic at an intersection level, capturing individual vehicle interactions and optimizing traffic signals. So this thesis focuses on microsimulation because it involves studying one intersection and a small network. Microsimulation is ideal for this detailed and specific analysis, allowing for an in-depth look at traffic flow and signal timing at the chosen intersection (Alemdar et al., 2021).

2.2 Data Collections for Thesis

In transportation management, various data types are used for simulation and validation models to enhance traffic flow and improve planning. Drone imagery provides high-resolution aerial views that capture real-time traffic patterns and roadway conditions, offering valuable insights into congestion and traffic dynamics (Lei et al., 2024). Manual counts, such as turning movement counts, pedestrian counts, and vehicle classification counts, involve recording traffic data manually to understand vehicle volumes, movements, and types, which are crucial for effective traffic signal optimization and planning.

GPS data from vehicles delivers detailed information on travel times, speeds, and routes, helping to track real-time traffic conditions and validate traffic management strategies (Vlachogiannis et al. 2023). Smart sensors like SCATS (Sydney Coordinated Adaptive Traffic System) and Bluetooth technology play a significant role in modern traffic management (Emami et al., 2020). SCATS uses real-time data from intersection detectors to adjust signal timings dynamically based on traffic flow (Wolshon and Taylor, 1999), whereas Bluetooth sensors capture travel times by detecting signals from Bluetooth-enabled devices in vehicles. This technology provides a cost-effective and accurate way to monitor traffic flow and optimize signal control.

This thesis focuses on collecting and analyzing data from both SCATS and Bluetooth systems to create a comprehensive traffic model. By comparing the effectiveness of Bluetooth technology in providing accurate travel times for individual intersections and across the network with the SCATS system, the research aims to evaluate the strengths and limitations of each system. This comparison will help determine how these technologies can be integrated to enhance traffic management and improve overall network efficiency.

2.3 Using software and systems for this thesis

2.3.1 Sidra Intersection

Sidra Intersection provides a comprehensive set of functions for modelling many different types of intersections, including signalized intersections, roundabouts, and priority-controlled intersections. It enables engineers to simulate traffic movements, optimize signal timings, and evaluate the performance of intersection designs (Rubaee and Hameed, 1999).

2.3.1.1 Why choose Sidra Intersection

One of the primary reasons that transportation professionals choose Sidra Intersection is its strength and accuracy in modelling complex traffic interactions. It provides detailed analysis capabilities and supports a variety of methodologies for optimizing traffic signals and evaluating designs. Sidra is also known for its user-friendly interface and extensive documentation, which make it easier for engineers to understand and apply effectively (Rubaee and Hameed, 1999).

2.3.1.2 Advantages of Sidra

- Accurate simulation of traffic flow and intersection performance.
- Comprehensive analysis capabilities for many different kinds of intersection types.
- Optimization tools for signal timing and phasing.
- Detailed reporting and visualization abilities.
- User-friendly interface and extensive documentation.
- Widely recognized and accepted in the transportation engineering community.

2.3.1.3 Disadvantages of Sidra

- Sidra Intersection is commercial software, so it may be too costly for small organizations or projects.
- Learning Curve: While Sidra gives extensive documentation and support, understanding all of its features may take time and training.
- System Requirements: Running complex traffic simulations requires powerful hardware, which may be costly for some users.

2.3.2 Scats System

"Sydney Coordinated Adaptive Traffic System" is what SCATS indicates. This advanced traffic control system controls traffic signals at intersections in urban areas all around the world. To reduce congestion to improve flow, SCATS optimizes traffic signal timings in real time based on traffic conditions (Leitner et al., 2022). It analyses traffic and changes signal timing by applying sensors, cameras, and data analysis systems. SCATS is a well-liked option for urban traffic management because of effectively optimizes traffic flow and modifies changing traffic patterns.

Figure 1 provides a plan view of the intersection TS070 geometry, illustrating all left and right turns, as well as lanes in all directions. Numbers 1 to 22 mentioned on the line of the image, indicate the location of each sensor for each line and provide vehicle counts for that particular line. The letters A, B, C, D, E, F, F1 and G, mentioned on the left side of the image, indicate the phasing of the intersection.

Image removed due to copyright restriction.

Figure 1 SCATS plan view for Intersection TS070

The SCATS provides several benefits for traffic management. Because of its flexibility, traffic signal timings can be changed in real-time, significantly improving traffic flow and reducing congestion at intersections. SCATS helps to reduce emissions and travel times by reducing congestion and delays, thus contributing to environmental sustainability. Furthermore, transportation departments can effectively observe and coordinate traffic flow throughout a network of intersections according to its DTI management. Additionally, SCATS provides useful data collection and analysis methods that support infrastructure design and the evaluation of traffic movements (Leitner et al., 2022).

There are some difficulties with the system, too. The system is advanced and requires skilled expertise to operate, which might result in significant implementation and maintenance expenses. In addition, focusing excessively on technology might result in errors or issues with compatibility, which can limit effectiveness under some circumstances. SCATS continues to be an effective tool for managing urban traffic because of these errors, providing significant benefits in terms of reducing traffic and improving overall transportation performance (Vlachogiannis et al. 2023).

2.3.3 Bluetooth System for Traffic Management from Literature

The research focused on the role of Bluetooth detectors in modern urban traffic management, specifically in optimizing signalized distances to reduce congestion and delays. Bluetooth detectors, versus normal sensors such as logical loop detectors, provide real-time, direct measurements of vehicle travel times, offering a cost-effective solution for improving the performance of signalized intersections (Hart-Bishop, 2018). To reduce urban traffic congestion, a framework has been developed that integrates Bluetooth technology into traffic management systems. This approach simulates Bluetooth data collection and optimizes signalized intersections to improve traffic network efficiency with real-time data (Zarinbal, 2017). Bluetooth Media Access Control Scanners (BMS) are used to monitor traffic conditions by detecting the MAC addresses of Bluetooth devices, such as car navigation systems and mobile phones, within a certain range (Khol et al., 2013). These scanners collect data on unique identifiers, timestamps, and duration of device presence, which helps in tracking vehicular travel patterns. By analyzing this data, BMS can filter out non-vehicular devices and provide accurate insights into traffic flow and congestion. This method, as demonstrated with data from Brisbane City Council, shows how Bluetooth technology can effectively enhance traffic management by offering real-time, detailed information on vehicle movements (Ali et al., 2023). Their research suggests the significance of optimizing signal timings to reduce energy consumption and environmental impact, especially in areas with high vehicle traffic. To estimate incident concerns at signalized intersections a real-time model was developed that integrated extra value analysis and digital visual inspection. This study addresses the challenges of depending on normal accident data and shows the benefits of real-time assessment methods (Zahnow and Abewickrema, 2023).

The cost-effectiveness of Bluetooth technology is one of its primary benefits because sensors are less expensive than those used in traditional monitoring systems. Furthermore, Bluetooth systems function in an active approach, reducing interference with traffic flow. They give transportation organizations access to real-time data, which helps them plan and execute efficient traffic management strategies (Maripini et al., 2022).

Bluetooth technology in transportation does have limitations too. Particularly in busy urban settings where signal interference and a large number of Bluetooth-enabled devices can affect data collecting, accuracy problems are possible. Bluetooth sensors pick up unique identifiers (MAC addresses) from devices, which creates privacy concerns with data protection and privacy. Furthermore, the success of Bluetooth systems depends on drivers actively embracing the devices, and insufficient device penetration may result in low-quality data and availability in specific regions. The difficulties in maintaining Bluetooth technology in transportation include issues with signal interference and battery life, as well as the difficulties of collecting huge quantities of Bluetooth data (Friesen and McLeod, 2015).

2.3.4 Understanding How Traffic Detectors Operate

Bluetooth technology is being used increasingly for a variety of uses, such as traffic monitoring. When it comes to traffic control and monitoring, Bluetooth sensors are installed at important spots like intersections or on side roads to identify passing Bluetooth-enabled devices like cell phones or in-car Bluetooth systems. These sensors can estimate travel times, traffic flow, and origin-destination patterns by receiving Bluetooth device unique identifiers, or Probe ID addresses (Zarinbal, 2017).

Figure 2 shows the Bluetooth system at the intersection, indicating the coverage area, which is typically a radius of 100 to 150 meters in Adelaide. Bluetooth sensors are placed at the corners of each intersection. Each sensor has a unique ID used to count vehicles and measure travel time. For example, at Intersection A, when a vehicle is detected by a Bluetooth sensor, it creates a probe ID and notes the time. When the same vehicle is detected at Intersection B, the sensor records the same probe ID and time. This method helps calculate the travel time between intersections and track vehicle movements and turning counts using probe IDs.

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Figure 2 Bluetooth System

2.4 Challenges and Future Directions.

Despite Bluetooth technologies ensuring applications in traffic management, challenges remain, such as providing the accuracy and dependability of Bluetooth data in many different types of urban traffic configurations. Future research should focus on improving methods for collecting data and improving the accuracy of traffic prediction models that depend on Bluetooth data.

2.5 Literature summary

The use of Bluetooth technology in traffic management systems is an important development towards addressing the challenges of modern urban traffic congestion. The research evaluated emphasizes the ability of Bluetooth devices and data to enhance traffic performance, reduce delays, and increase overall transportation efficiency (Shirazi and Morris, 2016). Additional research is needed to build current analytical approaches, like deep learning, with Bluetooth data for traffic management. This literature analysis emphasizes the importance of Bluetooth technology in current traffic management and provides an organized plan for future research focused on more effectively applying these features (Liu et al., 2022).

This investigation aims to complete the research gap that has been identified regarding the use of Bluetooth technology for traffic signal monitoring and control. Specifically, this research will compare and contrast Bluetooth technology with existing systems, such as SCATS, integrate methods to enhance the accuracy of predictions and evaluate Bluetooth data consistency in a variety of urban traffic scenarios (Alghamdi et al., 2016). A detailed literature review establishes the research's context and explains its objectives before moving on to the methods. In addition to the development of Bluetooth-based sensors and using of SCATS system data, real-time data from urban traffic intersections is analyzed, including traffic volume, flow, travel time, delays, and signal phasing time (Hart-Bishop, 2018). Then, using Sidra software, a simulation model of some selected intersections and their network is created, working as the standard model for comparison. The combination of Bluetooth and SCATS data in the model provides an accurate analysis, evaluating the efficacy, accuracy, and quality of every system in the observation and control of traffic signals (Zarinbal, 2017). The results are then carefully analyzed and discussed, with a focus on the methodology behind the choice of each system and the device as well as how each one provides to reaching the goals of the research. Using Bluetooth technology and advanced analytical models, the research aims to provide relevant data on future developments in traffic management solutions (Zarinbal, 2017).

2.6 Research Gap

The research gap in the use of Bluetooth technology for traffic signal monitoring and control primarily focuses on three primary areas: the need for deep analysis of comparisons between Bluetooth-based systems and traditional traffic management systems like SCAT, the addition of deep learning methods to improve the accuracy of predictions and real-time responsiveness of traffic signal systems, and the consistency and reliability of Bluetooth data across different urban traffic These gaps show the possibility for significant progress in traffic management by conducting more comprehensive comparison studies, using advanced analytical models, and enhancing data collection methods for more reliable and efficient traffic management solutions.

3 METHODOLOGY

3.1 Study Area

The SA Location Viewer indicates that Greenhill Road has a large volume of traffic, which is why it was selected as the study area. There were two phases to the research method.

For this research, chose this location because intersection TS070 which is indicated by the purple color square in fig. 3 is particularly busy during the AM time period, according to the SA location site. Additionally, the network consisting of intersections TS067, TS0316, and TS181 experiences high traffic volume in the PM time, which is indicated by the red rectangular in Fig. 3, also check how the Bluetooth system works during the busiest time period and how that makes this system in compare to SCATS system and check this system used in busiest time or not. These factors make this intersection and network ideal for this thesis.

The collection and analysis of data in the initial stage were concentrated on TS070, a single intersection. To achieve specific research aims and obtain preliminary insights, this intersection was extensively studied. For turning counts, heavy vehicle ratios, saturation flow, and queue durations, detailed SCATS operation sheets, vehicle counts, and live data collection were applied.

A network of intersections along Greenhill Road, including TS067, TS0316, and TS0181, was chosen for the second phase. Utilizing information from these intersections, a thorough traffic simulation model was developed. A solid foundation for the simulation was established by combining data from the Add-insight traffic intelligence system via Bluetooth, SCATS data, and manual data collection. To achieve additional traffic management aims for the network on Greenhill Road, this phase aimed to evaluate traffic patterns and optimize signal timings.

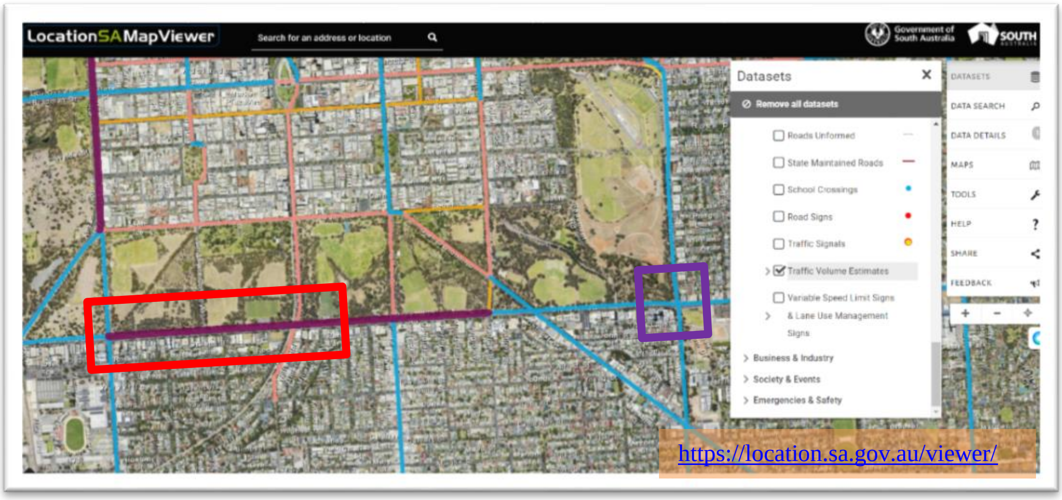

Figure 3: SA Location Shows Traffic Volume

In the project shows in Figure 4, data collection involves SCATS data for traffic management, Bluetooth data for vehicle tracking, and manual data for additional insights. Using this information, Sidra Intersection software is utilized to create and analyze various models, including existing, optimized, and practical models, to assess intersection performance. The analysis covers metrics such as delays, travel time, speed, fuel consumption, and queue lengths. Additionally, the Sidra Network is evaluated through these models to determine average delays, travel time, and speed. Finally, the project compares travel times from SCATS and Bluetooth data to assess their accuracy and reliability, aiming to enhance traffic flow and network efficiency. More details and explanation provided in below steps.

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Methodology

- Data Collection
  - Scats Data
  - Bluetooth Data
  - Manual Data
- Create Sidra Intersection
  - Existing Model
  - Sidra Optimized
  - Sidra Practical
- Analysis Intersection
  - Delays
  - Travel Time
  - Speed
  - Fuel consumption
  - Queue
- Create Sidra Network
  - Existing Model
  - Sidra Optimized
  - Sidra Practical
- Analysis Network
  - Avg. Delays
  - Avg. Travel Time
  - Avg. Speed
- Analysis Route
  - Travel Time from SCATS
  - Travel Time from Bluetooth
  - Comparing Travel Time

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Figure 4 Methodology Process Chart

3.2 Data Collection

3.2.1 Scats data

There are several different sources were used to get SCATS information. Flinders University made its SCATS database available, which included an extensive amount of information collected from traffic lights. This database provided detailed SCATS operating records that detailed the phasing of the signals, turning movements, and phase percentages during peak hours for every intersection. (see Appendix A)

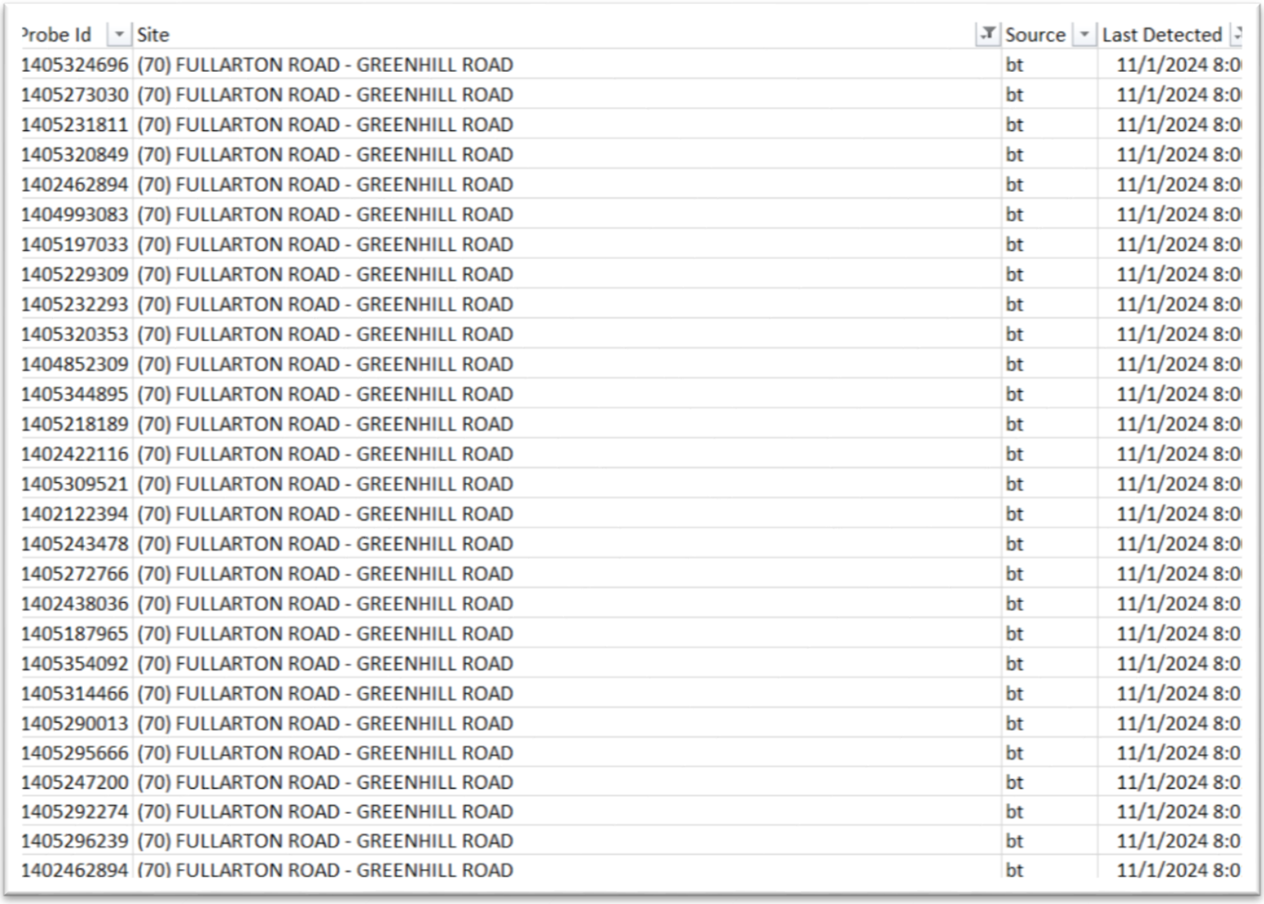
The vehicle counts obtained from SCATS detectors—which collect data every five minutes—were utilized. The DIT and the SCATS database at Flinders University provided this data, which included thorough traffic counts for every intersection. In addition, the Strategic Monitor acquired SCATS phasing data, which provided current signal phasing and cycle length time.

In addition to the SCATS data, additional sources of data were provided, such as intersection drawings that provide geometry and lane width, Google Maps, and DIT manual turning counts. Data from the Add-insight - Traffic Intelligence System was collected in real time. Where appropriate, onsite surveys were carried out to resolve any problems in the data. A strong basis for traffic analysis and modelling is provided by the integration of these different sources.

3.2.2 Bluetooth data

Figure 5 shows the Bluetooth data, including Probe ID, Site, and Date. The Probe ID is assigned when a vehicle passes through any of the intersections equipped with Bluetooth sensors, and this ID remains the same for that vehicle throughout the day. The Site indicates the specific intersection, while the Date includes both the time and date of the data collection.

The Add-insight Traffic Intelligence System, which supplied data at one-second intervals, was used to collect Bluetooth data. This fresh and real-time data was essential for a thorough research of the traffic.



Probe Id	Site	Source	Last Detected
1405324696	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405273030	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405231811	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405320849	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1402462894	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1404993083	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405197033	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405229309	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405232293	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405320353	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1404852309	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405344895	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405218189	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1402422116	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405309521	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1402122394	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405243478	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405272766	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1402438036	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405187965	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405354092	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405314466	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405290013	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405295666	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405247200	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405292274	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1405296239	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0
1402462894	(70) FULLARTON ROAD - GREENHILL ROAD	bt	11/1/2024 8:0

Figure 5 Bluetooth data

3.2.3 Manual data

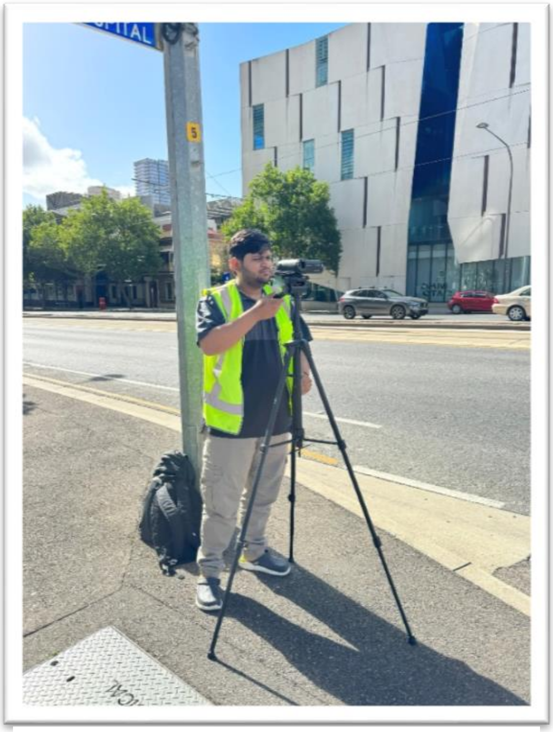


Figure 6 Manual data collecting on each site

There were certain intersections where missing SCATS sensors prohibited collecting of exact turning counts, requiring live data collection. For the reason of manually counting the turning vehicles, onsite visits and hour-long video recordings were performed at these an intersection. Furthermore, manual records of the ratios of heavy vehicles were kept at expected intersections. Comprehensive data was collected by personally monitoring the saturation flow and queue lengths in each direction. The accuracy and thoroughness of the traffic analysis and modelling depended significantly on this manual data collection.

For the research collected manual data for my network research at intersections TS067, TS316, and TS181 because these intersections lack SCATS sensors for left turns. Additionally, some vehicles at these intersections go straight and turn left. To obtain accurate results, so collected manually data specifically for left turns at those intersections.

3.3 Parameters of this Research

These parameters are crucial for optimizing intersection performance as they provide a detailed understanding of traffic dynamics and guide focused intervention. Delay time is important because it highlights where vehicles are experiencing significant wait times, indicating areas that need improved signal timings to reduce congestion. Travel time assesses the overall efficiency of the network, helping to identify routes and intersections where delays are causing inefficiencies, thus guiding efforts to streamline traffic flow. Speed data is essential for evaluating traffic conditions and safety; it identifies areas where speeds are too low, suggesting congestion, or too high, indicating potential safety issues, and informs adjustments to signal timings and speed limits. Queue length measures the build-up of vehicles at intersections, which is critical for determining if lane configurations and signal timings are adequate to handle traffic volumes, helping to minimize backups and improve throughput. Fuel consumption is directly linked to traffic efficiency and environmental impact, providing a measure of the effectiveness of traffic management strategies in reducing idling and emissions, thus promoting sustainable transportation. By analyzing these parameters, traffic engineers can develop and implement strategies to optimize signal timings, improve intersection design, enhance traffic flow, and reduce environmental impacts, leading to more efficient and effective intersection performance.

3.3.1 Delay Time

In transportation, delay time means the time it takes for a vehicle to arrive at its destination after the expected or scheduled travel time. It is the difference between the actual trip time and the expected or ideal travel time.

Delay times are essential in transportation management and planning because they can impact the efficiency and reliability of transportation systems. Accurate delay time estimation is essential for providing passengers and shippers accurate real travel time information, as well as for efficient resource allocation and scheduling.

3.3.2 Travel Time

Travel time is the amount of time it takes to travel from one location to another. It indicates the duration of a trip or route, which is often measured in minutes and Seconds.

Accurate travel time estimation is critical for effective transportation planning, scheduling, and giving accurate information to passengers and transportation service users.

3.3.3 Speed

Speed is defined as the velocity at which an object's position changes over time. It indicates how quickly an object moves or covers a particular distance. Speed is usually stated as a distance moved per unit of time, like kilometers per hour (km/h).

3.3.4 Queue

A queue is a line of vehicles that forms at a red traffic signal and waits to continue through the intersection when the light turns green. This data allows them to analyze intersection performance, optimize signal timing, and identify intersections that may require changes, such as creating turning lanes or changing signal phasing to reduce queueing and delays. Traffic data, lane capacities, signal timing, turning movements, and road geometry, are some of the elements affecting queue development. Increased lines may indicate that the intersection has high traffic during peak hours.

3.3.5 Fuel Consumption

Fuel consumption in transportation refers to the amount of fuel (gasoline, diesel, etc.) used or consumed by vehicles to travel a specified distance. Improving fuel efficiency with, optimizing routes, reducing delays, and encouraging sustainable transportation modes are all changes to reduce overall fuel consumption in the transportation industry.

3.4 Sidra Intersection TS070

3.4.1 Optimized with Scats System

First of all, the TS070 intersection was analyzed by collecting SCATS data, Bluetooth data, and manual data. At this intersection, SCATS sensors are placed in all directions and for all movements. As a result, manual counts are only required for heavier vehicles, evaluating saturation flow, and analyzing exists in each lane.

Table 1 shows that data collected from the SCATS system, detailing vehicle counts for different directions and movements at an intersection during the AM peak period, which is busiest time for that intersection TS070. The table shows the total vehicle count of 6,226 for the intersection, breaking it down by each direction and movement. It also provides the percentage distribution of vehicles making right turns, through movements, and left turns in each direction. This percentage helps to understand the traffic flow and distribution of movements at the intersection TS070.

Table 1 Scats Data for TS070 AM Peak

TS070 Scats System			
Direction	Movement	Counts	% of vehicle Movement on each direction
North	Right	541	8.69
North	Through	1015	16.30
North	Left	147	2.36
West	Right	257	4.13
West	Through	762	12.24
West	Left	287	4.61
South	Right	625	10.04
South	Through	990	15.90
South	Left	92	1.48
East	Right	645	10.36
East	Through	680	10.92
East	Left	185	2.97
	Total	6226	100.00

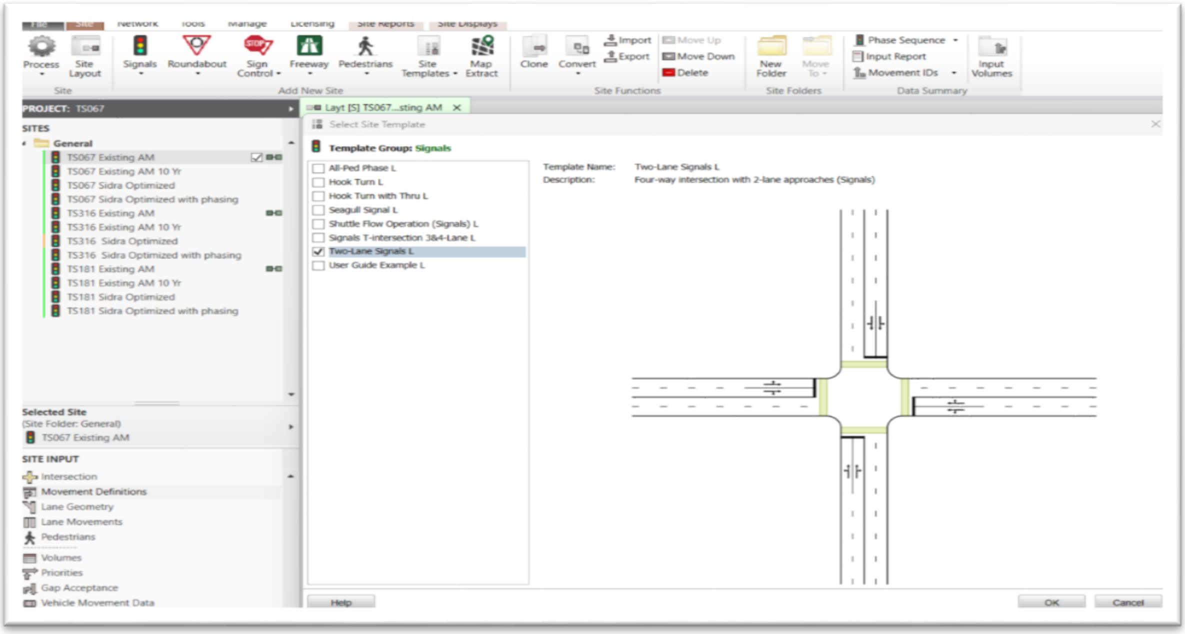
Furthermore, the SIDRA modelling process was started in steps. After installing the software, a license was required. That was able to use the software easily because of Flinders University, which provided SIDRA Intersection licenses.

The initial stage was to design the intersection's geometry using software. That was got this geometry from Google Maps and also used the SCATS Viewer provided by Flinders University.

Figure 7 Google Map Geometry for TS070

(https://www.google.com/maps/@-34.9325313,138.6052686,14.75z?entry=ttu)

Figure 8 shows a number of sample models. It can start by directly modifying these samples to simplify the geometry and obtain results quickly and optimize efficiently.



PROJECT: TS067

SITES

General
- TS067 Existing AM
- TS067 Existing AM 10 Yr
- TS067 Sidra Optimized
- TS067 Sidra Optimized with phasing
- TS316 Existing AM
- TS316 Existing AM 10 Yr
- TS316 Sidra Optimized
- TS316 Sidra Optimized with phasing
- TS181 Existing AM
- TS181 Existing AM 10 Yr
- TS181 Sidra Optimized
- TS181 Sidra Optimized with phasing

Selected Site
(Site Folder: General)
TS067 Existing AM

SITE INPUT
- Intersection
- Movement Definitions
- Lane Geometry
- Lane Movements
- Pedestrians
- Volumes
- Priorities
- Gap Acceptance
- Vehicle Movement Data

Layt [S] TS067...sting AM

Select Site Template

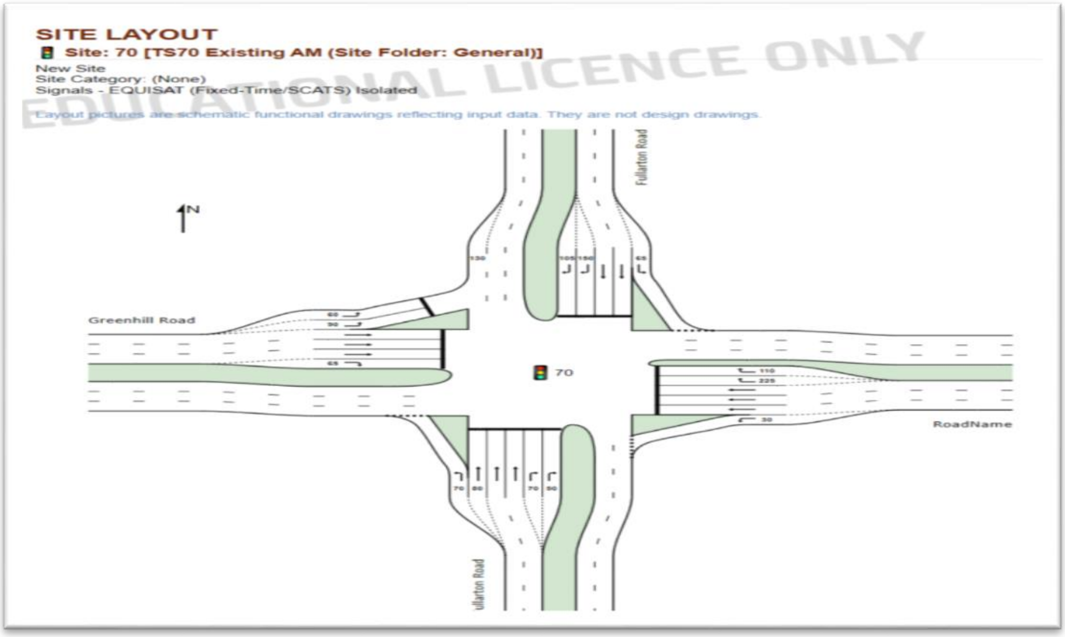
Template Group: Signals

☐ All-Ped Phase L
☐ Hook Turn L
☐ Hook Turn with Thru L
☐ Seagull Signal L
☐ Shuttle Flow Operation (Signals) L
☐ Signals T-intersection 3&4-Lane L
☑ Two-Lane Signals L
☐ User Guide Example L

Template Name: Two-Lane Signals L
Description: Four-way intersection with 2-lane approaches (Signals)

Figure 8 Two-lane Signals L

Figure 9 shows the geometry of intersection TS070 as modelled in SIDRA Intersection software. The model accurately reflects the road lengths, widths, and lane configurations as depicted in Google Maps images. It includes measurements for short lanes, as well as provisions for left turns, right turns, and straight-through movements, all consistent with the live pictures of the intersection.



SITE LAYOUT

Site: 70 [TS70 Existing AM (Site Folder: General)]

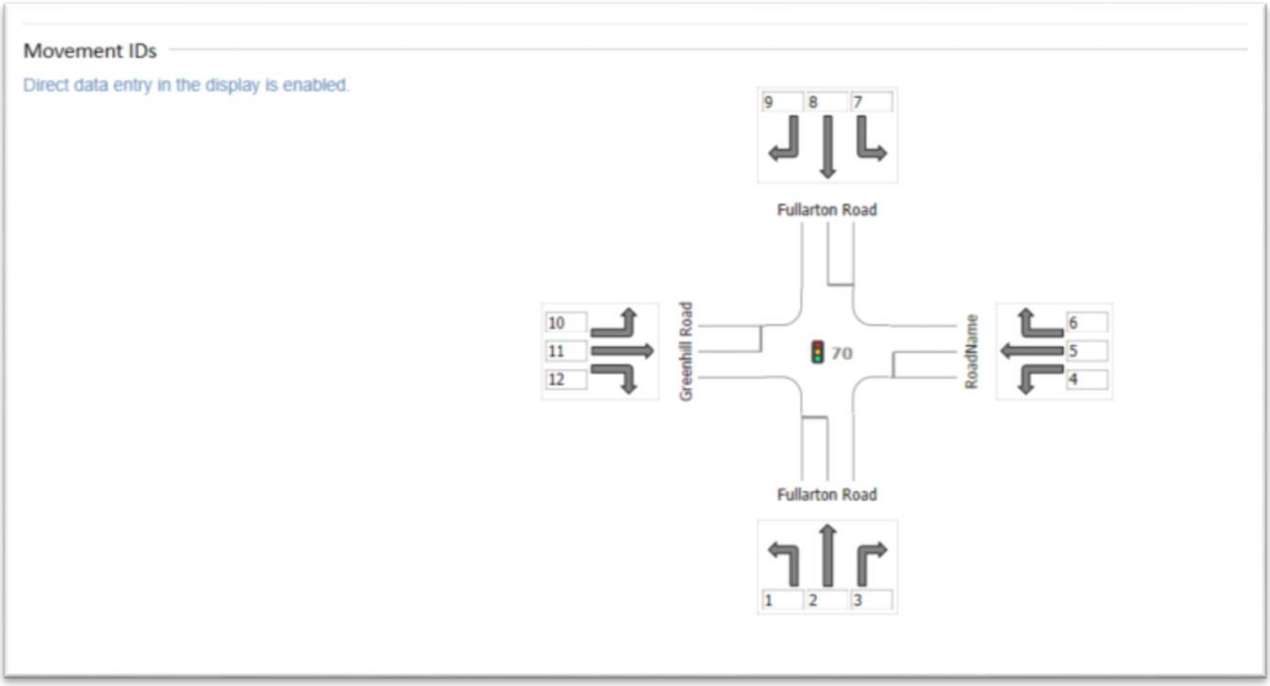
New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated

Layout pictures are schematic functional drawings reflecting input data. They are not design drawings.

EDUCATIONAL LICENCE ONLY

Figure 9 Modified Geometry TS070

Figure 10 shows the identification of movements at the intersection, including right turns, left turns, and straight-through movements for each direction.

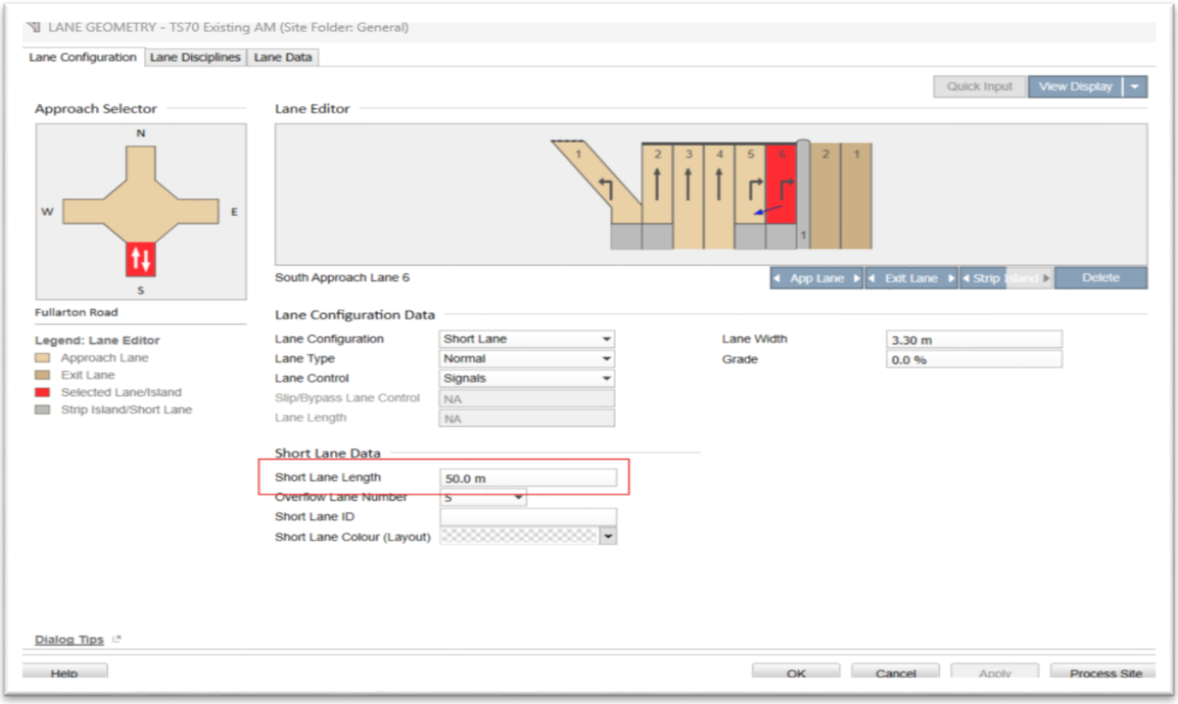


Movement IDs

Direct data entry in the display is enabled.

Figure 10 Movement Definition for TS070

Figure 11 shows the adjustments made to the short lane measurements, aligning them with real-time data and Google Maps. By measuring the lane dimensions from Google Maps and inputting the same size into the model, the geometry is accurately represented, leading to precise results.



LANE GEOMETRY - TS70 Existing AM (Site Folder: General)

South Approach Lane 6

Lane Configuration Data

Lane Configuration: Short Lane
Lane Type: Normal
Lane Control: Signals
Slip/Bypass Lane Control: NA
Lane Length: NA
Lane Width: 3.30 m
Grade: 0.0 %

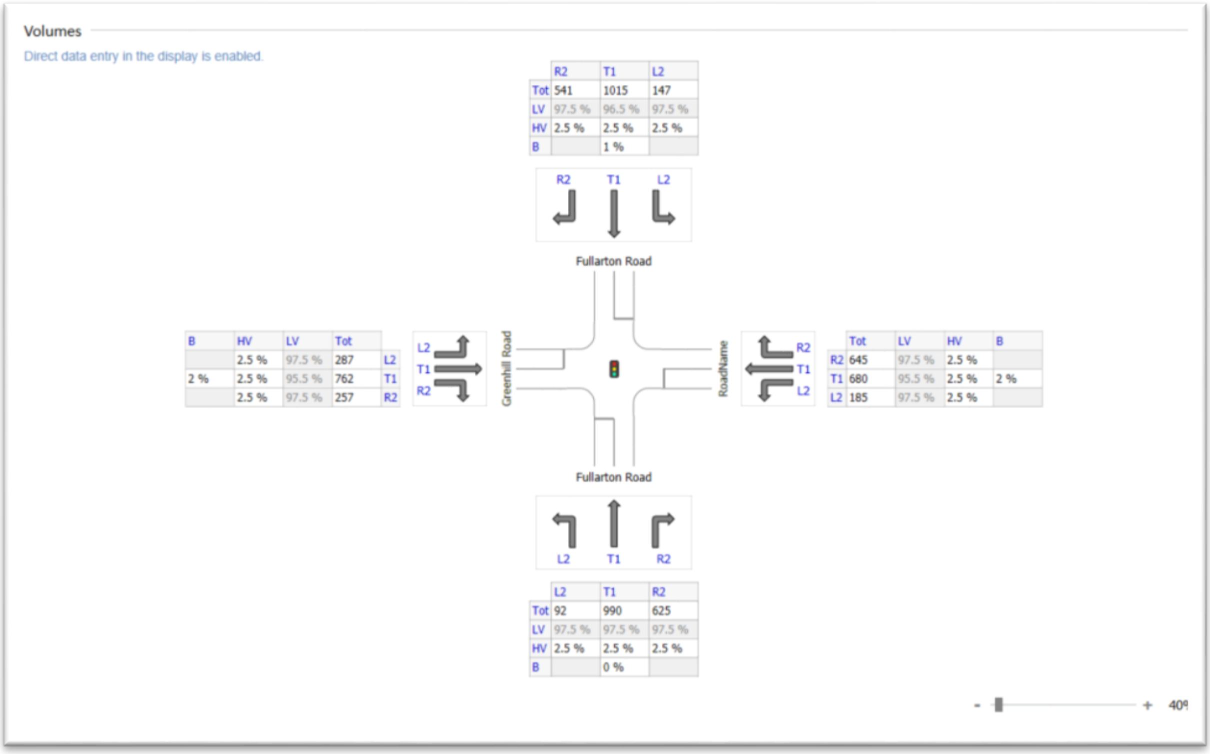
Short Lane Data

Short Lane Length: 50.0 m
Overflow Lane Number: 5
Short Lane ID:
Short Lane Colour (Layout)

Figure 11 Change Lane length

Figure 12 shows the vehicle volumes in each direction. The volume data, obtained from the SCATS system, is input into the model. This allows for the management of heavy vehicle counts and provides insights into traffic flow patterns, which is get from the manual data. The figure 12 helps in understanding the distribution of vehicle volumes across different directions.

It was included the percentage of heavy vehicles from the manual data to the intersection model. Furthermore, using the JTC application, we calculated the saturation flow at this intersection using that recorded video and put it into the model.



Volumes

Direct data entry in the display is enabled.

	R2	T1	L2
Tot	541	1015	147
LV	97.5 %	96.5 %	97.5 %
HV	2.5 %	2.5 %	2.5 %
B		1 %	

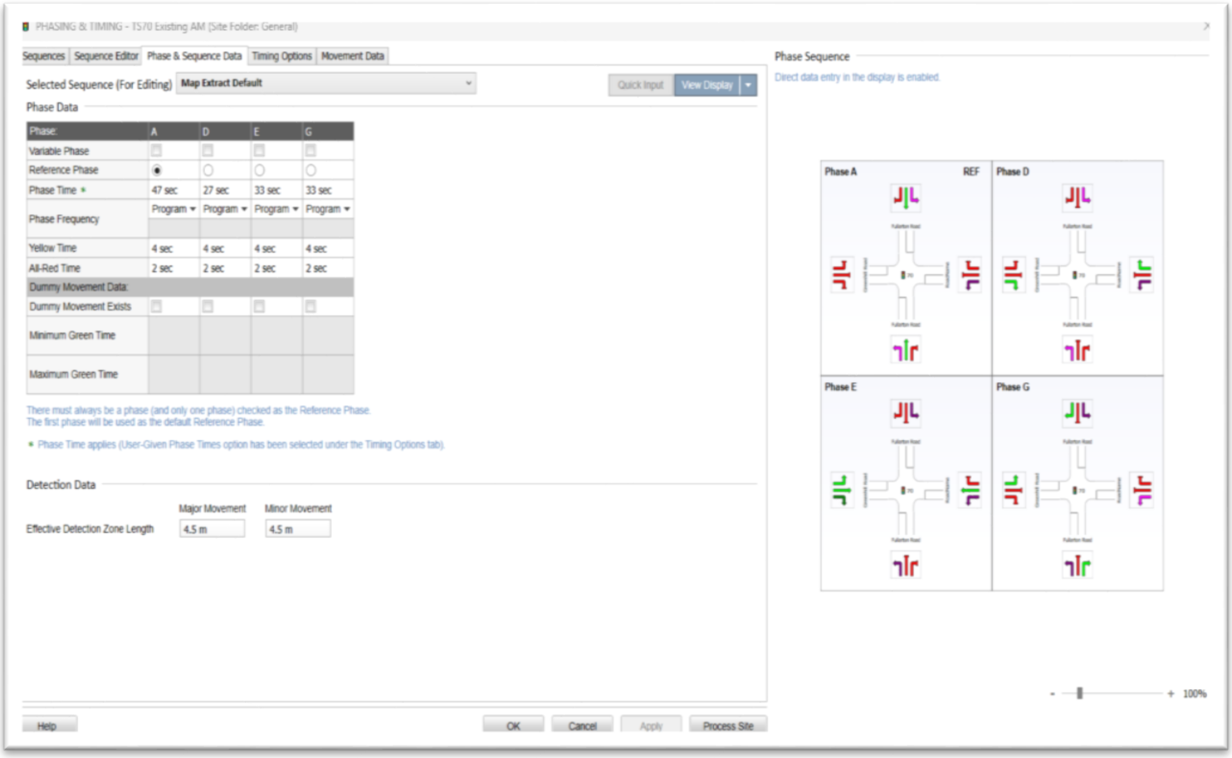
B	HV	LV	Tot	
	2.5 %	97.5 %	287	L2
2 %	2.5 %	95.5 %	762	T1
	2.5 %	97.5 %	257	R2

	Tot	LV	HV	B
R2	645	97.5 %	2.5 %	
T1	680	95.5 %	2.5 %	2 %
L2	185	97.5 %	2.5 %	

	L2	T1	R2
Tot	92	990	625
LV	97.5 %	97.5 %	97.5 %
HV	2.5 %	2.5 %	2.5 %
B		0 %	

Figure 12 Vehicles Volume form Scats data for TS070

Figure 13 shows the phasing and timing of the intersection. It allows for the modification of signal phases and timings. The figure shows the intersection's phasing and timing as per real-time data, reflecting live movements and timings, especially during busy periods.



Selected Sequence (For Editing): Map Extract Default

Phase Data

Phase:	A	D	E	G
Variable Phase	☐	☐	☐	☐
Reference Phase	●	○	○	○
Phase Time *	47 sec	27 sec	33 sec	33 sec
Phase Frequency	Program	Program	Program	Program
Yellow Time	4 sec	4 sec	4 sec	4 sec
All-Red Time	2 sec	2 sec	2 sec	2 sec
Dummy Movement Data:				
Dummy Movement Exists	☐	☐	☐	☐
Minimum Green Time				
Maximum Green Time				

There must always be a phase (and only one phase) checked as the Reference Phase.
The first phase will be used as the default Reference Phase.

* Phase Time applies (User-Given Phase Times option has been selected under the Timing Options tab).

Direct data entry in the display is enabled.

Detection Data

	Major Movement	Minor Movement
Effective Detection Zone Length	4.5 m	4.5 m

Figure 13 Phasing and timing for TS070

Finally, that was obtained the intersection findings using SCATS data and made the existing model and got results like Delay time, Trave Time, Speed, Queue, and fuel consumption as shown in Table 2 in the first column. After that improved the model by introducing fixed cycle time, SIDRA-generated phasing time, and simulation, which is called Sidra Optimized model, and got that result respectively. Another approach combined SIDRA-generated cycle and phasing times with SIDRA-mediated simulation, which is called Sidra Practical, and got that result from the software as shown in below Table 2.

Table 2 Result of TS070 from Scats Data

TS070 Scats System (AM Peak period)			
	Existing	Sidra	Sidra Practical
Delay (s)	45.7	45.6	23.2
Travel Time (s)	67.7	67.2	54.7
Speed (km/h)	36.2	37.9	44.8
Queue (m)	64	64	29.4
Fuel Consumption (L/h)	241.7	240	230
CO2 (kg/h)	572.2	571.5	544.5

3.4.2 Optimized with Bluetooth System

Using Bluetooth data, first of all, reached the Add-insight site to collect data for intersection TS070 and near intersections such as TS290, TS069, TS515, and TS531 during the AM peak time from 8 to 9 AM for one hour.

As per the details provided in (2.3.4), understanding the detector work involves analyzing three types of columns: Probe ID, Site Location, and Date & Time. As shown in Figure 14, data from the North direction indicates the movement of three vehicles, indicated by A, B, and C. The Probe ID uniquely identifies each vehicle, the Site Location specifies the exact detection point, and the Date & Time column records when each vehicle was detected. This setup helps in tracking vehicle movements accurately and understanding traffic patterns from the North direction.

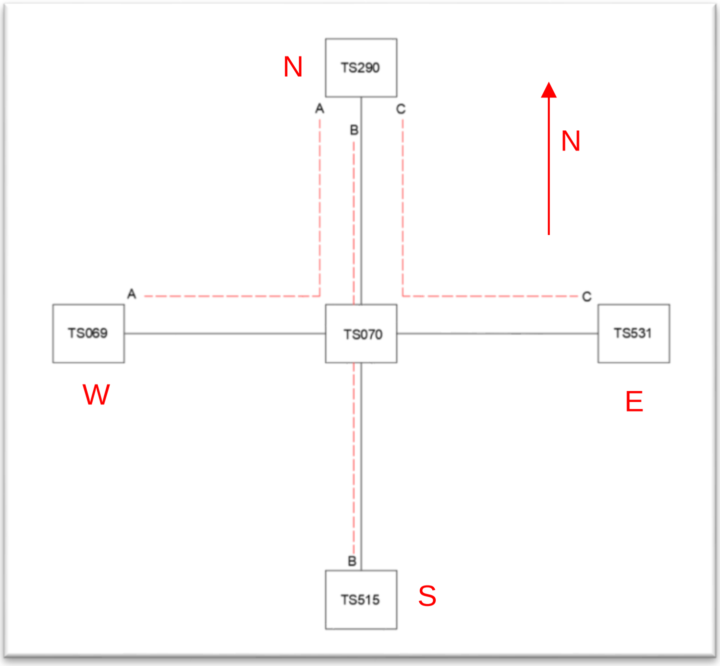


Figure 14 Bluetooth sensors

If vehicles A, are detected in this order: TS290 → TS070 → TS069, with the last detection at TS069, it means that vehicle A made a right turn from the north.

If vehicle B is detected in the sequence: TS290 → TS070 → TS531, the last detection at TS531 indicates that vehicle B made a left turn from the north.

If vehicle C is detected in the sequence: TS290 → TS070 → TS515, with the last detection at TS515, it means that vehicle C travelled straight from the north.

After using the aforementioned method to determine vehicle counts for intersection TS070, Table 3 shows data collected from the Bluetooth system, detailing vehicle counts for different directions and movements at an intersection during the AM peak period, which is the busiest time for that intersection TS070. The table shows the total vehicle count of 979 for the intersection, breaking it down by each direction and movement. It also provides the percentage distribution of vehicles making right turns, through movements, and left turns in each direction. This percentage helps to understand the traffic flow and distribution of movements at the intersection TS070.

Table 3 Vehicles Counts Using Bluetooth Data

TS070 Bluetooth			
Intersection	Direction	Counts	% of vehicle Movement in each direction
290 (N)	Right	101	10.32
290 (N)	Through	178	18.18
290 (N)	Left	15	1.53
69 (W)	Right	14	1.43
69 (W)	Through	134	13.69
69 (W)	Left	111	11.34
577 (S)	Right	12	1.23
577 (S)	Through	168	17.16
577 (S)	Left	23	2.35
531 (E)	Right	42	4.29
531 (E)	Through	157	16.04
531 (E)	Left	24	2.45
	Total	979	100.00

After determining the direction of the vehicles using this data, we had difficulty identifying between vehicles, pedestrians, and cyclists. To solve this issue, used the interquartile outlier elimination method, which is explained below.

3.4.3 Interquartile Outlier

Image removed due to copyright restriction.

Figure 15 Interquartile Outlier

The outlier formula, often known as the 1.5 IQR rule, is a standard method for identifying outliers in a data set. Outliers are extraordinary results that differ significantly from the majority of your data set (Thomas, 2022).

Image removed due to copyright restriction.

Figure 16 Upper and Lower Cut-off

The formula analyses upper and lower bounds as cutoff points to identify outliers. An outlier is defined as a value greater than 1.5 times the interquartile range (IQR) above the third quartile (Q3). Similarly, any value greater than 1.5 times the IQR below the first quartile (Q1) is classified as an Outlier.

The interquartile range (IQR) is the distance between the first and third quartiles. To get the interquartile range, subtract the first and third quartiles.

IQR = Q3 - Q1

Upper Boundary = Q3 + 1.5 * IQR

Lower Boundary = Q1 – 1.5 * IQR

That was used probe IDs and detection times to determine travel times for each vehicle. Using this method, removed pedestrians and cyclists from our vehicle count data.

As shown in Table 4 after removing the outlier total number of vehicle counts is nearly 15% of the scats counts, because the SCATS vehicle count is 6226, and got vehicles counted after removing the outlier from the Bluetooth system was 915.

As per the research paper, the detection of vehicles at the intersection rate is 7 – 16% (Ayodele, 2017) after that, we created three types of models and reached the results shown in the figure below.

Table 4 after removing the outlier

TS070 Bluetooth After removing Outlier			
Intersection	Direction	Counts	% of vehicle Movement in each direction
290	Right	96	10.49
290	Through	164	17.92
290	Left	14	1.53
69	Right	12	1.31
69	Through	125	13.66
69	Left	105	11.48
577	Right	23	2.51
577	Through	155	16.94
577	Left	11	1.20
531	Right	38	4.15
531	Through	150	16.39
531	Left	22	2.40
	Total	915	100.00

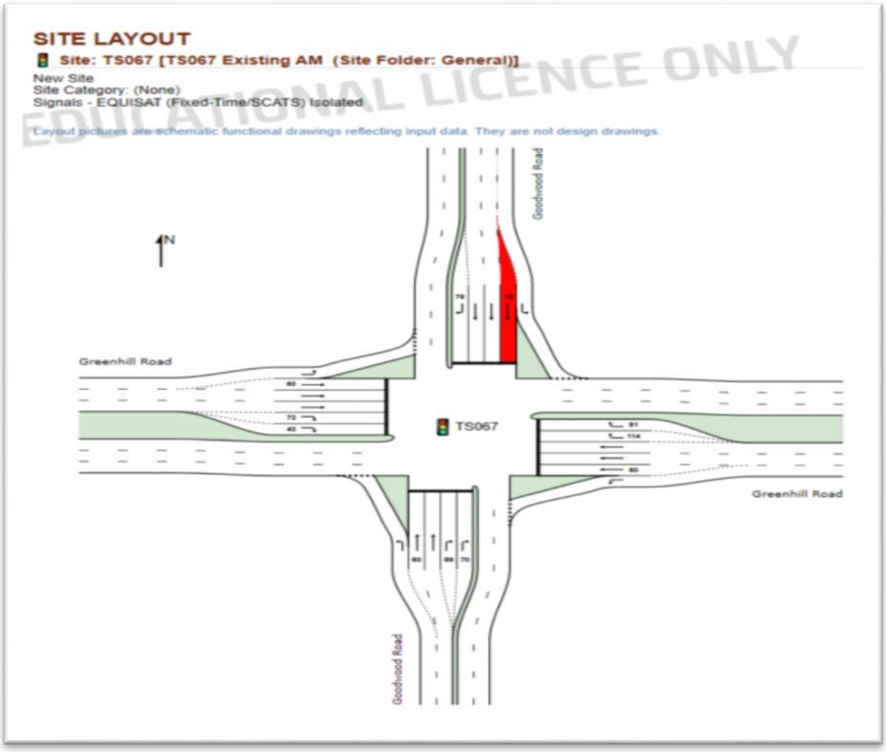
3.5 Sidra Network and Analysed

The chosen network on Green Hill Road because of the high volume of vehicles, according to the SA Location site. That was found to evaluate and optimize traffic conditions on this road.

For the analysis, the chosen one 3 intersections: TS067, TS316, and TS181. Using SIDRA software, it was created intersections similar to TS070 followed by all required research.

Figure 17 Google Map TS067 - TS316 - TS181

Figures 18, 19, and 20 show the geometry of intersections TS067, TS316, and TS181, respectively, as modelled in SIDRA Intersection software. The models accurately reflect the road lengths, widths, and lane configurations based on Google Maps images. They include measurements for short lanes and accommodate left turns, right turns, and straight-through movements, all consistent with live pictures of the intersections.



SITE LAYOUT

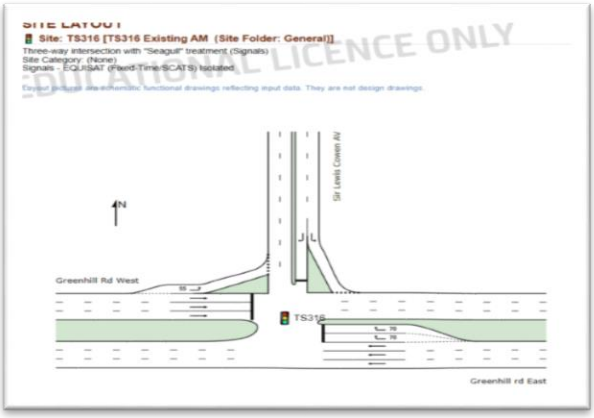
Site: TS067 [TS067 Existing AM (Site Folder: General)]

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated

Layout pictures are schematic functional drawings reflecting input data. They are not design drawings.

EDUCATIONAL LICENCE ONLY

Figure 18 Sidra Geometry TS067



SITE LAYOUT

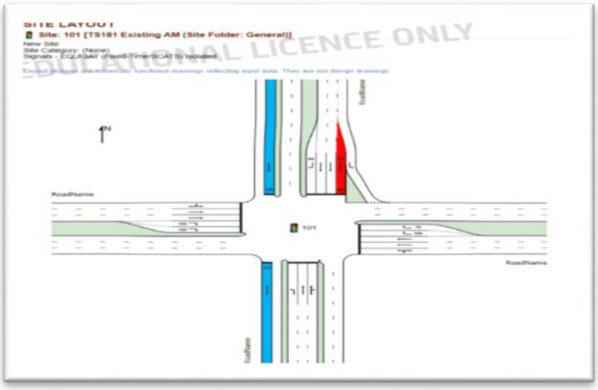
Site: TS316 [TS316 Existing AM (Site Folder: General)]

Three-way intersection with "Seagull" treatment (Signals)
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated

EDUCATIONAL LICENCE ONLY

Layout pictures are schematic functional drawings reflecting input data. They are not design drawings.

Figure 19 Sidra Geometry TS316



SITE LAYOUT

Site: 101 [TS181 Existing AM (Site Folder: General)]

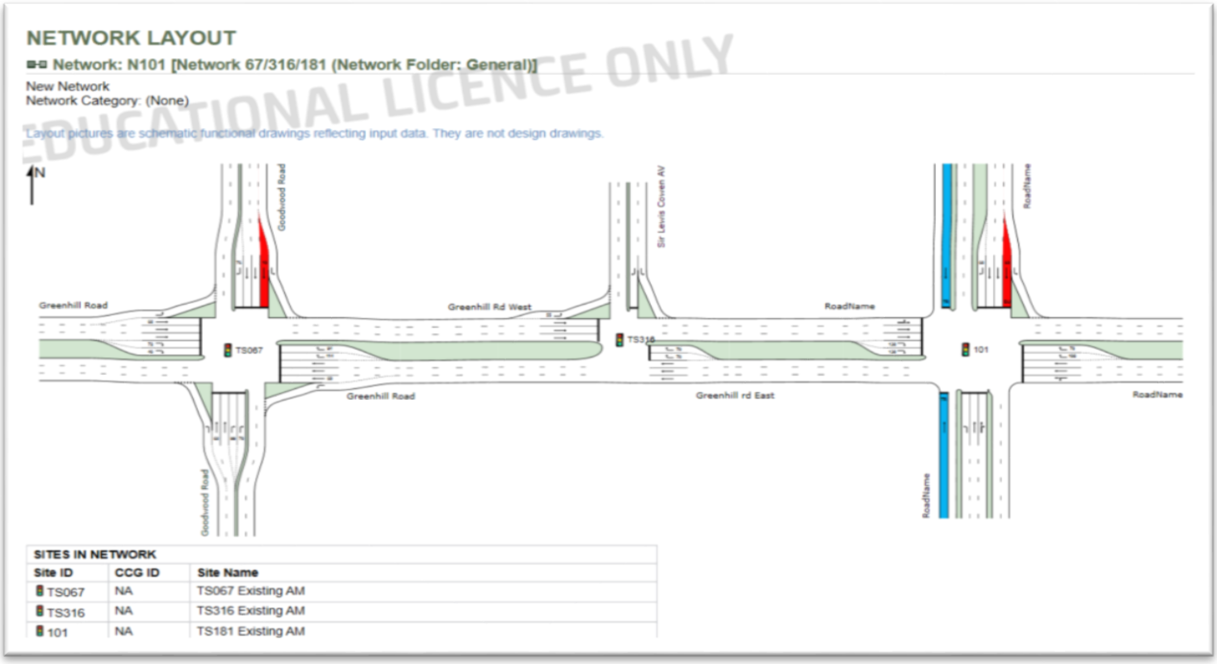
New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated

EDUCATIONAL LICENCE ONLY

Layout pictures are schematic functional drawings reflecting input data. They are not design drawings.

Figure 20 Sidra Geometry TS181

Following that, that was created different models for each intersection, similar to TS070, and then linked to create a network throughout Green Hills Road. As per shown in Figure 21.



NETWORK LAYOUT

Network: N101 [Network 67/316/181 (Network Folder: General)]

New Network
Network Category: (None)

EDUCATIONAL LICENCE ONLY

Layout pictures are schematic functional drawings reflecting input data. They are not design drawings.

SITES IN NETWORK

Site ID	CCG ID	Site Name
TS067	NA	TS067 Existing AM
TS316	NA	TS316 Existing AM
101	NA	TS181 Existing AM

Figure 21 Network TS067- TS316 - TS181

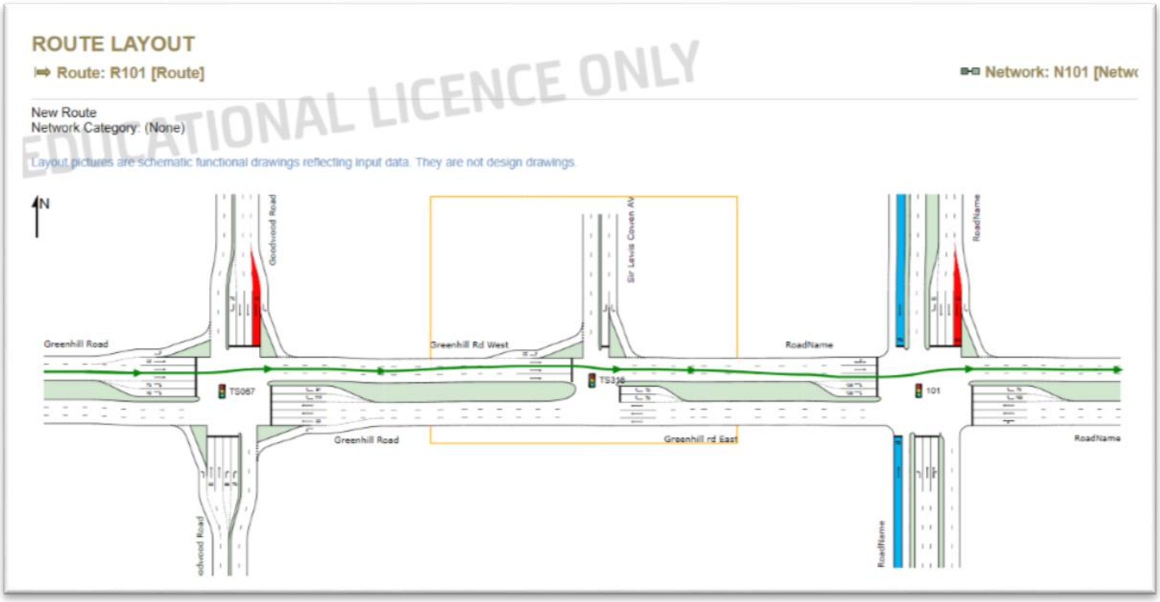
After modelling the intersections in the SIDRA Intersection and integrating the SCATS data, that was analyzed the network to obtain results for the existing model. Using SIDRA Intersection software, first of all, fixed the cycle time and allowed SIDRA to optimize the phasing time. Subsequently, it was used SIDRA's practical option, which optimizes both cycle time and phasing time. The results for these different scenarios are detailed in Table 5 like Avg. Delays, Avg. Travel Time, and Avg. Speed.

Table 5 Result of Network

Network			
Model	AVG. delays (s)	AVG. Travel time	AVG. Speed
Existing Network	53.2	301.1	19.6
Sidra Optimized Network	47.4	263.1	21.3
Sidra Optimized Network Practical	41.5	251.7	23.4
10-Year Future Existing Model	279.8	1266.1	4.7

3.6 Route Analysis

After analyzing the entire network, they focused on one route shown in Fig 22, which is the busiest during the AM time period, to obtain travel time data. The main reason for choosing this specific route is that using data from the entire intersection would not yield precise results. Therefore, the selected busiest route is for a more accurate analysis. Using SIDRA Intersection software, made the rout easily from the software and also analyzed this route and obtained the travel time results.



Layout pictures are schematic functional drawings reflecting input data. They are not design drawings.

Figure 22 Busiest Route for Network

3.6.1 Travel Time from Bluetooth

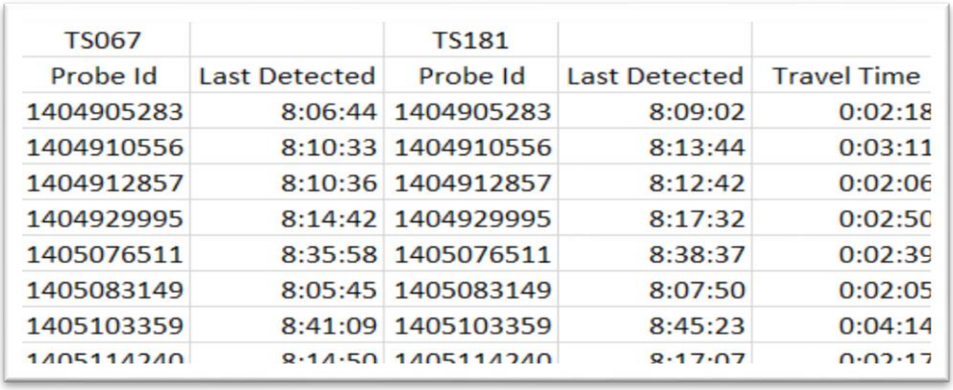
In this analysis, Bluetooth data was used to calculate travel times across a network of intersections. The travel time calculations were initially performed using the Interquartile Outlier method, which helps identify and exclude data points that fall outside the interquartile range. This method ensures the travel time data reflects typical conditions by removing outliers.

Further analysis focused on calculating travel times specifically for the AM peak period, which is a critical time for evaluating traffic flow and congestion. The results of this period are detailed in below.

To calculate travel time using Bluetooth data for the network route TS067-TS316-TS181, the process begins by collecting Bluetooth detection data from Addin-sight for the intersections TS067 and TS181. This data should include the Probe ID, Site (indicating the intersection where the detection occurred), and the Time of detection, as outlined in section 3.2.2.

As shown in Figure 23, the data should be separated by each intersection, ensuring that each Probe ID has its detection time clearly identified at both TS067 and TS181. For each Probe ID, the detection times at both intersections should be identified. For example, if Probe ID 1404905283 is detected at TS067 at 08:06:44 and then at TS181 at 08:09:02, these times should be noted.

The travel time for each Probe ID is then calculated by subtracting the detection time at TS067 from the detection time at TS181. In the given example, the travel time would be 2 minutes and 18 seconds. Since the Probe ID could correspond to a vehicle, pedestrian, or cyclist, it is necessary to filter out pedestrians and cyclists. This can be achieved by using the interquartile range (IQR) method to identify and remove outliers, as described in section 3.4.3. By focusing on the interquartile range, the slower travel times typically associated with pedestrians and cyclists can be excluded, ensuring that the remaining data more accurately represents vehicle travel times.



TS067		TS181		
Probe Id	Last Detected	Probe Id	Last Detected	Travel Time
1404905283	8:06:44	1404905283	8:09:02	0:02:18
1404910556	8:10:33	1404910556	8:13:44	0:03:11
1404912857	8:10:36	1404912857	8:12:42	0:02:06
1404929995	8:14:42	1404929995	8:17:32	0:02:50
1405076511	8:35:58	1405076511	8:38:37	0:02:39
1405083149	8:05:45	1405083149	8:07:50	0:02:05
1405103359	8:41:09	1405103359	8:45:23	0:04:14
1405114240	8:14:50	1405114240	8:17:07	0:02:17

Figure 23 Travel Time

Figure 24 presents a graphical representation of travel times from Bluetooth data for the route between intersections TS067 and TS181. On the Y-axis, the travel time is depicted, reflecting the duration taken for vehicles, cyclists, and pedestrians to travel between these points. The X-axis shows the number of detected vehicles, pedestrians, and cyclists, providing a measure of traffic volume and movement.

Each dot in figure 24 represents a detected entity (vehicle, cyclist, or pedestrian) at the intersection. The density of these dots indicates the volume of traffic, with a higher concentration of dots suggesting heavier traffic flow. The top of the dots is noted to identify whether they correspond to vehicles, pedestrians, or cyclists. This visualization helps in understanding the distribution and flow of different types of road users and how they impact travel times through the whole network TS067, TS316, and TS181.

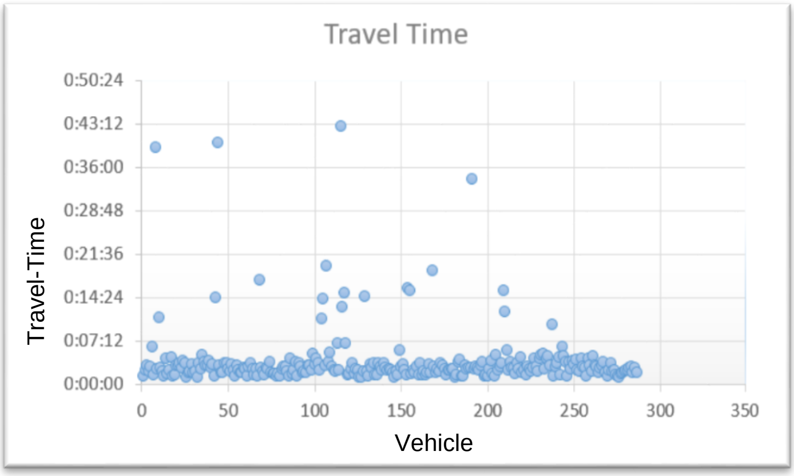


Figure 24 without Remove Outlier

Figure 25 shows the travel time results after applying the interquartile range outlier removal method. This figure provides a refined view of the data by excluding outliers—primarily cyclists and pedestrians—thus focusing solely on vehicle travel times.

On the X-axis, the number of vehicles traveling through the intersections TS067, TS316, and TS181 is shown. The Y-axis continues to represent travel time, but with outliers removed, the data is cleaner and more focused on vehicle movement. The removal of outliers helps to present a more accurate picture of typical vehicle travel times, minimizing the impact of non-vehicular data that may skew results.

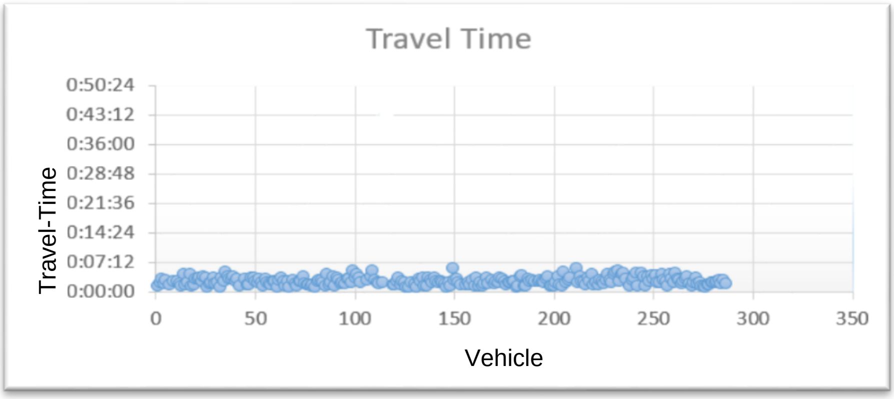


Figure 25 after removing the Outlier

After outliers are removed using the interquartile range (IQR) method to filter out pedestrians and cyclists, the remaining dataset will predominantly represent vehicle travel times. From this filtered dataset, the number of remaining vehicle travel times should be counted to determine the vehicle count. Subsequently, the average travel time for these vehicles is calculated by summing all the travel times and dividing by the vehicle count. For instance, if the average travel time for vehicles on the route TS067-TS316-TS181 is found to be 3 minutes and 8 seconds, this value represents the typical travel time for vehicles along this route after excluding outliers.

It was found travel time using Bluetooth data and removing outliers using the interquartile outlier method, which is 3:08 minutes means 188 (s).

3.6.2 Travel time from Scats System

After modelling the intersections in the SIDRA Intersection and integrating the SCATS data, it was analyzed the network to obtain, and using that software found the busiest route, and made that route for the results for the existing model. Using SIDRA Intersection software, first of all fixed the cycle time and allowed SIDRA to optimize the phasing time. Subsequently, it was used SIDRA's practical option, which optimizes both cycle time and phasing time. The results for these different scenarios are detailed in Table 6 like Avg. Delays, Avg. Travel Time, and Avg. Speed.

Table 6 Result for Route

Route 67-316-181			
Model	AVG. delays (s)	AVG. Travel time	AVG. Speed
Existing Network	146	190	19.7
Sidra Optimized Network	126.6	166.8	22.4
Sidra Optimized Network With Phasing Time	121	165.5	22.6
10 Year Future Existing Model	1047	1106.8	3.4

4 RESULT AND DISCUSSION

4.1 Result for Intersection

For the intersection, as shown in the Table 7, that was increased the vehicle count from the Bluetooth data due to limitations in the Bluetooth system's accuracy. While the Bluetooth system has some data accuracy issues and limitations, the SCATS system provides more accurate data but comes with its own limitations and costs. By comparing the Bluetooth data with SCATS data, it was found that the Bluetooth system got fewer vehicle counts by approximately 15%, as per shown that in (3.4.3). To ensure consistency and validation, it was adjusted the vehicle count in the Bluetooth data to match the SCATS system's count and conducted simulations accordingly for the intersection.

By comparing SCATS and Bluetooth data, it can be seen that SCATS lane summary results are equivalent to real-time results. When Bluetooth results are compared to SCATS data, the number of vehicles must be increased by a particular percentage as shown in Table 7. In this study, Bluetooth data were raised by 600%, 575%, and 550%. It was discovered that a 575% increase provided results that almost matched the SCATS results. To optimize intersections using Bluetooth data, a 575% increase should be applied.

Table 7 Scats and Bluetooth Data Comparison

Intersection	Direction	Scats	Bluetooth	550% increased Bluetooth	575% increased Bluetooth	600% increased Bluetooth
North	Right	541	96	624	648	672
North	Through	1015	164	1066	1107	1148
North	Left	147	14	91	94	98
West	Right	257	12	78	81	84
West	Through	762	125	812	843	875
West	Left	287	105	682	708	735
South	Right	625	23	149	155	161
South	Through	990	155	1007	1046	1085
South	Left	92	11	71	74	77
East	Right	645	38	247	256	266
East	Through	680	150	975	1012	1050
East	Left	185	22	143	148	154
	Total	6226	915	5947	6176	6405

Table 8 shows that a 575% increase in Bluetooth counts results in the smallest percentage difference when compared to SCATS data, indicating that it provides the closest match. The data shows that the differences between SCATS and the adjusted Bluetooth counts for the 575%, 550%, and 600%

increases are 16.7, 46.8, and 36.1, respectively. The corresponding percentage differences are 18.37%, 25.21%, and 27.25%. These results clearly demonstrate that a 575% increase yields a more accurate alignment with SCATS data compared to the 550% and 600% increases.

Thus, by applying a 575% increase to Bluetooth counts, the results can be made comparable to SCATS data. This adjustment allows for effective optimization of intersection models using Bluetooth data. Implementing this approach enables accurate real-time monitoring of intersections, facilitating adjustments in cycle times and phasing based on current traffic conditions. As shown in the table, optimizing intersections with this adjusted Bluetooth data enhances overall results and improves intersection performance.

Table 8 Result for Intersection

TS070 Comparisons Scats VS Bluetooth										
	Existing									
	Scats	575%	550%	600%	575%	550%	600%	575%	550%	600%
Delay	45.7	44.3	44.2	44.4	1.4	1.5	1.3	3.063457	3.282276	2.844639
Travel Time	67.7	66.5	64	69.1	1.2	3.7	1.4	1.772526	5.465288	2.06795
Speed	36.2	36.8	36.8	36.9	0.6	0.6	0.7	1.657459	1.657459	1.933702
Ques	64	70.5	67.6	73.4	6.5	3.6	9.4	10.1563	5.625	14.6875
Fuel Consumption	241.7	239.6	230.6	248.6	2.1	11.1	6.9	0.868846	4.59247	2.85478
CO2	572.2	567.3	545.9	588.6	4.9	26.3	16.4	0.856344	4.596295	2.86613
					Differences with Scats			Differences %		
					16.7	46.8	36.1	18.37	25.21	27.25

Figures 26, 27, 28, 29, 30, and 31 show the delay time, travel time, speed, queue length, fuel consumption, and CO2 emissions, respectively. By increasing the Bluetooth vehicle count by 575%, we obtained results that are approximately similar to the SCATS results. This indicates that increasing the Bluetooth vehicle count by 575% provides validation and simulation that optimize the intersection for real-time conditions, addressing the research gap.

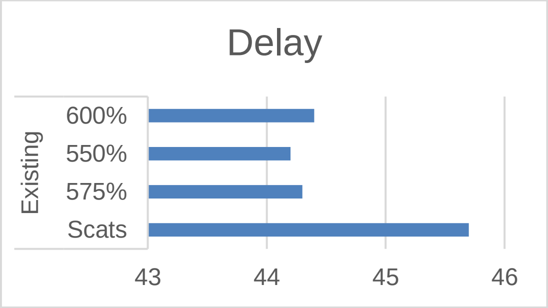


Figure 26 Delay analysis for Intersection

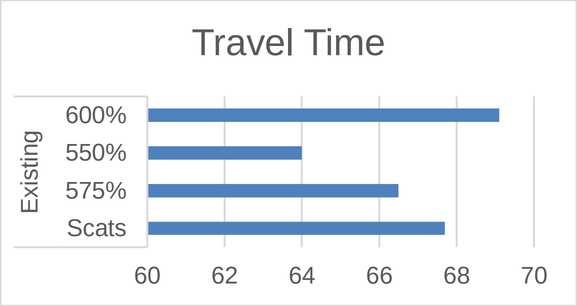


Figure 27 Travel time analysis for Intersection

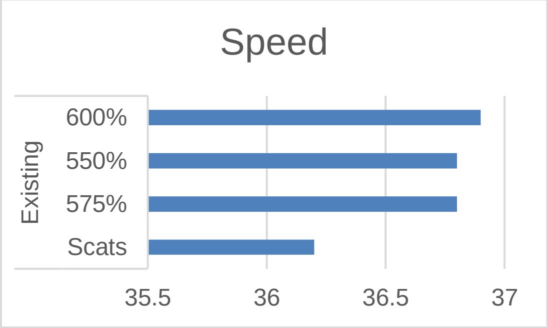


Figure 28 Speed analysis for Intersection

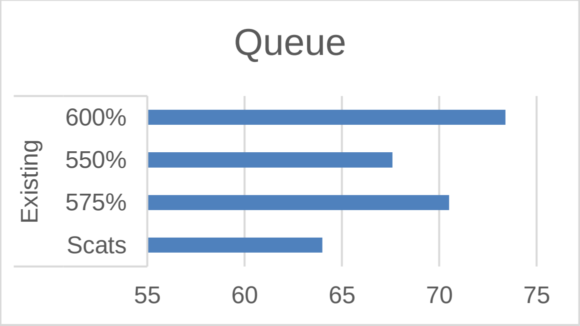


Figure 29 Queue analysis for Intersection

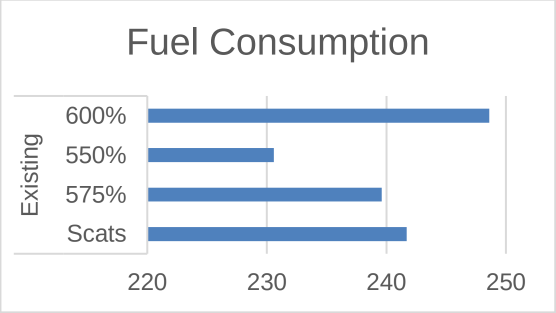


Figure 30 Fuel Consumption

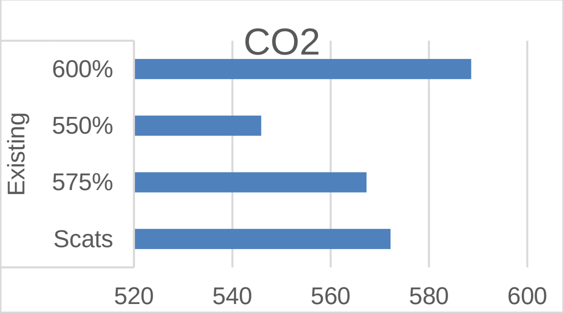


Figure 31 CO2 analysis for Intersection

4.2 Result for Network

Following the intersection analysis, four different types of networks were created: the Existing Network, the SIDRA Optimized Network with Fixed Cycle Time (where the cycle time is fixed and SIDRA optimizes the phasing time), the SIDRA Optimized Network with Practical Time (where SIDRA calculates both travel and phasing times), and the 10 Year Future Network. The results, as detailed in Table 9, compare these networks in terms of average delays, average travel time, and average speed. The analysis reveals that average delays are reduced, travel time is reduced, and average speed is increased across the networks. This clearly demonstrates that the intersection is functioning properly and shows significant improvements for the network.

Table 9 Result for Network

Network			
Model	AVG. delays (s)	AVG. Travel time	AVG. Speed
Existing Network	53.2	301.1	19.6
Sidra Optimized Network	47.4	263.1	21.3
Sidra Optimized Network With Phasing Time	41.5	251.7	23.4
10 Year Future Existing Model	279.8	1266.1	4.7

Figures 32, 33, and 34 show that for the network, average delay, average travel time, and average speed are improving using the SIDRA Intersection software. Specifically, the delay was reduced from 53.2 to 41.5 seconds, travel time decreased from 301.1 to 251.7 seconds, and speed increased from

19.6 km/h to 23.4 km/h. This indicates that by using SIDRA Intersection software, we can easily optimize intersections and achieve significant improvements.

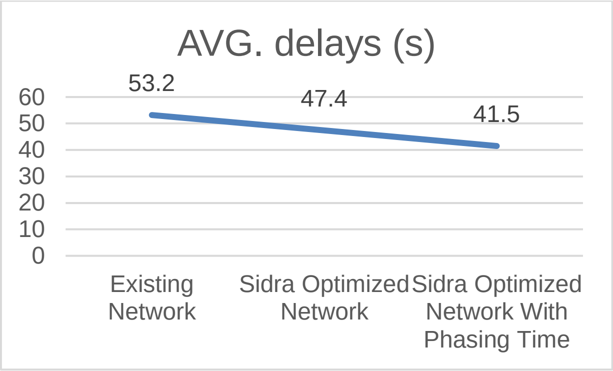


Figure 32 AVG Delays for Network

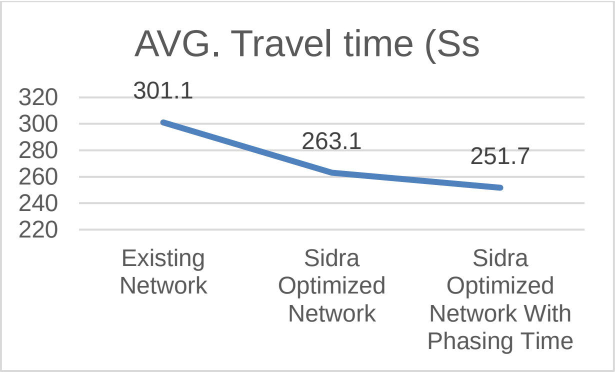


Figure 33 AVG Travel time for network

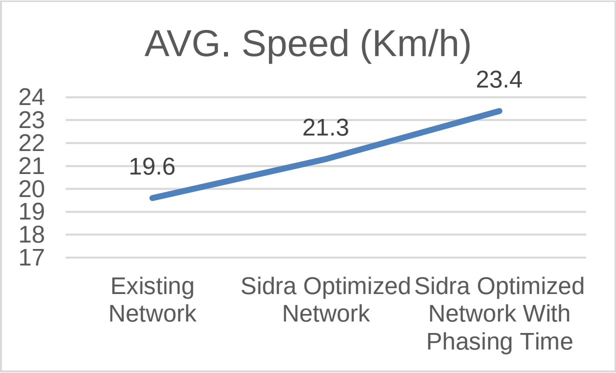


Figure 34 AVG Speed for Network

4.3 Result for Route

It can be seen in the table below the results for the chosen route from my network, which is the busiest route. It is clear from Table 10 that average delay, average travel time, and average speed are improving respectively for the existing model, SIDRA optimized, and SIDRA practical scenarios. According to my research gap, the main focus was on travel time. That is the travel time for the existing model and also determined the travel time using the Bluetooth system. The results were nearly the same for both the SCATS system and the Bluetooth system, confirming that was obtained the correct result for travel time as per my research gap.

It was found travel time using Bluetooth data and removing outliers using the interquartile outlier method. As per shows above section (3.6 Rout Analysis) which is 3:08 minutes means 188 (s).
We can see that in that table for the existing model AVG travel tie is 190 (s) which is similar to 188 (s).

Table 10 Result for Route

Route 67-316-181			
Model	AVG. delays (s)	AVG. Travel time	AVG. Speed
Existing Network	146	190	19.7
Sidra Optimized Network	126.6	166.8	22.4
Sidra Optimized Network With Phasing Time	121	165.5	22.6
10-Year Future Existing Model	1047	1106.8	3.4

Figures 35, 36, and 37 show that for the network, average delay, average travel time, and average speed are improving using the SIDRA Intersection software. Specifically, the delay is reduced from 146 to 121 seconds, travel time decreased from 190 to 165.5 seconds, and speed increased from 19.7 km/h to 22.6 km/h. This indicates that by using SIDRA Intersection software, we can easily optimize intersections and achieve significant improvements.

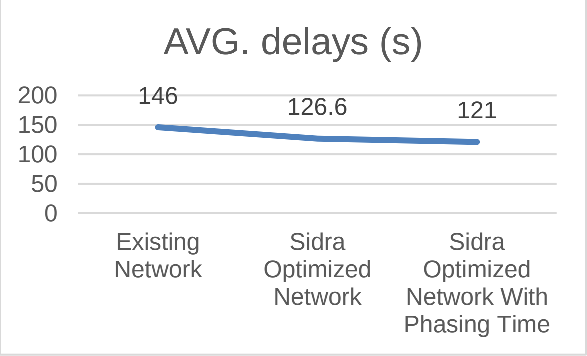


Figure 35 AVG delay for Route

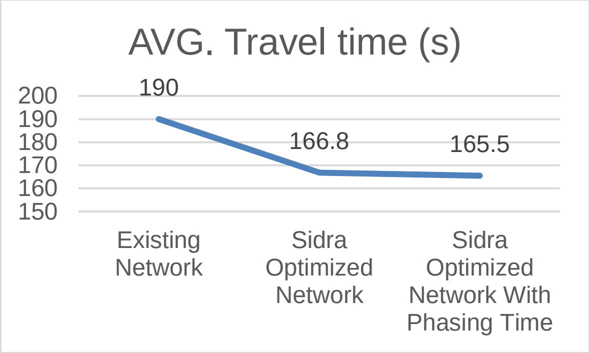


Figure 36 AVG Travel Time For Route

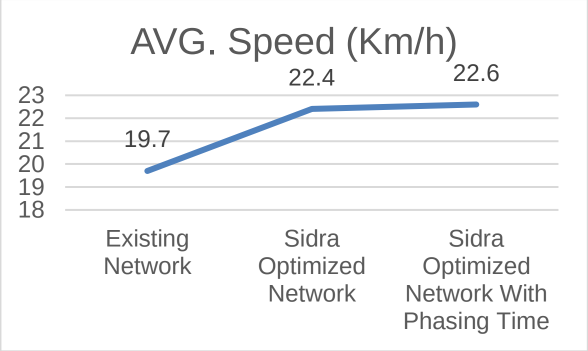


Figure 37 AVG Speed for Route

5 CONCLUSION

The research identified significant gaps in the use of Bluetooth technology for traffic signal monitoring and control, highlighting three key areas for improvement. First, there is a need for a comprehensive analysis comparing Bluetooth-based technologies with traditional traffic management systems like SCATS. Second, integrating deep learning methods could enhance prediction accuracy and real-time responsiveness in traffic signal systems. Third, the accuracy and reliability of Bluetooth data must be validated across various urban traffic settings. Addressing these gaps presents an opportunity for substantial advancements in traffic management through more detailed analyses, advanced modeling, and improved data collection methods, leading to more effective and reliable solutions.

In the first case, a model was developed using SCATS and Bluetooth systems from SIDRA Intersection to compare traffic parameters such as delays, travel time, fuel consumption, and CO2 emissions. Outliers in the Bluetooth data were removed using the interquartile range method, resulting in a 15% match of vehicle counts to SCATS data. To achieve a closer alignment with SCATS, Bluetooth counts were increased by 575%. This adjustment allowed for accurate comparisons of delays, travel time, speed, queue lengths, fuel consumption, and CO2 emissions with real-time data.

The optimized Bluetooth system proved effective for controlling, monitoring, and optimizing intersections.

In the second case, a network along Greenhill Road, including intersections TS067, TS316, and TS181, was optimized using three different models: the existing model, a SIDRA optimized model with an established cycle time, and a SIDRA practical optimized model with varying cycle and phasing times. The analysis revealed that optimization reduced delays, reduced travel times, and increased speeds.

In case three, SIDRA was used to identify the busiest route at the intersection and determine travel times. The existing SCATS model indicated a travel time of 190 seconds. In comparison, the Bluetooth system recorded a travel time of 3 minutes and 8 seconds, which is equivalent to 188 seconds. The close alignment between the SCATS and Bluetooth travel times suggests that the Bluetooth system provides an accurate measurement of travel times for specific networks. This indicates that Bluetooth technology can effectively monitor and measure travel times, offering reliable performance comparable to traditional systems like SCATS.

Overall, the study successfully demonstrated that integrating Bluetooth and SCATS data can enhance traffic management. By appropriately adjusting Bluetooth vehicle counts and optimizing intersections and networks, real-time data can be effectively utilized to improve traffic flow and reduce delays. The combination of advanced analytical models and detailed comparisons provided valuable insights, closing identified gaps and highlighting the advantages of using Bluetooth technology for more reliable traffic signal monitoring and control.

6 FUTURE WORK

Future research on this topic will concentrate on a few significant areas to improve traffic control systems. First, Bluetooth vehicle count technology will be integrated throughout the entire traffic network. This involves installing more Bluetooth sensors in strategic locations to improve data collection and accuracy in tracking vehicle movements. Second, a detailed comparison of the Bluetooth-based vehicle counting system's penetration rates with existing SCATS (Sydney Coordinated Adaptive Traffic System) data will be performed. This comparison aims to evaluate the benefit and availability of Bluetooth technology for collecting traffic data in comparison to SCATS. Third, Aim-sun modelling software will be used to verify traffic movement patterns and validate the results of Sidra Intersection modelling. Aim-sun will provide a complete simulation environment to assure the accuracy and dependability of traffic analysis. Finally, Sidra Intersection will be modelled for future years, taking into consideration expected traffic growth. This includes predicting traffic volumes and patterns to better understand how the network will perform in the future as well as discovering possibilities for improvement in traffic management strategies. These measures aim to improve traffic management systems by using innovative technologies and extensive modelling methodologies, ensuring that the traffic network remains efficient and responsive to present and future demands.

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8 APPENDICES

Counter	Total Count	Interval Time
(1) (70 - 1) SCATS Site 70 - Detector 1	36	11/1/2024 8:00
(1) (70 - 1) SCATS Site 70 - Detector 1	36	11/1/2024 8:05
(1) (70 - 1) SCATS Site 70 - Detector 1	47	11/1/2024 8:10
(1) (70 - 1) SCATS Site 70 - Detector 1	55	11/1/2024 8:15
(1) (70 - 1) SCATS Site 70 - Detector 1	50	11/1/2024 8:20
(1) (70 - 1) SCATS Site 70 - Detector 1	38	11/1/2024 8:25
(1) (70 - 1) SCATS Site 70 - Detector 1	46	11/1/2024 8:30
(1) (70 - 1) SCATS Site 70 - Detector 1	43	11/1/2024 8:35
(1) (70 - 1) SCATS Site 70 - Detector 1	43	11/1/2024 8:40
(1) (70 - 1) SCATS Site 70 - Detector 1	50	11/1/2024 8:45
(1) (70 - 1) SCATS Site 70 - Detector 1	43	11/1/2024 8:50
(1) (70 - 1) SCATS Site 70 - Detector 1	41	11/1/2024 8:55
(2) (70 - 2) SCATS Site 70 - Detector 2	24	11/1/2024 8:00
(2) (70 - 2) SCATS Site 70 - Detector 2	48	11/1/2024 8:05
(2) (70 - 2) SCATS Site 70 - Detector 2	49	11/1/2024 8:10
(2) (70 - 2) SCATS Site 70 - Detector 2	43	11/1/2024 8:15
(2) (70 - 2) SCATS Site 70 - Detector 2	42	11/1/2024 8:20
(2) (70 - 2) SCATS Site 70 - Detector 2	36	11/1/2024 8:25
(2) (70 - 2) SCATS Site 70 - Detector 2	41	11/1/2024 8:30
(2) (70 - 2) SCATS Site 70 - Detector 2	41	11/1/2024 8:35
(2) (70 - 2) SCATS Site 70 - Detector 2	48	11/1/2024 8:40
(2) (70 - 2) SCATS Site 70 - Detector 2	39	11/1/2024 8:45
(2) (70 - 2) SCATS Site 70 - Detector 2	40	11/1/2024 8:50
(2) (70 - 2) SCATS Site 70 - Detector 2	36	11/1/2024 8:55
(3) (70 - 3) SCATS Site 70 - Detector 3	20	11/1/2024 8:00
(3) (70 - 3) SCATS Site 70 - Detector 3	23	11/1/2024 8:05
(3) (70 - 3) SCATS Site 70 - Detector 3	22	11/1/2024 8:10
(3) (70 - 3) SCATS Site 70 - Detector 3	24	11/1/2024 8:15
(3) (70 - 3) SCATS Site 70 - Detector 3	27	11/1/2024 8:20
(3) (70 - 3) SCATS Site 70 - Detector 3	21	11/1/2024 8:25
(3) (70 - 3) SCATS Site 70 - Detector 3	25	11/1/2024 8:30
(3) (70 - 3) SCATS Site 70 - Detector 3	14	11/1/2024 8:35
(3) (70 - 3) SCATS Site 70 - Detector 3	17	11/1/2024 8:40

(3) (70 - 3) SCATS Site 70 - Detector 3	23	11/1/2024 8:45
(3) (70 - 3) SCATS Site 70 - Detector 3	31	11/1/2024 8:50
(3) (70 - 3) SCATS Site 70 - Detector 3	20	11/1/2024 8:55
(4) (70 - 4) SCATS Site 70 - Detector 4	21	11/1/2024 8:00
(4) (70 - 4) SCATS Site 70 - Detector 4	22	11/1/2024 8:05
(4) (70 - 4) SCATS Site 70 - Detector 4	27	11/1/2024 8:10
(4) (70 - 4) SCATS Site 70 - Detector 4	26	11/1/2024 8:15
(4) (70 - 4) SCATS Site 70 - Detector 4	29	11/1/2024 8:20
(4) (70 - 4) SCATS Site 70 - Detector 4	28	11/1/2024 8:25
(4) (70 - 4) SCATS Site 70 - Detector 4	22	11/1/2024 8:30
(4) (70 - 4) SCATS Site 70 - Detector 4	15	11/1/2024 8:35
(4) (70 - 4) SCATS Site 70 - Detector 4	16	11/1/2024 8:40
(4) (70 - 4) SCATS Site 70 - Detector 4	22	11/1/2024 8:45
(4) (70 - 4) SCATS Site 70 - Detector 4	24	11/1/2024 8:50
(4) (70 - 4) SCATS Site 70 - Detector 4	22	11/1/2024 8:55
(5) (70 - 5) SCATS Site 70 - Detector 5	17	11/1/2024 8:00
(5) (70 - 5) SCATS Site 70 - Detector 5	18	11/1/2024 8:05
(5) (70 - 5) SCATS Site 70 - Detector 5	27	11/1/2024 8:10
(5) (70 - 5) SCATS Site 70 - Detector 5	18	11/1/2024 8:15
(5) (70 - 5) SCATS Site 70 - Detector 5	26	11/1/2024 8:20
(5) (70 - 5) SCATS Site 70 - Detector 5	22	11/1/2024 8:25
(5) (70 - 5) SCATS Site 70 - Detector 5	21	11/1/2024 8:30
(5) (70 - 5) SCATS Site 70 - Detector 5	13	11/1/2024 8:35
(5) (70 - 5) SCATS Site 70 - Detector 5	17	11/1/2024 8:40
(5) (70 - 5) SCATS Site 70 - Detector 5	22	11/1/2024 8:45
(5) (70 - 5) SCATS Site 70 - Detector 5	23	11/1/2024 8:50
(5) (70 - 5) SCATS Site 70 - Detector 5	20	11/1/2024 8:55
(6) (70 - 6) SCATS Site 70 - Detector 6	18	11/1/2024 8:00
(6) (70 - 6) SCATS Site 70 - Detector 6	28	11/1/2024 8:05
(6) (70 - 6) SCATS Site 70 - Detector 6	24	11/1/2024 8:10
(6) (70 - 6) SCATS Site 70 - Detector 6	18	11/1/2024 8:15
(6) (70 - 6) SCATS Site 70 - Detector 6	20	11/1/2024 8:20
(6) (70 - 6) SCATS Site 70 - Detector 6	16	11/1/2024 8:25
(6) (70 - 6) SCATS Site 70 - Detector 6	20	11/1/2024 8:30
(6) (70 - 6) SCATS Site 70 - Detector 6	19	11/1/2024 8:35
(6) (70 - 6) SCATS Site 70 - Detector 6	21	11/1/2024 8:40
(6) (70 - 6) SCATS Site 70 - Detector 6	19	11/1/2024 8:45

(6) (70 - 6) SCATS Site 70 - Detector 6	22	11/1/2024 8:50
(6) (70 - 6) SCATS Site 70 - Detector 6	23	11/1/2024 8:55
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(7) (70 - 7) SCATS Site 70 - Detector 7	36	11/1/2024 8:05
(7) (70 - 7) SCATS Site 70 - Detector 7	40	11/1/2024 8:10
(7) (70 - 7) SCATS Site 70 - Detector 7	37	11/1/2024 8:15
(7) (70 - 7) SCATS Site 70 - Detector 7	35	11/1/2024 8:20
(7) (70 - 7) SCATS Site 70 - Detector 7	45	11/1/2024 8:25
(7) (70 - 7) SCATS Site 70 - Detector 7	44	11/1/2024 8:30
(7) (70 - 7) SCATS Site 70 - Detector 7	61	11/1/2024 8:35
(7) (70 - 7) SCATS Site 70 - Detector 7	35	11/1/2024 8:40
(7) (70 - 7) SCATS Site 70 - Detector 7	33	11/1/2024 8:45
(7) (70 - 7) SCATS Site 70 - Detector 7	46	11/1/2024 8:50
(7) (70 - 7) SCATS Site 70 - Detector 7	39	11/1/2024 8:55
(8) (70 - 8) SCATS Site 70 - Detector 8	49	11/1/2024 8:00
(8) (70 - 8) SCATS Site 70 - Detector 8	43	11/1/2024 8:05
(8) (70 - 8) SCATS Site 70 - Detector 8	51	11/1/2024 8:10
(8) (70 - 8) SCATS Site 70 - Detector 8	42	11/1/2024 8:15
(8) (70 - 8) SCATS Site 70 - Detector 8	37	11/1/2024 8:20
(8) (70 - 8) SCATS Site 70 - Detector 8	44	11/1/2024 8:25
(8) (70 - 8) SCATS Site 70 - Detector 8	38	11/1/2024 8:30
(8) (70 - 8) SCATS Site 70 - Detector 8	60	11/1/2024 8:35
(8) (70 - 8) SCATS Site 70 - Detector 8	40	11/1/2024 8:40
(8) (70 - 8) SCATS Site 70 - Detector 8	41	11/1/2024 8:45
(8) (70 - 8) SCATS Site 70 - Detector 8	44	11/1/2024 8:50
(8) (70 - 8) SCATS Site 70 - Detector 8	40	11/1/2024 8:55
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(9) (70 - 9) SCATS Site 70 - Detector 9	4	11/1/2024 8:10
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(9) (70 - 9) SCATS Site 70 - Detector 9	8	11/1/2024 8:40
(9) (70 - 9) SCATS Site 70 - Detector 9	9	11/1/2024 8:45
(9) (70 - 9) SCATS Site 70 - Detector 9	12	11/1/2024 8:50

(9) (70 - 9) SCATS Site 70 - Detector 9	11	11/1/2024 8:55
(10) (70 - 10) SCATS Site 70 - Detector 10	4	11/1/2024 8:00
(10) (70 - 10) SCATS Site 70 - Detector 10	5	11/1/2024 8:05
(10) (70 - 10) SCATS Site 70 - Detector 10	3	11/1/2024 8:10
(10) (70 - 10) SCATS Site 70 - Detector 10	4	11/1/2024 8:15
(10) (70 - 10) SCATS Site 70 - Detector 10	7	11/1/2024 8:20
(10) (70 - 10) SCATS Site 70 - Detector 10	5	11/1/2024 8:25
(10) (70 - 10) SCATS Site 70 - Detector 10	6	11/1/2024 8:30
(10) (70 - 10) SCATS Site 70 - Detector 10	7	11/1/2024 8:35
(10) (70 - 10) SCATS Site 70 - Detector 10	7	11/1/2024 8:40
(10) (70 - 10) SCATS Site 70 - Detector 10	10	11/1/2024 8:45
(10) (70 - 10) SCATS Site 70 - Detector 10	8	11/1/2024 8:50
(10) (70 - 10) SCATS Site 70 - Detector 10	6	11/1/2024 8:55
(11) (70 - 11) SCATS Site 70 - Detector 11	16	11/1/2024 8:00
(11) (70 - 11) SCATS Site 70 - Detector 11	18	11/1/2024 8:05
(11) (70 - 11) SCATS Site 70 - Detector 11	19	11/1/2024 8:10
(11) (70 - 11) SCATS Site 70 - Detector 11	12	11/1/2024 8:15
(11) (70 - 11) SCATS Site 70 - Detector 11	18	11/1/2024 8:20
(11) (70 - 11) SCATS Site 70 - Detector 11	18	11/1/2024 8:25
(11) (70 - 11) SCATS Site 70 - Detector 11	18	11/1/2024 8:30
(11) (70 - 11) SCATS Site 70 - Detector 11	13	11/1/2024 8:35
(11) (70 - 11) SCATS Site 70 - Detector 11	22	11/1/2024 8:40
(11) (70 - 11) SCATS Site 70 - Detector 11	18	11/1/2024 8:45
(11) (70 - 11) SCATS Site 70 - Detector 11	25	11/1/2024 8:50
(11) (70 - 11) SCATS Site 70 - Detector 11	18	11/1/2024 8:55
(12) (70 - 12) SCATS Site 70 - Detector 12	36	11/1/2024 8:00
(12) (70 - 12) SCATS Site 70 - Detector 12	23	11/1/2024 8:05
(12) (70 - 12) SCATS Site 70 - Detector 12	42	11/1/2024 8:10
(12) (70 - 12) SCATS Site 70 - Detector 12	31	11/1/2024 8:15
(12) (70 - 12) SCATS Site 70 - Detector 12	33	11/1/2024 8:20
(12) (70 - 12) SCATS Site 70 - Detector 12	30	11/1/2024 8:25
(12) (70 - 12) SCATS Site 70 - Detector 12	34	11/1/2024 8:30
(12) (70 - 12) SCATS Site 70 - Detector 12	27	11/1/2024 8:35
(12) (70 - 12) SCATS Site 70 - Detector 12	36	11/1/2024 8:40
(12) (70 - 12) SCATS Site 70 - Detector 12	28	11/1/2024 8:45
(12) (70 - 12) SCATS Site 70 - Detector 12	37	11/1/2024 8:50
(12) (70 - 12) SCATS Site 70 - Detector 12	39	11/1/2024 8:55

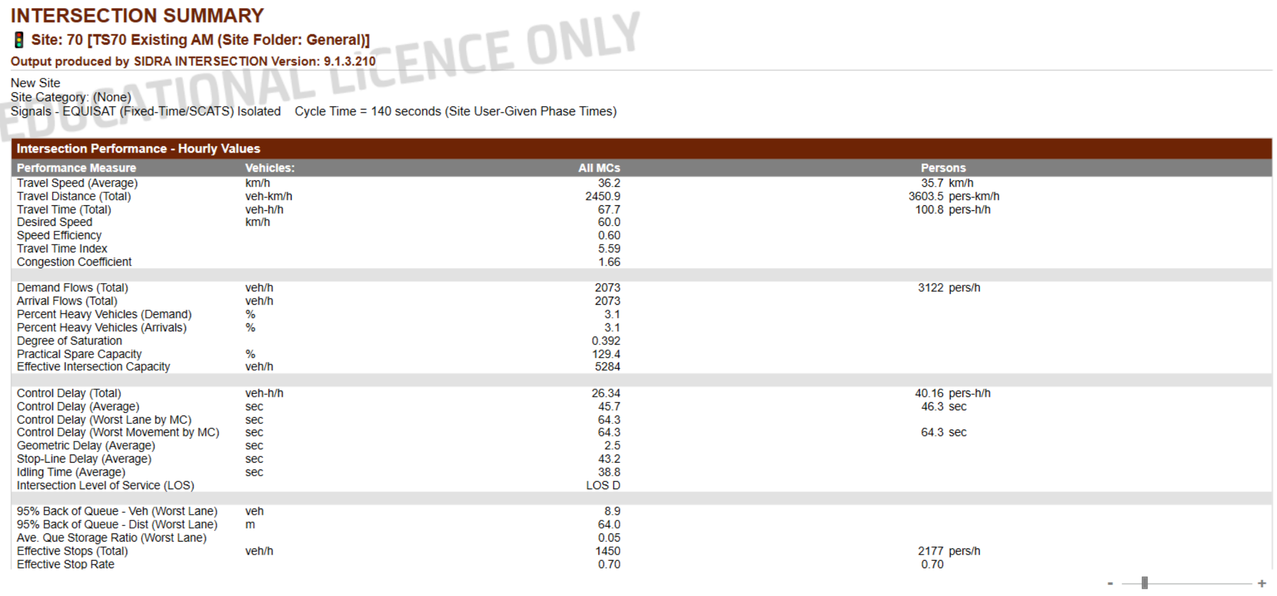
(13) (70 - 13) SCATS Site 70 - Detector 13	10	11/1/2024 8:00
(13) (70 - 13) SCATS Site 70 - Detector 13	8	11/1/2024 8:05
(13) (70 - 13) SCATS Site 70 - Detector 13	11	11/1/2024 8:10
(13) (70 - 13) SCATS Site 70 - Detector 13	14	11/1/2024 8:15
(13) (70 - 13) SCATS Site 70 - Detector 13	10	11/1/2024 8:20
(13) (70 - 13) SCATS Site 70 - Detector 13	11	11/1/2024 8:25
(13) (70 - 13) SCATS Site 70 - Detector 13	7	11/1/2024 8:30
(13) (70 - 13) SCATS Site 70 - Detector 13	7	11/1/2024 8:35
(13) (70 - 13) SCATS Site 70 - Detector 13	8	11/1/2024 8:40
(13) (70 - 13) SCATS Site 70 - Detector 13	8	11/1/2024 8:45
(13) (70 - 13) SCATS Site 70 - Detector 13	13	11/1/2024 8:50
(13) (70 - 13) SCATS Site 70 - Detector 13	13	11/1/2024 8:55
(14) (70 - 14) SCATS Site 70 - Detector 14	22	11/1/2024 8:00
(14) (70 - 14) SCATS Site 70 - Detector 14	17	11/1/2024 8:05
(14) (70 - 14) SCATS Site 70 - Detector 14	22	11/1/2024 8:10
(14) (70 - 14) SCATS Site 70 - Detector 14	15	11/1/2024 8:15
(14) (70 - 14) SCATS Site 70 - Detector 14	21	11/1/2024 8:20
(14) (70 - 14) SCATS Site 70 - Detector 14	20	11/1/2024 8:25
(14) (70 - 14) SCATS Site 70 - Detector 14	24	11/1/2024 8:30
(14) (70 - 14) SCATS Site 70 - Detector 14	17	11/1/2024 8:35
(14) (70 - 14) SCATS Site 70 - Detector 14	21	11/1/2024 8:40
(14) (70 - 14) SCATS Site 70 - Detector 14	17	11/1/2024 8:45
(14) (70 - 14) SCATS Site 70 - Detector 14	24	11/1/2024 8:50
(14) (70 - 14) SCATS Site 70 - Detector 14	26	11/1/2024 8:55
(15) (70 - 15) SCATS Site 70 - Detector 15	29	11/1/2024 8:00
(15) (70 - 15) SCATS Site 70 - Detector 15	17	11/1/2024 8:05
(15) (70 - 15) SCATS Site 70 - Detector 15	19	11/1/2024 8:10
(15) (70 - 15) SCATS Site 70 - Detector 15	18	11/1/2024 8:15
(15) (70 - 15) SCATS Site 70 - Detector 15	24	11/1/2024 8:20
(15) (70 - 15) SCATS Site 70 - Detector 15	22	11/1/2024 8:25
(15) (70 - 15) SCATS Site 70 - Detector 15	21	11/1/2024 8:30
(15) (70 - 15) SCATS Site 70 - Detector 15	17	11/1/2024 8:35
(15) (70 - 15) SCATS Site 70 - Detector 15	21	11/1/2024 8:40
(15) (70 - 15) SCATS Site 70 - Detector 15	23	11/1/2024 8:45
(15) (70 - 15) SCATS Site 70 - Detector 15	24	11/1/2024 8:50
(15) (70 - 15) SCATS Site 70 - Detector 15	22	11/1/2024 8:55
(16) (70 - 16) SCATS Site 70 - Detector 16	3	11/1/2024 8:00

(16) (70 - 16) SCATS Site 70 - Detector 16	4	11/1/2024 8:05
(16) (70 - 16) SCATS Site 70 - Detector 16	4	11/1/2024 8:10
(16) (70 - 16) SCATS Site 70 - Detector 16	3	11/1/2024 8:15
(16) (70 - 16) SCATS Site 70 - Detector 16	5	11/1/2024 8:20
(16) (70 - 16) SCATS Site 70 - Detector 16	1	11/1/2024 8:25
(16) (70 - 16) SCATS Site 70 - Detector 16	6	11/1/2024 8:30
(16) (70 - 16) SCATS Site 70 - Detector 16	3	11/1/2024 8:35
(16) (70 - 16) SCATS Site 70 - Detector 16	9	11/1/2024 8:40
(16) (70 - 16) SCATS Site 70 - Detector 16	5	11/1/2024 8:45
(16) (70 - 16) SCATS Site 70 - Detector 16	6	11/1/2024 8:50
(16) (70 - 16) SCATS Site 70 - Detector 16	2	11/1/2024 8:55
(17) (70 - 17) SCATS Site 70 - Detector 17	25	11/1/2024 8:00
(17) (70 - 17) SCATS Site 70 - Detector 17	18	11/1/2024 8:05
(17) (70 - 17) SCATS Site 70 - Detector 17	17	11/1/2024 8:10
(17) (70 - 17) SCATS Site 70 - Detector 17	24	11/1/2024 8:15
(17) (70 - 17) SCATS Site 70 - Detector 17	25	11/1/2024 8:20
(17) (70 - 17) SCATS Site 70 - Detector 17	15	11/1/2024 8:25
(17) (70 - 17) SCATS Site 70 - Detector 17	8	11/1/2024 8:30
(17) (70 - 17) SCATS Site 70 - Detector 17	11	11/1/2024 8:35
(17) (70 - 17) SCATS Site 70 - Detector 17	18	11/1/2024 8:40
(17) (70 - 17) SCATS Site 70 - Detector 17	14	11/1/2024 8:45
(17) (70 - 17) SCATS Site 70 - Detector 17	20	11/1/2024 8:50
(17) (70 - 17) SCATS Site 70 - Detector 17	11	11/1/2024 8:55
(18) (70 - 18) SCATS Site 70 - Detector 18	50	11/1/2024 8:00
(18) (70 - 18) SCATS Site 70 - Detector 18	39	11/1/2024 8:05
(18) (70 - 18) SCATS Site 70 - Detector 18	29	11/1/2024 8:10
(18) (70 - 18) SCATS Site 70 - Detector 18	37	11/1/2024 8:15
(18) (70 - 18) SCATS Site 70 - Detector 18	37	11/1/2024 8:20
(18) (70 - 18) SCATS Site 70 - Detector 18	32	11/1/2024 8:25
(18) (70 - 18) SCATS Site 70 - Detector 18	30	11/1/2024 8:30
(18) (70 - 18) SCATS Site 70 - Detector 18	31	11/1/2024 8:35
(18) (70 - 18) SCATS Site 70 - Detector 18	40	11/1/2024 8:40
(18) (70 - 18) SCATS Site 70 - Detector 18	31	11/1/2024 8:45
(18) (70 - 18) SCATS Site 70 - Detector 18	35	11/1/2024 8:50
(18) (70 - 18) SCATS Site 70 - Detector 18	32	11/1/2024 8:55
(19) (70 - 19) SCATS Site 70 - Detector 19	27	11/1/2024 8:00
(19) (70 - 19) SCATS Site 70 - Detector 19	37	11/1/2024 8:05

(19) (70 - 19) SCATS Site 70 - Detector 19	41	11/1/2024 8:10
(19) (70 - 19) SCATS Site 70 - Detector 19	42	11/1/2024 8:15
(19) (70 - 19) SCATS Site 70 - Detector 19	45	11/1/2024 8:20
(19) (70 - 19) SCATS Site 70 - Detector 19	42	11/1/2024 8:25
(19) (70 - 19) SCATS Site 70 - Detector 19	39	11/1/2024 8:30
(19) (70 - 19) SCATS Site 70 - Detector 19	46	11/1/2024 8:35
(19) (70 - 19) SCATS Site 70 - Detector 19	49	11/1/2024 8:40
(19) (70 - 19) SCATS Site 70 - Detector 19	37	11/1/2024 8:45
(19) (70 - 19) SCATS Site 70 - Detector 19	39	11/1/2024 8:50
(19) (70 - 19) SCATS Site 70 - Detector 19	32	11/1/2024 8:55
(20) (70 - 20) SCATS Site 70 - Detector 20	10	11/1/2024 8:00
(20) (70 - 20) SCATS Site 70 - Detector 20	14	11/1/2024 8:05
(20) (70 - 20) SCATS Site 70 - Detector 20	11	11/1/2024 8:10
(20) (70 - 20) SCATS Site 70 - Detector 20	18	11/1/2024 8:15
(20) (70 - 20) SCATS Site 70 - Detector 20	16	11/1/2024 8:20
(20) (70 - 20) SCATS Site 70 - Detector 20	17	11/1/2024 8:25
(20) (70 - 20) SCATS Site 70 - Detector 20	13	11/1/2024 8:30
(20) (70 - 20) SCATS Site 70 - Detector 20	20	11/1/2024 8:35
(20) (70 - 20) SCATS Site 70 - Detector 20	19	11/1/2024 8:40
(20) (70 - 20) SCATS Site 70 - Detector 20	9	11/1/2024 8:45
(20) (70 - 20) SCATS Site 70 - Detector 20	6	11/1/2024 8:50
(20) (70 - 20) SCATS Site 70 - Detector 20	16	11/1/2024 8:55
(21) (70 - 21) SCATS Site 70 - Detector 21	12	11/1/2024 8:00
(21) (70 - 21) SCATS Site 70 - Detector 21	12	11/1/2024 8:05
(21) (70 - 21) SCATS Site 70 - Detector 21	11	11/1/2024 8:10
(21) (70 - 21) SCATS Site 70 - Detector 21	15	11/1/2024 8:15
(21) (70 - 21) SCATS Site 70 - Detector 21	11	11/1/2024 8:20
(21) (70 - 21) SCATS Site 70 - Detector 21	13	11/1/2024 8:25
(21) (70 - 21) SCATS Site 70 - Detector 21	10	11/1/2024 8:30
(21) (70 - 21) SCATS Site 70 - Detector 21	15	11/1/2024 8:35
(21) (70 - 21) SCATS Site 70 - Detector 21	16	11/1/2024 8:40
(21) (70 - 21) SCATS Site 70 - Detector 21	9	11/1/2024 8:45
(21) (70 - 21) SCATS Site 70 - Detector 21	11	11/1/2024 8:50
(21) (70 - 21) SCATS Site 70 - Detector 21	12	11/1/2024 8:55
(22) (70 - 22) SCATS Site 70 - Detector 22	9	11/1/2024 8:00
(22) (70 - 22) SCATS Site 70 - Detector 22	8	11/1/2024 8:05
(22) (70 - 22) SCATS Site 70 - Detector 22	8	11/1/2024 8:10

(22) (70 - 22) SCATS Site 70 - Detector 22	9	11/1/2024 8:15
(22) (70 - 22) SCATS Site 70 - Detector 22	11	11/1/2024 8:20
(22) (70 - 22) SCATS Site 70 - Detector 22	9	11/1/2024 8:25
(22) (70 - 22) SCATS Site 70 - Detector 22	5	11/1/2024 8:30
(22) (70 - 22) SCATS Site 70 - Detector 22	8	11/1/2024 8:35
(22) (70 - 22) SCATS Site 70 - Detector 22	7	11/1/2024 8:40
(22) (70 - 22) SCATS Site 70 - Detector 22	7	11/1/2024 8:45
(22) (70 - 22) SCATS Site 70 - Detector 22	7	11/1/2024 8:50
(22) (70 - 22) SCATS Site 70 - Detector 22	4	11/1/2024 8:55
(23) (70 - 23) SCATS Site 70 - Detector 23	3	11/1/2024 8:00
(23) (70 - 23) SCATS Site 70 - Detector 23	9	11/1/2024 8:05
(23) (70 - 23) SCATS Site 70 - Detector 23	15	11/1/2024 8:10
(23) (70 - 23) SCATS Site 70 - Detector 23	16	11/1/2024 8:15
(23) (70 - 23) SCATS Site 70 - Detector 23	19	11/1/2024 8:20
(23) (70 - 23) SCATS Site 70 - Detector 23	14	11/1/2024 8:25
(23) (70 - 23) SCATS Site 70 - Detector 23	14	11/1/2024 8:30
(23) (70 - 23) SCATS Site 70 - Detector 23	22	11/1/2024 8:35
(23) (70 - 23) SCATS Site 70 - Detector 23	19	11/1/2024 8:40
(23) (70 - 23) SCATS Site 70 - Detector 23	11	11/1/2024 8:45
(23) (70 - 23) SCATS Site 70 - Detector 23	26	11/1/2024 8:50
(23) (70 - 23) SCATS Site 70 - Detector 23	17	11/1/2024 8:55

Appendices A Scats data looks from add-insight



INTERSECTION SUMMARY

Site: 70 [TS70 Existing AM (Site Folder: General)]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

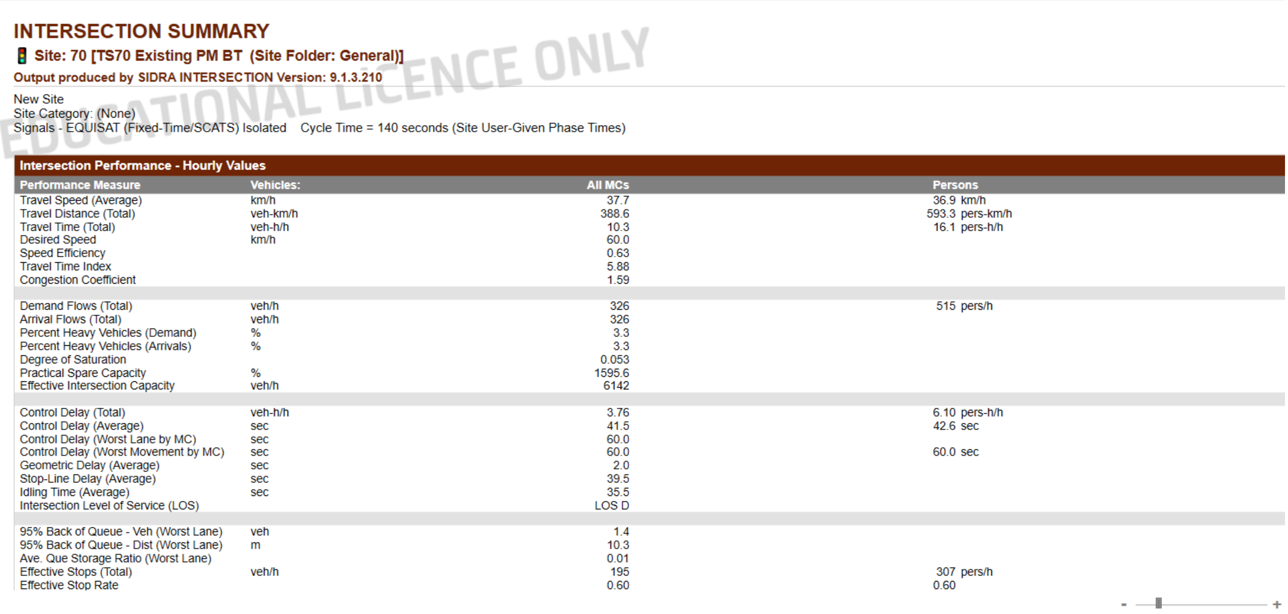
EDUCATIONAL LICENCE ONLY

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 140 seconds (Site User-Given Phase Times)

Intersection Performance - Hourly Values

Performance Measure	Vehicles:	All MCs	Persons
Travel Speed (Average)	km/h	36.2	35.7 km/h
Travel Distance (Total)	veh-km/h	2450.9	3603.5 pers-km/h
Travel Time (Total)	veh-h/h	67.7	100.8 pers-h/h
Desired Speed	km/h	60.0	
Speed Efficiency		0.60	
Travel Time Index		5.59	
Congestion Coefficient		1.66	
Demand Flows (Total)	veh/h	2073	3122 pers/h
Arrival Flows (Total)	veh/h	2073	
Percent Heavy Vehicles (Demand)	%	3.1	
Percent Heavy Vehicles (Arrivals)	%	3.1	
Degree of Saturation		0.392	
Practical Spare Capacity	%	129.4	
Effective Intersection Capacity	veh/h	5284	
Control Delay (Total)	veh-h/h	26.34	40.16 pers-h/h
Control Delay (Average)	sec	45.7	46.3 sec
Control Delay (Worst Lane by MC)	sec	64.3	
Control Delay (Worst Movement by MC)	sec	64.3	64.3 sec
Geometric Delay (Average)	sec	2.5	
Stop-Line Delay (Average)	sec	43.2	
Idling Time (Average)	sec	38.8	
Intersection Level of Service (LOS)		LOS D	
95% Back of Queue - Veh (Worst Lane)	veh	8.9	
95% Back of Queue - Dist (Worst Lane)	m	64.0	
Ave. Que Storage Ratio (Worst Lane)		0.05	
Effective Stops (Total)	veh/h	1450	2177 pers/h
Effective Stop Rate		0.70	0.70

Appendices B Result for TS070 existing PM



INTERSECTION SUMMARY

Site: 70 [TS70 Existing PM BT (Site Folder: General)]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

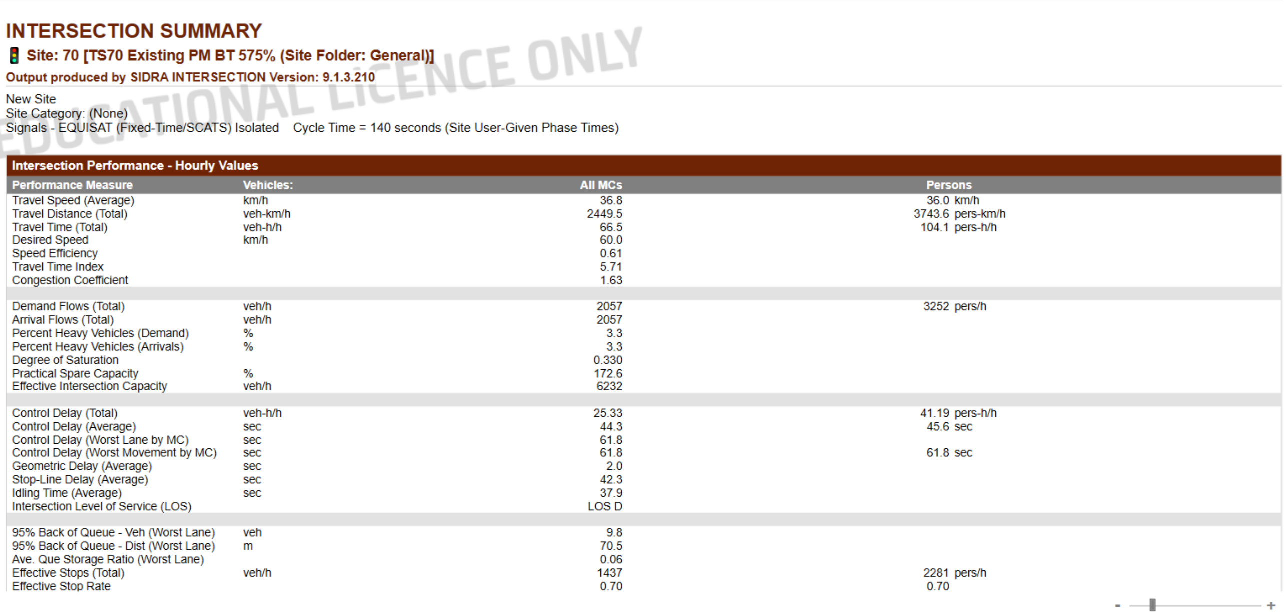
EDUCATIONAL LICENCE ONLY

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 140 seconds (Site User-Given Phase Times)

Intersection Performance - Hourly Values

Performance Measure	Vehicles:	All MCs	Persons
Travel Speed (Average)	km/h	37.7	36.9 km/h
Travel Distance (Total)	veh-km/h	388.6	593.3 pers-km/h
Travel Time (Total)	veh-h/h	10.3	16.1 pers-h/h
Desired Speed	km/h	60.0	
Speed Efficiency		0.63	
Travel Time Index		5.88	
Congestion Coefficient		1.59	
Demand Flows (Total)	veh/h	326	515 pers/h
Arrival Flows (Total)	veh/h	326	
Percent Heavy Vehicles (Demand)	%	3.3	
Percent Heavy Vehicles (Arrivals)	%	3.3	
Degree of Saturation		0.053	
Practical Spare Capacity	%	1595.6	
Effective Intersection Capacity	veh/h	6142	
Control Delay (Total)	veh-h/h	3.76	6.10 pers-h/h
Control Delay (Average)	sec	41.5	42.6 sec
Control Delay (Worst Lane by MC)	sec	60.0	
Control Delay (Worst Movement by MC)	sec	60.0	60.0 sec
Geometric Delay (Average)	sec	2.0	
Stop-Line Delay (Average)	sec	39.5	
Idling Time (Average)	sec	35.5	
Intersection Level of Service (LOS)		LOS D	
95% Back of Queue - Veh (Worst Lane)	veh	1.4	
95% Back of Queue - Dist (Worst Lane)	m	10.3	
Ave. Que Storage Ratio (Worst Lane)		0.01	
Effective Stops (Total)	veh/h	195	307 pers/h
Effective Stop Rate		0.60	0.60

Appendices C Result for TS070 Existing BT



INTERSECTION SUMMARY

Site: 70 [TS70 Existing PM BT 575% (Site Folder: General)]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

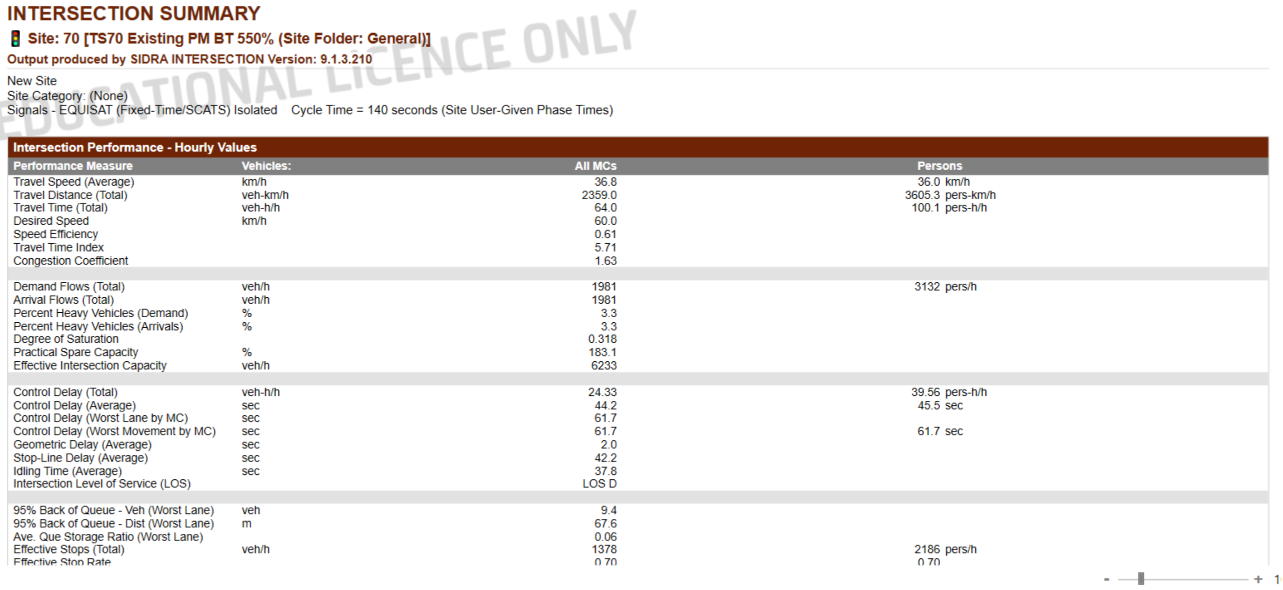
EDUCATIONAL LICENCE ONLY

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 140 seconds (Site User-Given Phase Times)

Intersection Performance - Hourly Values

Performance Measure	Vehicles:	All MCs	Persons
Travel Speed (Average)	km/h	36.8	36.0 km/h
Travel Distance (Total)	veh-km/h	2449.5	3743.6 pers-km/h
Travel Time (Total)	veh-h/h	66.5	104.1 pers-h/h
Desired Speed	km/h	60.0	
Speed Efficiency		0.61	
Travel Time Index		5.71	
Congestion Coefficient		1.63	
Demand Flows (Total)	veh/h	2057	3252 pers/h
Arrival Flows (Total)	veh/h	2057	
Percent Heavy Vehicles (Demand)	%	3.3	
Percent Heavy Vehicles (Arrivals)	%	3.3	
Degree of Saturation		0.330	
Practical Spare Capacity	%	172.6	
Effective Intersection Capacity	veh/h	6232	
Control Delay (Total)	veh-h/h	25.33	41.19 pers-h/h
Control Delay (Average)	sec	44.3	45.6 sec
Control Delay (Worst Lane by MC)	sec	61.8	
Control Delay (Worst Movement by MC)	sec	61.8	61.8 sec
Geometric Delay (Average)	sec	2.0	
Stop-Line Delay (Average)	sec	42.3	
Idling Time (Average)	sec	37.9	
Intersection Level of Service (LOS)		LOS D	
95% Back of Queue - Veh (Worst Lane)	veh	9.8	
95% Back of Queue - Dist (Worst Lane)	m	70.5	
Ave. Que Storage Ratio (Worst Lane)		0.06	
Effective Stops (Total)	veh/h	1437	2281 pers/h
Effective Stop Rate		0.70	0.70

Appendices D Result for TS070 BT data 575%



INTERSECTION SUMMARY

Site: 70 [TS70 Existing PM BT 550% (Site Folder: General)]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

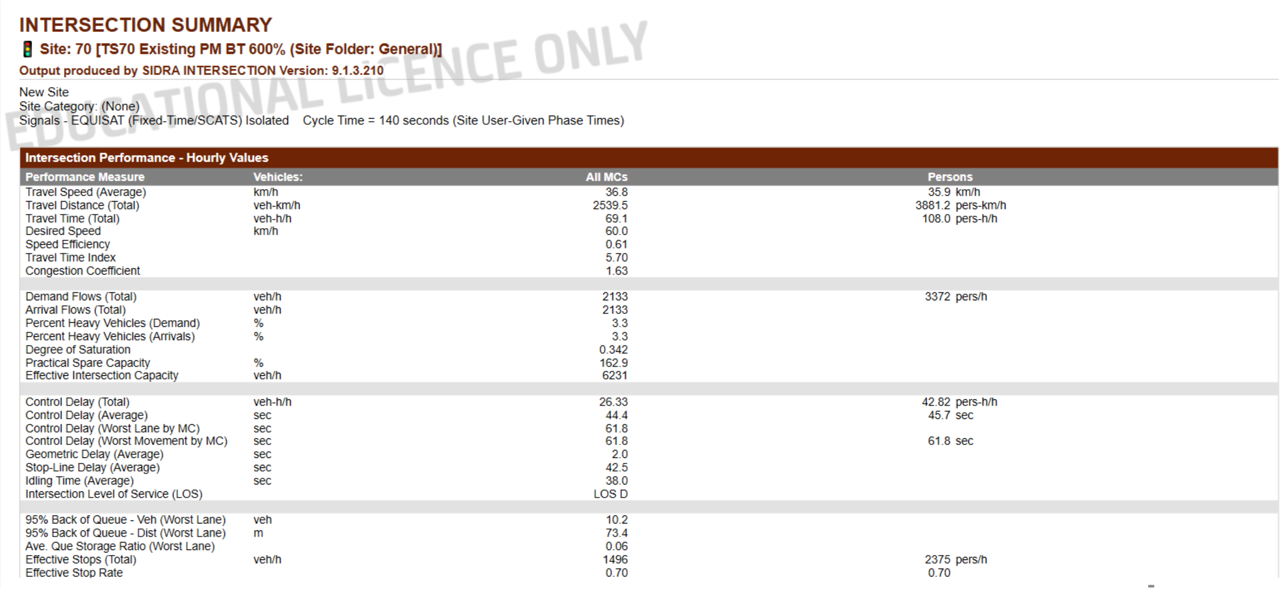
EDUCATIONAL LICENCE ONLY

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 140 seconds (Site User-Given Phase Times)

Intersection Performance - Hourly Values

Performance Measure	Vehicles:	All MCs	Persons
Travel Speed (Average)	km/h	36.8	36.0 km/h
Travel Distance (Total)	veh-km/h	2359.0	3605.3 pers-km/h
Travel Time (Total)	veh-h/h	64.0	100.1 pers-h/h
Desired Speed	km/h	60.0	
Speed Efficiency		0.61	
Travel Time Index		5.71	
Congestion Coefficient		1.63	
Demand Flows (Total)	veh/h	1981	3132 pers/h
Arrival Flows (Total)	veh/h	1981	
Percent Heavy Vehicles (Demand)	%	3.3	
Percent Heavy Vehicles (Arrivals)	%	3.3	
Degree of Saturation		0.318	
Practical Spare Capacity	%	183.1	
Effective Intersection Capacity	veh/h	6233	
Control Delay (Total)	veh-h/h	24.33	39.56 pers-h/h
Control Delay (Average)	sec	44.2	45.5 sec
Control Delay (Worst Lane by MC)	sec	61.7	
Control Delay (Worst Movement by MC)	sec	61.7	61.7 sec
Geometric Delay (Average)	sec	2.0	
Stop-Line Delay (Average)	sec	42.2	
Idling Time (Average)	sec	37.8	
Intersection Level of Service (LOS)		LOS D	
95% Back of Queue - Veh (Worst Lane)	veh	9.4	
95% Back of Queue - Dist (Worst Lane)	m	67.6	
Ave. Que Storage Ratio (Worst Lane)		0.06	
Effective Stops (Total)	veh/h	1378	2186 pers/h
Effective Stop Rate		0.70	0.70

Appendices E Result for TS070 BT data 550%



INTERSECTION SUMMARY

Site: 70 [TS70 Existing PM BT 600% (Site Folder: General)]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

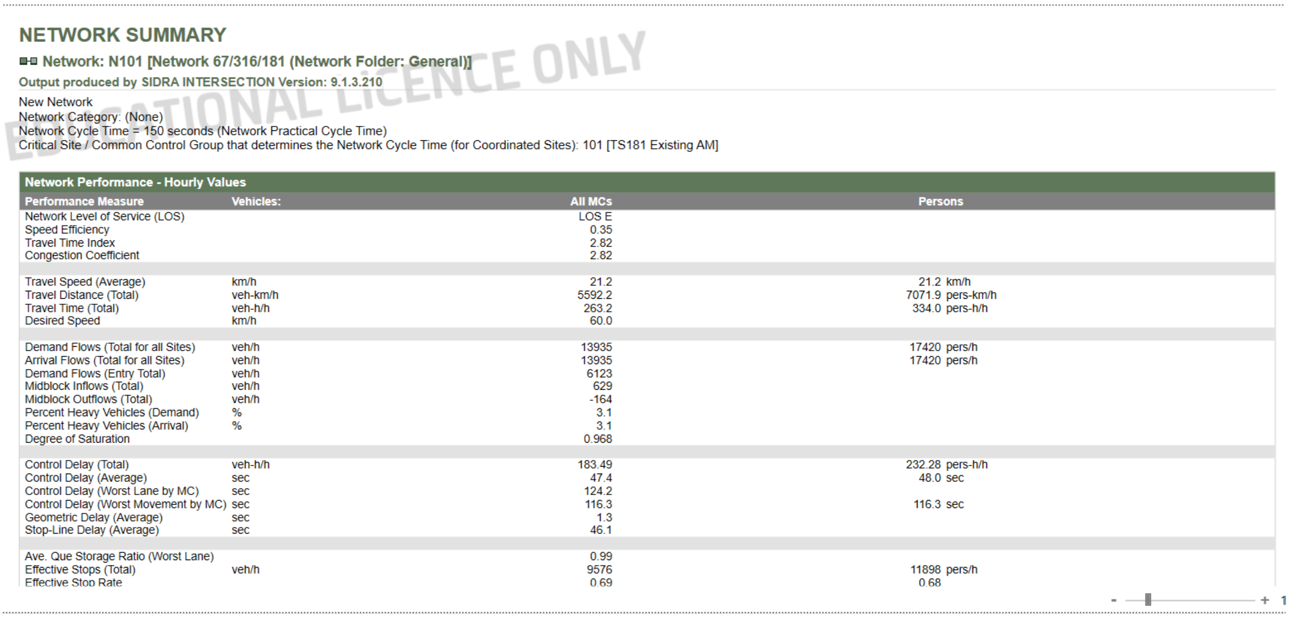
EDUCATIONAL LICENCE ONLY

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 140 seconds (Site User-Given Phase Times)

Intersection Performance - Hourly Values

Performance Measure	Vehicles:	All MCs	Persons
Travel Speed (Average)	km/h	36.8	35.9 km/h
Travel Distance (Total)	veh-km/h	2539.5	3881.2 pers-km/h
Travel Time (Total)	veh-h/h	69.1	108.0 pers-h/h
Desired Speed	km/h	60.0	
Speed Efficiency		0.61	
Travel Time Index		5.70	
Congestion Coefficient		1.63	
Demand Flows (Total)	veh/h	2133	3372 pers/h
Arrival Flows (Total)	veh/h	2133	
Percent Heavy Vehicles (Demand)	%	3.3	
Percent Heavy Vehicles (Arrivals)	%	3.3	
Degree of Saturation		0.342	
Practical Spare Capacity	%	162.9	
Effective Intersection Capacity	veh/h	6231	
Control Delay (Total)	veh-h/h	26.33	42.82 pers-h/h
Control Delay (Average)	sec	44.4	45.7 sec
Control Delay (Worst Lane by MC)	sec	61.8	
Control Delay (Worst Movement by MC)	sec	61.8	61.8 sec
Geometric Delay (Average)	sec	2.0	
Stop-Line Delay (Average)	sec	42.5	
Idling Time (Average)	sec	38.0	
Intersection Level of Service (LOS)		LOS D	
95% Back of Queue - Veh (Worst Lane)	veh	10.2	
95% Back of Queue - Dist (Worst Lane)	m	73.4	
Ave. Que Storage Ratio (Worst Lane)		0.06	
Effective Stops (Total)	veh/h	1496	2375 pers/h
Effective Stop Rate		0.70	0.70

Appendices F Result for TS070 BT data 600%



NETWORK SUMMARY

Network: N101 [Network 67/316/181 (Network Folder: General)]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

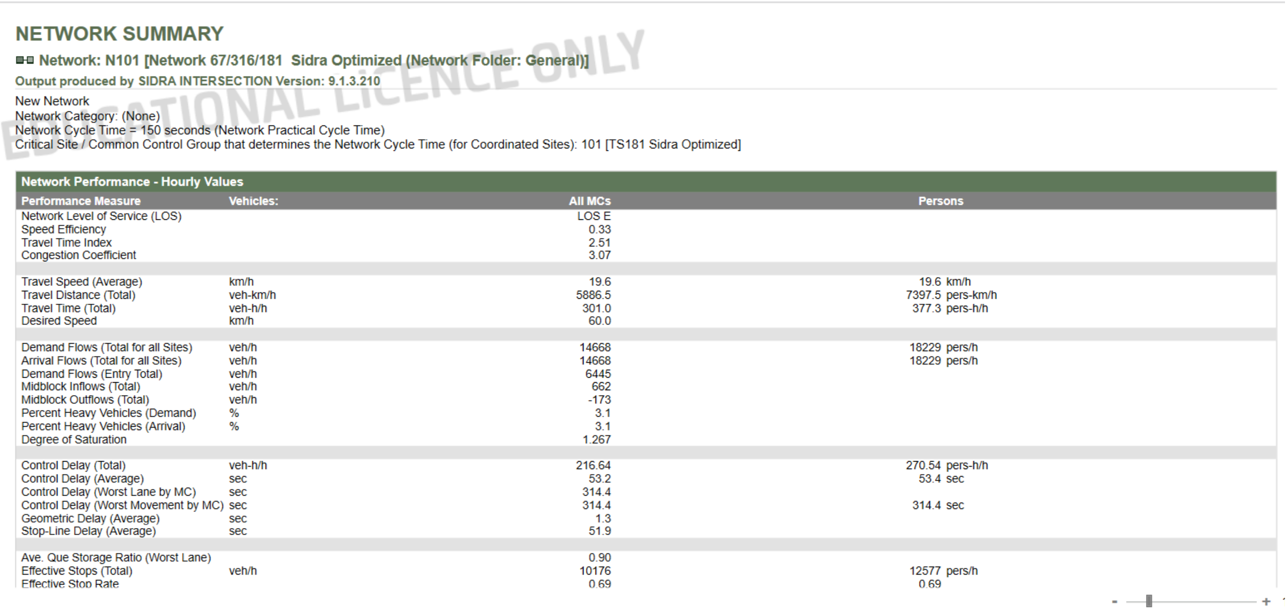
EDUCATIONAL LICENCE ONLY

New Network
Network Category: (None)
Network Cycle Time = 150 seconds (Network Practical Cycle Time)
Critical Site / Common Control Group that determines the Network Cycle Time (for Coordinated Sites): 101 [TS181 Existing AM]

Network Performance - Hourly Values

Performance Measure	Vehicles:	All MCs	Persons
Network Level of Service (LOS)		LOS E	
Speed Efficiency		0.35	
Travel Time Index		2.82	
Congestion Coefficient		2.82	
Travel Speed (Average)	km/h	21.2	21.2 km/h
Travel Distance (Total)	veh-km/h	5592.2	7071.9 pers-km/h
Travel Time (Total)	veh-h/h	263.2	334.0 pers-h/h
Desired Speed	km/h	60.0	
Demand Flows (Total for all Sites)	veh/h	13935	17420 pers/h
Arrival Flows (Total for all Sites)	veh/h	13935	17420 pers/h
Demand Flows (Entry Total)	veh/h	6123	
Midblock Inflows (Total)	veh/h	629	
Midblock Outflows (Total)	veh/h	-164	
Percent Heavy Vehicles (Demand)	%	3.1	
Percent Heavy Vehicles (Arrival)	%	3.1	
Degree of Saturation		0.968	
Control Delay (Total)	veh-h/h	183.49	232.28 pers-h/h
Control Delay (Average)	sec	47.4	48.0 sec
Control Delay (Worst Lane by MC)	sec	124.2	
Control Delay (Worst Movement by MC)	sec	116.3	116.3 sec
Geometric Delay (Average)	sec	1.3	
Stop-Line Delay (Average)	sec	46.1	
Ave. Que Storage Ratio (Worst Lane)		0.99	
Effective Stops (Total)	veh/h	9576	11898 pers/h
Effective Stop Rate		0.69	0.68

Appendices G Result for Network 67- 316-181 Existing model



NETWORK SUMMARY

Network: N101 [Network 67/316/181 Sidra Optimized (Network Folder: General)]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

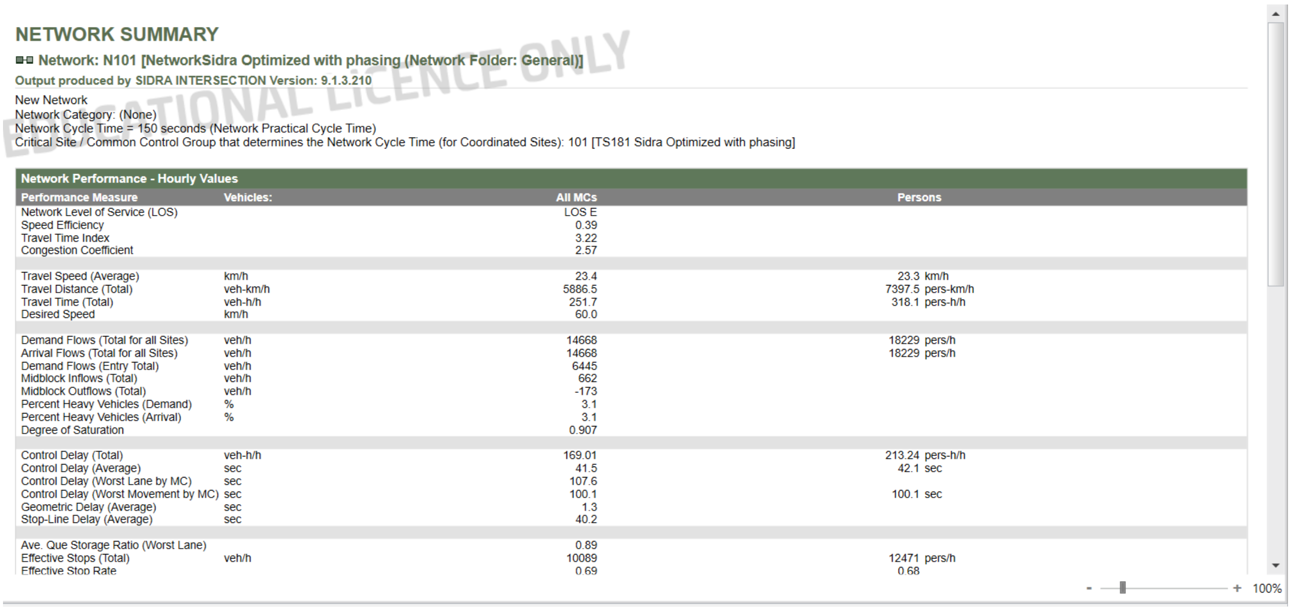
EDUCATIONAL LICENCE ONLY

New Network
Network Category: (None)
Network Cycle Time = 150 seconds (Network Practical Cycle Time)
Critical Site / Common Control Group that determines the Network Cycle Time (for Coordinated Sites): 101 [TS181 Sidra Optimized]

Network Performance - Hourly Values

Performance Measure	Vehicles:	All MCs	Persons
Network Level of Service (LOS)		LOS E	
Speed Efficiency		0.33	
Travel Time Index		2.51	
Congestion Coefficient		3.07	
Travel Speed (Average)	km/h	19.6	19.6 km/h
Travel Distance (Total)	veh-km/h	5886.5	7397.5 pers-km/h
Travel Time (Total)	veh-h/h	301.0	377.3 pers-h/h
Desired Speed	km/h	60.0	
Demand Flows (Total for all Sites)	veh/h	14668	18229 pers/h
Arrival Flows (Total for all Sites)	veh/h	14668	18229 pers/h
Demand Flows (Entry Total)	veh/h	6445	
Midblock Inflows (Total)	veh/h	662	
Midblock Outflows (Total)	veh/h	-173	
Percent Heavy Vehicles (Demand)	%	3.1	
Percent Heavy Vehicles (Arrival)	%	3.1	
Degree of Saturation		1.267	
Control Delay (Total)	veh-h/h	216.64	270.54 pers-h/h
Control Delay (Average)	sec	53.2	53.4 sec
Control Delay (Worst Lane by MC)	sec	314.4	
Control Delay (Worst Movement by MC)	sec	314.4	314.4 sec
Geometric Delay (Average)	sec	1.3	
Stop-Line Delay (Average)	sec	51.9	
Ave. Que Storage Ratio (Worst Lane)		0.90	
Effective Stops (Total)	veh/h	10176	12577 pers/h
Effective Stop Rate		0.69	0.69

Appendices H Result for Network 67- 316-181 Sidra optimized model



NETWORK SUMMARY

Network: N101 [NetworkSidra Optimized with phasing (Network Folder: General)]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

EDUCATIONAL LICENCE ONLY

New Network
Network Category: (None)
Network Cycle Time = 150 seconds (Network Practical Cycle Time)
Critical Site / Common Control Group that determines the Network Cycle Time (for Coordinated Sites): 101 [TS181 Sidra Optimized with phasing]

Network Performance - Hourly Values

Performance Measure	Vehicles:	All MCs	Persons
Network Level of Service (LOS)		LOS E	
Speed Efficiency		0.39	
Travel Time Index		3.22	
Congestion Coefficient		2.57	
Travel Speed (Average)	km/h	23.4	23.3 km/h
Travel Distance (Total)	veh-km/h	5886.5	7397.5 pers-km/h
Travel Time (Total)	veh-h/h	251.7	318.1 pers-h/h
Desired Speed	km/h	60.0	
Demand Flows (Total for all Sites)	veh/h	14668	18229 pers/h
Arrival Flows (Total for all Sites)	veh/h	14668	18229 pers/h
Demand Flows (Entry Total)	veh/h	6445	
Midblock Inflows (Total)	veh/h	662	
Midblock Outflows (Total)	veh/h	-173	
Percent Heavy Vehicles (Demand)	%	3.1	
Percent Heavy Vehicles (Arrival)	%	3.1	
Degree of Saturation		0.907	
Control Delay (Total)	veh-h/h	169.01	213.24 pers-h/h
Control Delay (Average)	sec	41.5	42.1 sec
Control Delay (Worst Lane by MC)	sec	107.6	
Control Delay (Worst Movement by MC)	sec	100.1	100.1 sec
Geometric Delay (Average)	sec	1.3	
Stop-Line Delay (Average)	sec	40.2	
Ave. Que Storage Ratio (Worst Lane)		0.89	
Effective Stops (Total)	veh/h	10089	12471 pers/h
Effective Stop Rate		0.69	0.68

100%

Appendices I Result for Network 67- 316-181 Sidra Practical model

Left turn from North Goodwood Rd				
Time	Count	Hourly %		
08.00-08.15	71	3.67605634	0.272030651	67
08.15-08.30	69	3.7826087	0.264367816	
08.30-08.45	55	4.74545455	0.210727969	
08.45-09.00	66	3.95454545	0.252873563	
	261			
The Data Recorded - 08.15 - 08.30				318

Appendices 1 Left turn from North Goodwood Rd

Left turn from South Goodwood Rd				
Time	Count	Hourly %		
08.00-08.15	148	3.87837838	0.257839721	46
08.15-08.30	128	4.484375	0.222996516	
08.30-08.45	157	3.65605096	0.273519164	
08.45-09.00	141	4.07092199	0.245644599	
	574			
The Data Recorded - 08.15 - 08.30				206

Appendices K Left turn from South Goodwood Rd

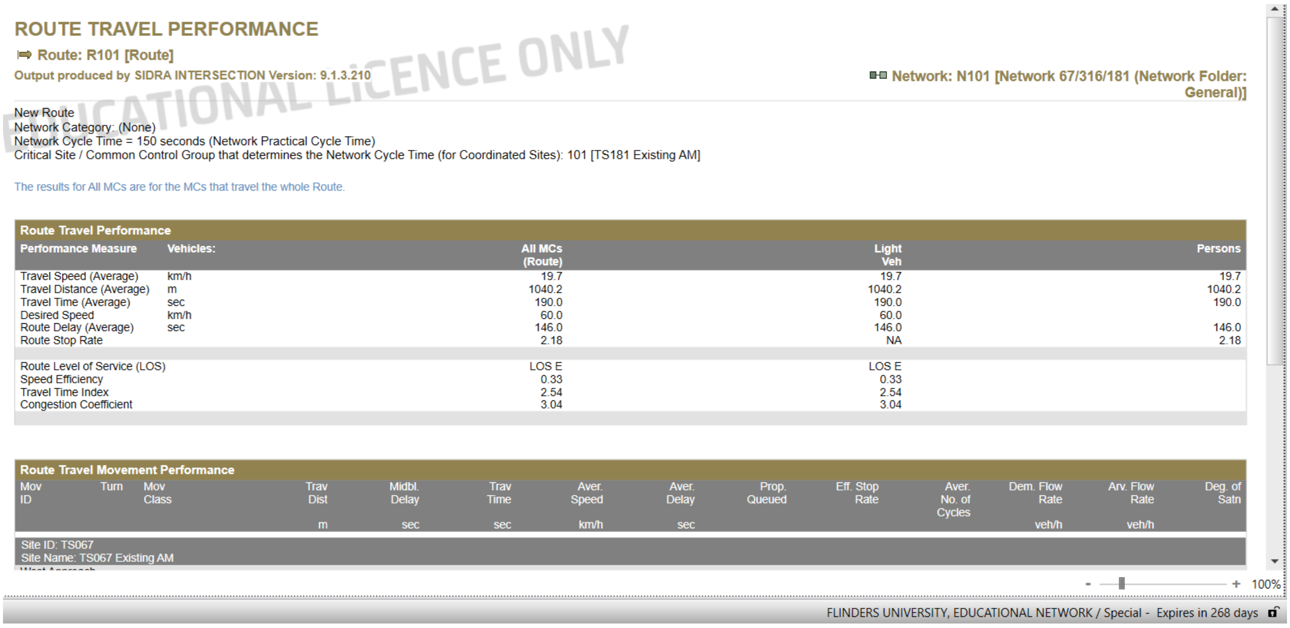
Left turn from West Greenhill Rd				
Time	Count	Hourly %		
08.00-08.15	327	4.31804281	0.231586402	3
08.15-08.30	341	4.14076246	0.241501416	
08.30-08.45	357	3.95518207	0.252832861	

08.45-09.00	387	3.64857881	0.27407932	
	1412			
The Data Recorded - 08.15 - 08.30				12

Appendices 2 Left turn from West Greenhill Rd

Left turn from East Greenhill Rd				
Time	Count		Hourly %	
08.00-08.15	315	4.25396825	0.235074627	54
08.15-08.30	347	3.86167147	0.258955224	
08.30-08.45	316	4.24050633	0.235820896	
08.45-09.00	362	3.70165746	0.270149254	
	1340			
The Data Recorded - 08.30 - 08.45				229

Appendices M Left turn from East Greenhill Rd



ROUTE TRAVEL PERFORMANCE

Route: R101 [Route]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

Network: N101 [Network 67/316/181 (Network Folder: General)]

EDUCATIONAL LICENCE ONLY

New Route
Network Category: (None)
Network Cycle Time = 150 seconds (Network Practical Cycle Time)
Critical Site / Common Control Group that determines the Network Cycle Time (for Coordinated Sites): 101 [TS181 Existing AM]

The results for All MCs are for the MCs that travel the whole Route.

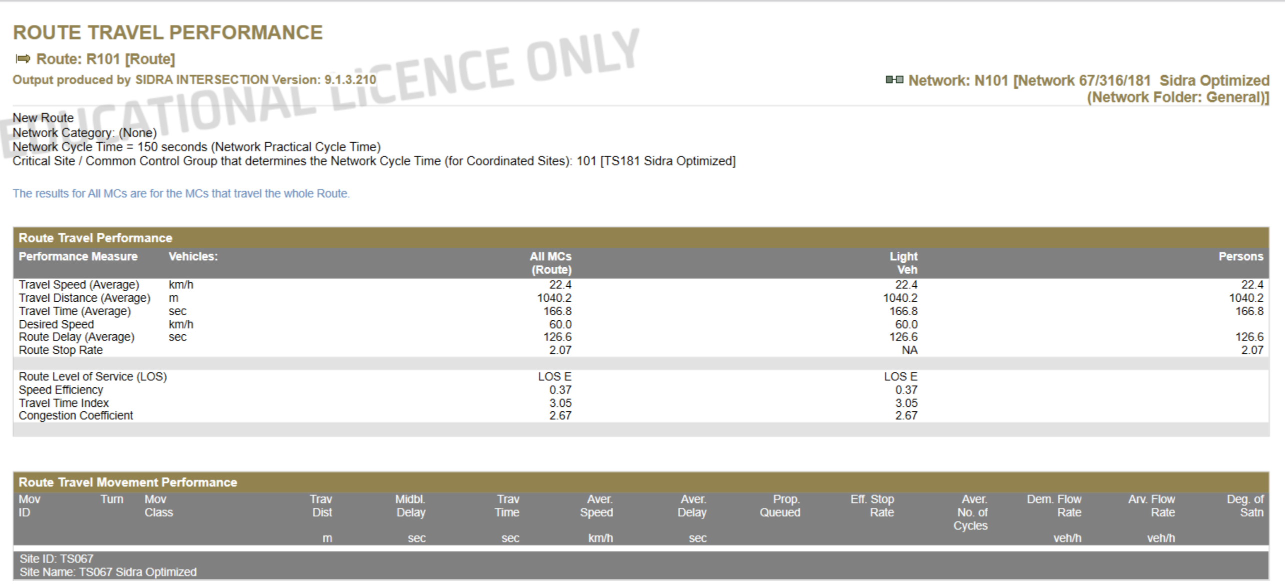
Route Travel Performance

Performance Measure	Vehicles:	All MCs (Route)	Light Veh	Persons
Travel Speed (Average)	km/h	19.7	19.7	19.7
Travel Distance (Average)	m	1040.2	1040.2	1040.2
Travel Time (Average)	sec	190.0	190.0	190.0
Desired Speed	km/h	60.0	60.0	
Route Delay (Average)	sec	146.0	146.0	146.0
Route Stop Rate		2.18	NA	2.18
Route Level of Service (LOS)		LOS E	LOS E	
Speed Efficiency		0.33	0.33	
Travel Time Index		2.54	2.54	
Congestion Coefficient		3.04	3.04	

Route Travel Movement Performance

Mov ID	Turn	Mov Class	Trav Dist m	Midbl. Delay sec	Trav Time sec	Aver. Speed km/h	Aver. Delay sec	Prop. Queued	Eff. Stop Rate	Aver. No. of Cycles	Dem. Flow Rate veh/h	Arv. Flow Rate veh/h	Deg. of Satn
Site ID: TS067 Site Name: TS067 Existing AM													

Appendices N Result for Route Existing Model



ROUTE TRAVEL PERFORMANCE

➡ Route: R101 [Route]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

Network: N101 [Network 67/316/181 Sidra Optimized (Network Folder: General)]

EDUCATIONAL LICENCE ONLY

New Route
Network Category: (None)
Network Cycle Time = 150 seconds (Network Practical Cycle Time)
Critical Site / Common Control Group that determines the Network Cycle Time (for Coordinated Sites): 101 [TS181 Sidra Optimized]

The results for All MCs are for the MCs that travel the whole Route.

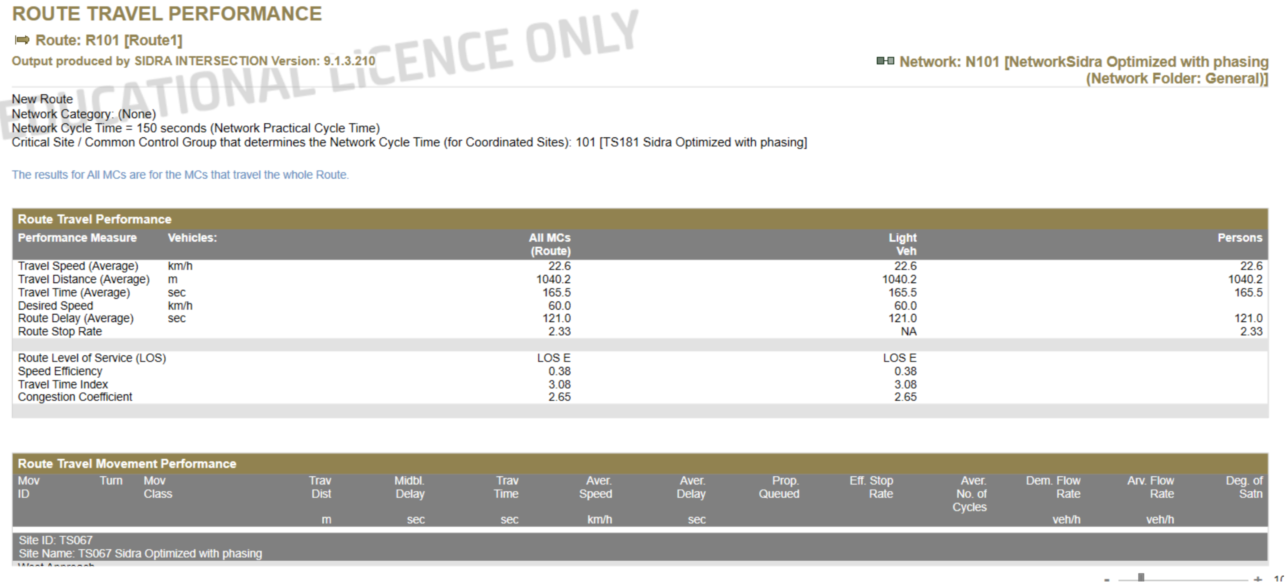
Route Travel Performance

Performance Measure	Vehicles:	All MCs (Route)	Light Veh	Persons
Travel Speed (Average)	km/h	22.4	22.4	22.4
Travel Distance (Average)	m	1040.2	1040.2	1040.2
Travel Time (Average)	sec	166.8	166.8	166.8
Desired Speed	km/h	60.0	60.0	
Route Delay (Average)	sec	126.6	126.6	126.6
Route Stop Rate		2.07	NA	2.07
Route Level of Service (LOS)		LOS E	LOS E	
Speed Efficiency		0.37	0.37	
Travel Time Index		3.05	3.05	
Congestion Coefficient		2.67	2.67	

Route Travel Movement Performance

Mov ID	Turn	Mov Class	Trav Dist m	Midbl. Delay sec	Trav Time sec	Aver. Speed km/h	Aver. Delay sec	Prop. Queued	Eff. Stop Rate	Aver. No. of Cycles	Dem. Flow Rate veh/h	Arv. Flow Rate veh/h	Deg. of Satn
Site ID: TS067 Site Name: TS067 Sidra Optimized													

Appendices 3 Result for Route with Sidra Optimized



ROUTE TRAVEL PERFORMANCE

➡ Route: R101 [Route1]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

Network: N101 [NetworkSidra Optimized with phasing (Network Folder: General)]

EDUCATIONAL LICENCE ONLY

New Route
Network Category: (None)
Network Cycle Time = 150 seconds (Network Practical Cycle Time)
Critical Site / Common Control Group that determines the Network Cycle Time (for Coordinated Sites): 101 [TS181 Sidra Optimized with phasing]

The results for All MCs are for the MCs that travel the whole Route.

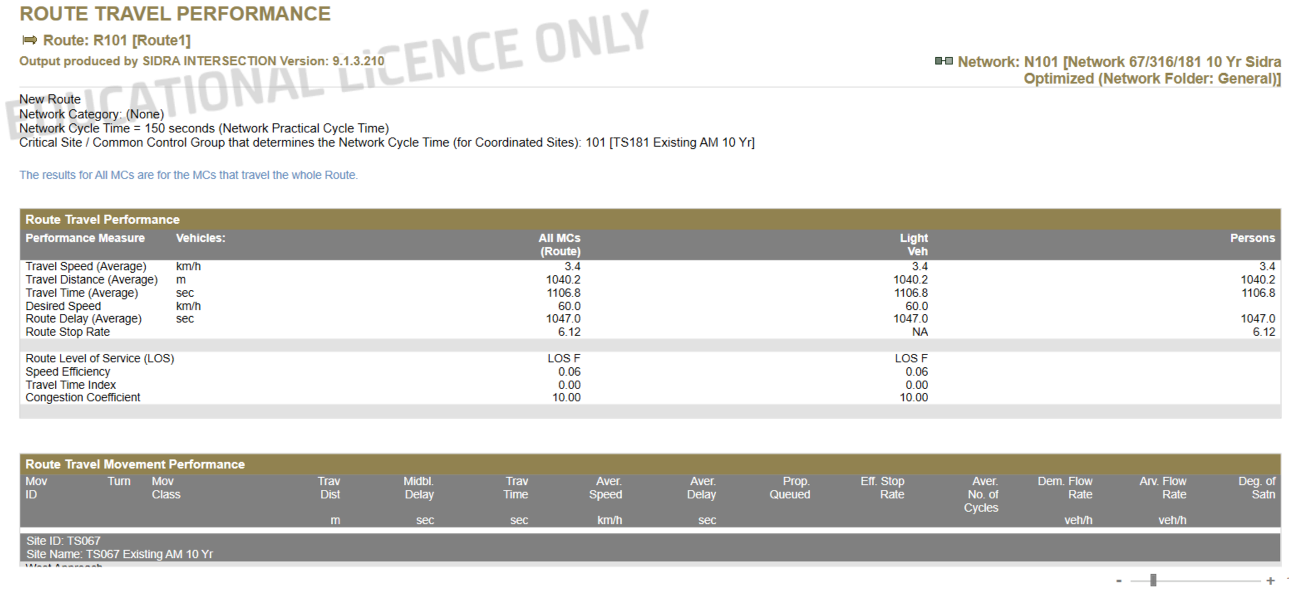
Route Travel Performance

Performance Measure	Vehicles:	All MCs (Route)	Light Veh	Persons
Travel Speed (Average)	km/h	22.6	22.6	22.6
Travel Distance (Average)	m	1040.2	1040.2	1040.2
Travel Time (Average)	sec	165.5	165.5	165.5
Desired Speed	km/h	60.0	60.0	
Route Delay (Average)	sec	121.0	121.0	121.0
Route Stop Rate		2.33	NA	2.33
Route Level of Service (LOS)		LOS E	LOS E	
Speed Efficiency		0.38	0.38	
Travel Time Index		3.08	3.08	
Congestion Coefficient		2.65	2.65	

Route Travel Movement Performance

Mov ID	Turn	Mov Class	Trav Dist m	Midbl. Delay sec	Trav Time sec	Aver. Speed km/h	Aver. Delay sec	Prop. Queued	Eff. Stop Rate	Aver. No. of Cycles	Dem. Flow Rate veh/h	Arv. Flow Rate veh/h	Deg. of Satn
Site ID: TS067 Site Name: TS067 Sidra Optimized with phasing													

Appendices P Result for Route with Sidra Practical



ROUTE TRAVEL PERFORMANCE

➡ Route: R101 [Route1]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

EDUCATIONAL LICENCE ONLY

Network: N101 [Network 67/316/181 10 Yr Sidra Optimized (Network Folder: General)]

New Route
Network Category: (None)
Network Cycle Time = 150 seconds (Network Practical Cycle Time)
Critical Site / Common Control Group that determines the Network Cycle Time (for Coordinated Sites): 101 [TS181 Existing AM 10 Yr]

The results for All MCs are for the MCs that travel the whole Route.

Route Travel Performance

Performance Measure	Vehicles:	All MCs (Route)	Light Veh	Persons
Travel Speed (Average)	km/h	3.4	3.4	3.4
Travel Distance (Average)	m	1040.2	1040.2	1040.2
Travel Time (Average)	sec	1106.8	1106.8	1106.8
Desired Speed	km/h	60.0	60.0	
Route Delay (Average)	sec	1047.0	1047.0	1047.0
Route Stop Rate		6.12	NA	6.12
Route Level of Service (LOS)		LOS F	LOS F	
Speed Efficiency		0.06	0.06	
Travel Time Index		0.00	0.00	
Congestion Coefficient		10.00	10.00	

Route Travel Movement Performance

Mov ID	Turn	Mov Class	Trav Dist m	Midbl. Delay sec	Trav Time sec	Aver. Speed km/h	Aver. Delay sec	Prop. Queued	Eff. Stop Rate	Aver. No. of Cycles	Dem. Flow Rate veh/h	Arv. Flow Rate veh/h	Deg. of Satn
Site ID: TS067 Site Name: TS067 Existing AM 10 Yr													

Appendices Q Result for Route with 10 Year Future