The Use of Intelligent Transport System (ITS) to Improve the Traffic Network Performance

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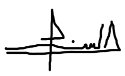

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Executive Summary

The motorway system is the world's most effective transportation infrastructure for reducing travel times and increasing the effectiveness of roads. However, the traffic flow via a motorway segment has also increased in recent years due to the rising population and vehicle ownership, which has reduced the effectiveness of the motorway network. As a result, numerous negative effects have emerged, including long travel times, delays, carbon dioxide (CO2) and nitrogen oxide (NOX) emissions, and detrimental effects on road safety. Occasionally, situations that frequently cause significant traffic congestion due to motorway capacity being exceeded accompany the effects of higher traffic flows.

There is a never-before-seen need for efficient and financially sustainable motorway management technologies because of the expansion of urban areas and the tightening of budgets. In this primer, ramp metering is suggested as a possible method to manage frequent congestion and safety issues. Ramp metering has been implemented, maintained, and even expanded in many areas despite early resistance and scepticism from numerous parties. This introduction includes recent information on difficulties that agencies run into when trying to introduce or broaden ramp metering in their areas.

While the geometric restrictions of the currently installed ramps are a typical issue, agency support and project expenses are also problematic for several organisations. Recent case studies offer suggestions for how these widespread problems might be solved as well as lessons learned. This introduction emphasises the importance of considering organisational capacity, community involvement, and geometric constraints while implementing or extending ramp metering.

This study report covers the how ramp metering improves the traffic flow on Motorway and ramp as well , following parameters were evaluated in this report speed on Motorway, queue length on ramp and delay time as well. For study purpose Bolivar Interchange were used which is the part of North South

Motorway, due its complexity of geometry and it is very close to the Princes Highway it remains busy most of the time. It also encompasses the investigation of potential mitigating actions that may be taken to lessen the effects of congestion by utilising Intelligent Transport Systems (ITS). The microsimulation model has been used to quantify the impact of traffic saturation based on location, duration, and time of occurrence on the motorway ramp for different lane blockage severity (half lane blockage and complete lane blockage). The ramp metering management has been used to establish the measures for mitigating the effects of congestion.

Because the Department of Infrastructure and Transport (DIT) uses AIMSUN solely, it was chosen for the Motorway ramp project. The interchange's high-resolution image served as the basis for the base model, which was created using it. It had been calibrated and validated by Department of Infrastructure and Transport (DIT) guidelines in terms of section flows, travel times, and queue length, and it had been determined that it was suitable for the detailed ramp modelling. Several scenarios were developed, and implications of each scenario and its attributes were developed after several methods were modelled.

The results of this study will be useful for creating ramp metering mechanisms using Intelligent Transport Systems for efficient Traffic Incident Management in motorways, which will benefit developers and road designers.

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Chapter 1

Introduction

The North-South Corridor is a crucial route for nonstop travel to and from Adelaide for business, jobs, and freight. However, according to the Department of Infrastructure and Transport (DIT), the current road network cannot support the anticipated vehicle and freight carrier travel growth in the coming years. In response, the South Australian and Australian Federal Governments proposed upgrading a 78 km stretch of the North-South Corridor from Gawler to Noarlunga, which will create a continuous North-South corridor with strategic constant road links, eliminating the worst bottlenecks and connecting the residential, recreational, and industrial areas from north to south, creating more opportunities for South Australia's social and economic development.

From Gawler in the north to Noarlunga in the south, the North-South Corridor stretches for 78 kilometres. Both the Northern Expressway in the north and the Southern Expressway in the south are already up to motorway standards. The south route, an urban arterial route with signalised intersections, makes up the remaining portion of the corridor. By 2030, the entire route is supposed to be upgraded to motorway standards.

Bolivar interchange was selected as case study for research which is a significant part of the North-South corridor. The figure 1 shows the overall layout of the research area and this interchange provide connections to adjacent areas like Parafield Garden, Paralowie, Bolivar, Burton and provide connections to heavy vehicles from roundabout. From the figure 1 colour banding shows the study area which is used for ramp metering, as these colour like blue and red shows two different ramps and at the end they merge in one single ramp and then traffic enters to the Motorway. During the site visits and data shows that these ramps become busier in the morning specifically from 7 am to 9 am due traffic saturation, the traffic which coming from the ramp enters to the freeway cause the decelerating on main Motorway. Specially in peak time it's become very prominent and causes the queue on ramp and create braking on Motorway as well. The second thing which is very important of this interchange is trucking station which is highlighted in black shaded in figure 1. This station provides services to heavy vehicles and after that these vehicles again merge to the North-South motorway in peak time these vehicles cause delay and create safety hazards specially lane serve well specially in low peak time but in peak times it become short due heavy traffic and traffic saturation.at merging point. Due to the traffic flows and heavy vehicles ramp metering is very important for safe merging and second thing which very important at merging need an auxiliary lane for safe merging current merging

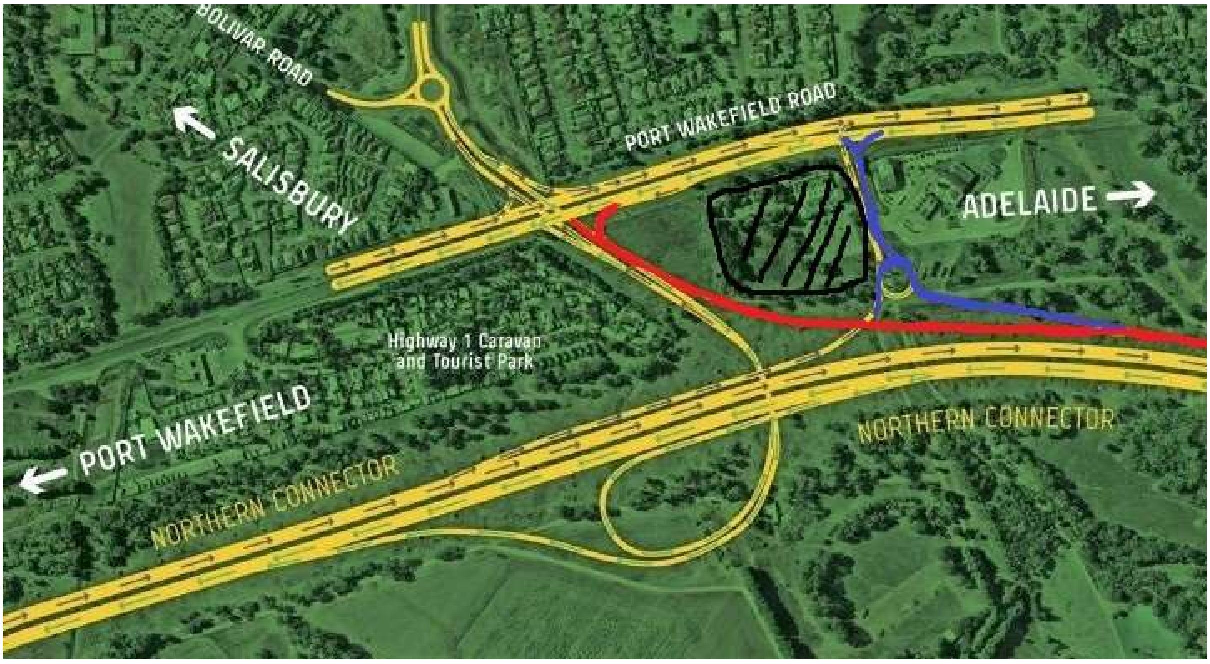

Figure 1 Bolivar Interchange *(DIT2016)*

Figure 1. Bolivar Interchange (DIT2016)

As a result, this research tries to offer insight into ramp traffic management by examining the effects of ramp metering on motorway ramps utilising microsimulation and analytical techniques with AIMSUN software. The main goal of this research is to determine the impact of traffic characteristics such as location, duration, and time of day (AM Peak/PM Peak), on vehicular travel time, level of traffic congestion, and vehicular delay, along with environmental impacts on Motorway ramp, and to investigate and suggest mitigation measures by introducing ramp metering into the Motorway section. A part of traffic management that makes use of Intelligent Transport System technologies is ramp metering.

1.1 Background

The South Australian Planning Strategy, which includes the 30-Year Plan for Greater Adelaide, the Strategic Infrastructure Plan for SA, and the Integrated Transport and Land Use Plan, all name the North-South Corridor as one of Adelaide's most crucial transportation routes. Between Gawler and Old Noarlunga, 78 kilometres, it will be the main route for north and southbound traffic, including freight trucks.

North-Connector (figure 2) shows the importance of research area, which is six lanes and 15.5 kilometres of length, the $867 million Northern Connector will be a crucial freight and commuter link between the Northern Expressway, South Road and Port River Expressway. The primary goal of this project is to bring economic advantages to the neighbourhood in South Australia, including building 480 full-time employees annually. The project has received $694 million from the Australian government and $173 million from the South Australian government.

Figure 2 North-Connector Bolivar Interchange (DIT-2016)

Figure 2. North-Connector Bolivar Interchange (DIT-2016)

A better connection between Adelaide, the Port of Adelaide, the northern suburbs, and beyond (including the mid-north, Barossa Valley, and the Riverland) will be made possible by the Motorway, which will also support regional growth and economic sustainability, more effective road travel, and increased safety.

One of the main justifications for the need for this research is that the level of the impact of congestion and the scope of the Intelligent Transport System to be implemented into the Motorway for effective ramp management during peak times have neither been quantified nor justified by DPTI. This topic is further discussed in the literature review section.

1.2 Research Aims and Objectives

Using analytical and simulation techniques, such as the AIMSUN software, this research examines the effects of ramp metering characteristics on the serviceability parameters of the road section, such as delay, congestion, vehicular travel time, and emissions, during the peak hours of the day (AM peak). The effects of installing an Intelligent Transport System on a motorway ramp during rush hour are assessed, and the best options are recommended to lessen the impact of congestion and enhance safety.

A research gap was found after a thorough literature analysis and investigation, and this gap must be filled with additional research. A set of specific goals was subsequently defined for a better research outcome.

The aims and objectives of the research are as follows:

- ❖ To create a microscopic traffic model for the Bolivar interchange ramp, microsimulation is used.
- ❖ The formalisation of the saturation zone of a traffic network. The saturation region, which is a generalisation of the saturation flow of a single-on-ramp, is a powerful performance statistic for a traffic network.
- ❖ By developing traffic-responsive ramp metering regulations at the microscopic level, it will be possible to comprehend the effects of various safety and connectivity protocols on the saturation region.
- ❖ Examine the performance of the existing motorway ramp in the absence of ramp metering and compare it to the performance of the Motorway by simulating various traffic model scenarios.
- ❖ Utilising ramp metering to assess how well nearby intersections and ramps work during peak times of traffic saturation.

- ❖ Offer alternate ideas for enhancing the motorway ramp model to accommodate future traffic growth and the use of intelligent transportation systems.
- ❖ Analyse how the use of the ITS has affected both the flow of people and the utilisation of the Motorway.

1.3 Report Structure

There are six distinct chapters in this research study, each of which is further broken into parts and subsections.

Following Chapter 1's fundamental project outline, Chapter 2 presents a thorough evaluation of the literature about the significance and importance of this research. The modified approach and criteria utilised for the modelling process of the motorway ramp using AIMSUN microsimulation software are then included in the following chapter, Chapter 3. This chapter will outline the procedures for gathering data, modelling it, calibrating it, validating it, and providing arguments for utilising the AIMSUN microsimulation tool. This chapter also discusses the limitations of the current model.

The results from the AIMSUN model are presented in Chapter 4 along with an evaluation of the Motorway's performance based on the traffic performance indicators of travel time, delay time, and congestion during peak hours.

The results generated are also briefly described in Chapter 5. This chapter also discusses the effects of integrating an intelligent transportation system (ITS) into the motorway segment as well as how this will change how people utilise the Motorway and move around it. Finally, Chapter 6 summarises this study's findings and offers suggestions for future research that will make use of an intelligent transport system to assess motorway occurrences.

Chapter 2

Literature Review

The purpose of the literature review is to both summarise the existing research on ramp metring and to draw attention to the significance of the thesis's issue. The research to be undertaken in this article will be based on an evaluation of several of the methods that are available to measure the effects of ramp modelling. Also, several tried-and-true strategies for using ITS technologies to lessen the effects of events will be investigated. The gap in the literature and how the study in this thesis will make a distinctive contribution to the present body of knowledge will be discussed as the section ends.

2.1 Impacts from freeway congestion

Urban areas around the country are experiencing a surge in traffic congestion, which has negative effects on quality of life, pollution levels, productivity, and personal annoyance(Waller et al., 2009). Although there is a tendency for traffic congestion to get worse over time, there are financial and land availability restrictions on how much transportation infrastructure can build. To effectively manage congestion using the available motorway capacity, this has increased the emphasis on using dynamic traffic management measures, such as speed harmonisation and peak-period shoulder use. This project implemented a variety of variable speed restriction and shoulder usage tactics and evaluated the effects on highway traffic flow and safety. These tactics were shown to homogenise traffic and improve driving conditions, but they had little effect on the system's throughput. Furthermore, covered are the ITS tools needed to implement these methods, enforcement concerns, potential roadblocks to their implementation, and a framework for cost-benefit analysis to establish their practicality.

This study initially looks at the connection between congestion and safety before looking at the connection between safety and the number of lanes on metropolitan motorways. Safety performance functions (SPFs) tuned for multilane motorways in Colorado, California, and Texas were used to examine the relationship between safety and congestion on urban motorways(Kononov et al., 2008). The focus of most SPF modelling efforts to far has been on the statistical technique and the underlying probability distribution, with only minor consideration given to the nature of the phenomena itself. In this study, neural networks were employed to discover the underlying connection between exposure and safety. The Highway Capacity Manual's traffic operations parameters were considered during the modelling procedure. The best way to define the form of the SPF is as a sigmoid, which represents a dose-response relationship between safety and traffic demand on urban motorways. According to a relationship between safety and congestion, level of service shows that safety deteriorates along with a decline in service quality. The widespread consensus among practitioners is that increased capacity provided by more lanes is related to greater safety. In most cases, consideration is not given to how much safety or for how long. According to a comparison of SPFs for multilane motorways, increasing lanes might initially produce a transient benefit in safety that vanishes as traffic volume rises. The slope of SPF, as characterised by its first derivative, steepens with growing yearly average daily traffic, indicating that accidents are rising more quickly than one might anticipate from a motorway with fewer lanes.

For the past few decades, urban motorway congestion has been highly acknowledged as a severe and worsening traffic problem in the world(Cao et al., 2015). Many active traffic and demand management (ATDM) techniques have been developed to ease motorway congestion. The variable speed limit (VSL) is one of them, and it attempts to control motorway mainline flow upstream to fulfil capacity requirements and to harmonise vehicle speed. Yet, due to the extraordinarily high demand in actual usage, congestion can still be unavoidable even with VSL applied.

In order, to propose a feasible speed limit during the control phase, previous, study updated an existing VSL technique by including a new local constraint. As a result of the fact that a queue is a result of the motorway congestion phenomena, the incentives for a queue to form in the applied coordinated VSL control situation were examined. Speed contours were used to show the congestion distribution over an entire motorway network in a variety of circumstances. This was done by taking into consideration a congestion occurrence (a queue build-up) that is defined by a quick and sharp speed drop.

In order, to determine the effects of the applied coordinated VSL control on the congestion distribution, the congestion distributions found in both VSL control and non-VS control conditions for various scenarios were examined. This modified coordinated VSL control strategy was implemented on an actual section of White mud Drive (WMD), an urban motorway corridor in Edmonton, Alberta, Canada. To test the above-mentioned performance, a calibrated micro-simulation VISSIM model (model functions) was used in place of the real-world traffic system. The exploration job in this study can serve as a foundation for future research on how to enhance the VSL control method that is now being used to achieve the effect of motorway congestion mitigation.

2.1.1 Impacts of ramp metering

Ramp metering improves traffic flow on motorways by reducing delays and easing traffic congestion(Haule et al., 2021). Because the ramp metering can help increase motorway safety. While ramp metering's operational advantages have been thoroughly measured, research on its safety implications is scant. This study's major objective was to assess how ramp metering affected the highway mainlines safety performance. When ramp metering is turned on, it created a model for predicting collision risks for sections that are downstream of the entrance ramps. The study was based on an I-95 ramp metering system along a route near Miami, Florida. The investigation employed real-time traffic, collision, and ramp metering operations data gathered from 2016 to 2018. In order, to assess the crash risk when ramp metres were enabled and deactivated, the study used a matched crash and non-crash case technique. The impacts of ramp metering activation were calculated using a bootstrap resampling technique, and significant factors that could predict accident risk when ramp metres were active were chosen. Findings showed that by lowering the crash risk downstream of the entrance ramps, ramp metering increases safety along the interstate corridor. The difference in average lane speeds between upstream and downstream detectors, the average traffic volume in the lanes at the downstream and upstream detectors, and the coefficient of variation of speed between lanes in the upstream detectors can all be used to predict the crash risk on segments downstream of the entrance ramps 5 minutes after ramp metering activation. Also, the crash risk 15 minutes later could be predicted by the coefficient of change of occupancy upstream. While assessing the use of ramp metres, transportation organisations may refer to the study's findings. Additionally, agencies could use the created crash risk prediction model in real-time to identify the elevated accident risk and give the upstream traffic the proper warning information.

Urban expressways, which are important for medium- and long-distance express transit, have an impact on a city's area's ability to move people and goods(Ci et al., 2022). On-ramp metering can increase an urban expressway system's operational effectiveness (ORM). This research developed an enhanced ALINEA approach based on the ALINEA algorithm with a wavelet neural network (WNN) optimised via chicken swarm optimisation (CSO). The algorithm incorporates the K-means algorithm to choose the key-point for coordinated control of dynamic multiple on-ramps. The main goals of the modified ALINEA approach were to address the issues with the mainline multi-lanes state and the in-flow of the upcoming control period. Simulation findings showed that the suggested coordinated control method can improve the urban expressway's traffic efficiency.

Study shows that Ramp metering (RM) is a control method that enables maintaining steady motorway flow (occupancy below critical values), delaying the advent of congestion(Cazorla et al., 2022). Depending on the application, a proper application guarantees a lower Total Travel time Spent in the Network (TTS) (travel time in the mainstream and waiting time at on-ramps). The advantages of RM result from reducing traffic and/or reducing queue spill over. The state of the art is reviewed in this study, and twenty-one pertinent documents describing case studies that contrast the effectiveness of two or more RM techniques are eventually chosen. The tactics employed and reported gains are utilised to categorise these publications (reduction in TTS). The authors advise using RM on heavily congested motorways with comparable TTS between ramps regardless of the approach. To determine where the control to be implemented, bottlenecks must be clearly recognised. Control settings ought to be established utilising both historical and current data and changed in response to a vanishing horizon. Inadequate input parameters, reactive rather than proactive techniques, and queue formation only on some coordinated ramps are all detrimental aspects that could increase the original conditions of congestion and spillback.

Ramp metering (RM) is a method of traffic management used to regulate the flow of vehicles accessing certain types of motorways, expressways, highways, and turnpikes that are designed for moving large volumes of traffic quickly(Grzybowska et al., 2022). Less congestion on the major road's thoroughfare is the goal of RM. Since the 1960s, RM algorithms have undergone substantial development, and this trend will continue in the future. The applications of the RM methods are always being upgraded, although the functionality of the algorithms remain valid throughout time. This study evaluates contemporary literature on the use of RM techniques, in contrast to earlier studies that concentrated on the RM methodological element. In order to serve as a future reference for academics and practitioners alike, this paper aims to provide a global perspective on the RM applications now in use and the algorithms employed. The document gives an overview of the evaluation of these plans as well as an indicative historical backdrop and features for each reported project. The study analyses difficulties and the potential future of RM technology based on the present understanding of RM techniques.

It investigates microscopic ramp metering under the restrictions of vehicle safety. With numerous on- and off-ramps, a ring road summarises the traffic network. Exogenous stochastic processes are used to simulate the times at which vehicles arrive at the on-ramps and the off-ramps that will take them where they're going. When a car exits an on-ramp, if it is not blocked by another vehicle, it accelerates towards the free flow speed; once it approaches another vehicle, it adopts a safe behaviour. As the car arrives at the designated off-ramp, it leaves the traffic network. We create ramp metering strategies that are sensitive to traffic and maximise the network's saturation region. The set of demands, such as arrival rates and the routeing matrix, for which the expected queue lengths at all on-ramps remain constrained is known as the saturation region of a policy. The synchronous cycles used by the proposed ramp metering regulations ensure that an on-ramp does not discharge any more vehicles than the number of vehicles in its queue at the start of the cycle. We offer three policies, under each of which each on-ramp I delays release for a period at the conclusion of the cycle, (ii) modifies the release rate during the cycle, or (iii) adopts a conservative safety criterion for release throughout the cycle. Nevertheless, none of the policies call for information regarding the demand. By examining the stochastic stability of the induced Markov chains, the saturation zone of these policies is identified. It is demonstrated to be greatest when the merging speed of all on-ramps is equal to the free flow speed.

Lately, traffic control systems have been created to effectively operate motorways to address societal issues brought on by traffic congestion(Vrbanić et al., 2021). The coordinated ramp metering (RM) technique and variable speed limit (VSL) control are two examples of effective motorway flow management strategies. The goal of this research is to create a dynamic VSL and RM control method for highway traffic efficiency using deep reinforcement learning (DRL).

Via traffic simulation in the highway segment with several VSL and RM controls, the deep deterministic policy gradient (DDPG) algorithm-based traffic control strategies are put to the test. The findings indicate that applying the method reduces congestion in the on-ramp area and causes it to move to other sections. By lowering the density and raising the average speed of the vehicles, the VSL or RM method typically improves the overall flow rates.

Yet, given the high degree of traffic flow, VSL or RM control might not be acceptable. According to the amount of traffic flow, it is necessary to implement the selective application of integrated control schemes. By using the adjacency matrix in the neural network layer, it is discovered that the integrated approach may be employed while considering the relationship between each state detector in many VSL sections and lanes. The findings of this study suggest the value of RM and DRL-based VSL as well as the significance of spatial correlation between state detectors.

Based on the current traffic flow and weather circumstances, variable speed limit (VSL) control automatically modifies the displayed speed limit to balance traffic speed, avoid congestion, and lower crash risks(Qu et al., 2021). Earlier studies have looked at how VSL regulation affects crash risks at the corridor level and bottleneck throughput. This study tries to close the gap by analysing real-world data to examine how compliant the drivers are under various VSL values and how the aggregated driving behaviour varies. This study uses statistical analysis to compare driving behaviour under various VSL values and examines the safety impacts of VSL controls on aggregate driving behaviours (mean speed, average speed difference, and the percentage of small space headway).

The high-resolution lane-by-lane traffic big data was collected from a European highway. According to data analytics, VSL control can successfully reduce the mean speed, the speed difference, and the proportion of tiny space headways.)

Furthermore, covered are the safety effects of VSL regulation on aggregated driving behaviour.) Aggregated driving behaviour factors exhibit a tendency of first lowering and then increasing together with the steady decline in VSL values, suggesting that possible traffic safety gains may be realised by adopting suitable VSL values that are in accordance with the current traffic conditions.

The findings demonstrate that drivers' speed management in the warning zone is enhanced, and their deceleration behaviour is more sophisticated in the connected vehicle environment(Lee et al., 2022). The driver's stability and speed control are enhanced, and 100 m before the tunnel entrance, the danger of an accident is diminished. Also, 300 metres past the tunnel entrance, the driver's stability and speed control have both been enhanced. In general, the driver can anticipate the tunnel in the connected vehicle environment and change his speed in time to assure his safety at the tunnel entry. The findings of this study are crucial to the development and study of warning systems in a connected vehicle environment and will direct the development of safety-related features in automated vehicles. In this study, a connected car environment test platform based on driving simulation technology is built and tested in certain situations related to tunnel entrances, serving as a guide for implementing active vehicle protection at the tunnel entry.

An overview of the many Variable Speed Limit (VSL) solutions that have been developed over the past 20 years is given in this study(Khondaker & Kattan, 2015). The theoretical foundation of VSL systems is first explained, along with how it can be applied as a dynamic traffic management device to enhance traffic flow and boost safety.

Following a description of the various VSL control mechanisms, from the first rule-based approaches to the most sophisticated network-wide coordinated approaches, potential advantages and areas for development are discussed. Together with certain other closely linked issues of VSL application, such as driver compliance with VSL and the integration of a differential speed restriction with VSL, the anticipated environmental benefits of VSL techniques are also examined.

The paper concludes with a critical review that highlights some of the major problems that emerged from the literature review and suggests some lines of enquiry for future studies that should be pursued as suggestions for best practises to support further development, application, and refinement of VSL.

2.1.2 Environmental Implications

In order, to fully understand the possible effects of intelligent transportation systems (ITS), it is now more crucial than ever to evaluate these systems(Kolosz & Grant-Muller, 2016). The goal of this study is to determine if traditional transport appraisal models and techniques are suitable for this purpose, particularly in terms of accurately portraying the environmental and socioeconomic effects of ITS. They consist of the most popular environmental systems analysis tools (ESATs), which take into account global standards and are very significant in signalling sustainability. Based on the literature, an overview of new techniques in relation to the objective of a smooth transition to a low carbon future is provided. Due to the decentralised structure of information communication technology, the evaluation of ITS is inherently ambiguous; hence, a variety of ways to capture this feature are explored. Given the various configurations of ubiquitous technology that could make up ITS services, the models, weights, and techniques are examined in terms of their capacity to estimate sustainability performance. Reflecting opinions about how sustainability should be measured through weighting systems is crucial. They can be included by locating, categorising, and choosing one or more ESATs according to how well suited they are for a given application. Lastly, suggestions are made regarding the tools that might be included to reflect the performance of ITS better fully.

It is common practise to create a ramp metering scheme for motorways with several on-ramps to control ramp entrance rates and reduce mainline disturbances(Du et al., 2018). Instead, then looking at how ramp metering affects the environment, most of the research that are now available focus on how well it affects mobility and safety. The estimations of vehicle emissions (Table 1) along mainline motorways under different ramp metering systems are the major subject of this paper. In a field test along Interstate Freeway I-45 in Houston, Texas, USA, with five on-ramps, vehicle speed and acceleration rates were measured,(Graph 1 & graph 2) and instant car emissions were computed in accordance. Three scenarios—no ramp metering, isolated ramp metering, and integrated ramp metering—were used in the test. The isolated ramp metering technique produces the most emissions on the Motorway mainline among the scenarios, according to the results. Due to the decreased travel time and carefully controlled on-ramp queue duration, the integrated ramp metering technique greatly improves mobility while also significantly reducing overall emissions. As a result, ramp metering that is integrated rather than separated has better mobility and environmental consequences.

Table 0-1 Results of tests showing a correlation between emission and speed(Du et al., 2018)

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Table 1. Results of tests showing a correlation between emission and speed(Du et al., 2018)

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Figure 3 Speed Comparison (Du et al., 2018)

Figure 3. Speed Comparison (Du et al., 2018)

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Figure 4 Acceleration range (Du et al., 2018)

Figure 4. Acceleration range (Du et al., 2018)

The ramp metering controls appear to have the ability to increase high emission rates. Yet, under ramp metering restrictions, mobility is greatly increased, which results in a sharp reduction in emission duration. As a result, it is anticipated that the isolated and integrated ramp metering controls will result in fewer overall emissions.

2.1.3 Financial Implications

On the M1 and M3 motorways in Queensland, Australia, the recently created traffic-responsive feedback control system HERO (heuristic ramp metering coordination), which coordinates local ramp-metering activities in motorway networks, was put into use(Faulkner et al., 2014). At the local level, HERO uses an expanded version of the feedback regulator ALINEA; it performs better than local ramp metering that is not coordinated and comes close to being as effective as advanced optimum control schemes. The Department of Transport and Main Roads of the State of Queensland has installed HERO at six on-ramps to the M1 and M3 highways. When compared to the fixed-rate ramp-metering system that was previously in operation, the results demonstrate considerable improvements in traffic throughput and trip times. With a benefit-cost ratio of 13.8:1 at a 7% discount rate, HERO's deployment has a very strong economic case, according to a quick economic benefit analysis. The capital investment made for this pilot has an economic payback period of about 4 months.

The ongoing growth of cities, coupled with high densities and an increasing need for travel, has resulted in an enormous rise in the volume of road traffic in the contemporary era, which is defined by dense urbanisation and frequent transit between interconnected areas(Trubia et al., 2021). Given the higher likelihood of unpleasant occurrences like accidents or road congestion with corresponding delays and the rising stress levels of the user and infrastructure, road traffic today needs to be managed properly to improve performance and safety conditions. Thankfully, this may be accomplished by using a variety of technical tools, such as ramp metering. Ramp metering makes it possible to achieve the aforementioned desired outcomes, such as increasing mobility, dependability, efficiency, and safety, as well as lowering environmental impact. Also, it has been demonstrated in the literature to be cost-effective. More study is required to improve the quality, effectiveness, and efficiency of ramp metering, especially in light of the rapid advancement of technology (such as connected autonomous vehicles and surveying drones) and new difficult situations (e.g., congested industrial areas and emergency vehicles). The goal of this review is to provide a broad overview of the primary ramp metering solutions, with a focus on recent research studies and a spotlight on some of the key algorithms employed in this context based on various conditions. The goal of this article is to introduce the topic of ramp metering by giving a comprehensive review of its history, development, and most recent analytical models.

Ramp metering's main goals are to prevent short-distance drivers from utilising the Motorway and to minimise traffic congestion on motorways by limiting the total flow entering the road(Chen et al., 2016). Ramp-metering deployment life-cycle cost analysis has drawn attention for determining the most cost-effective technique. Decision-makers are being urged to consider the environmental and social impacts of ramp-metering deployments in addition to agency costs due to growing worries about the consequences of congestion on the environment and rising accident rates. A high-level approach for benefit-cost analysis of ramp-metering deployments is presented in this research. The triple bottom line of sustainability was taken into consideration when building the framework (i.e., economic, environmental, and social factors). The framework, more particularly, consists of four key parts: (a) a life-cycle cost analysis; (b) an analysis of advantages from reduced travel time; (c) an analysis of benefits from decreased energy usage; and (d) an analysis of benefits from fewer accidents. The use of the framework is illustrated through a fictitious case study. A sensitivity analysis is carried out to ascertain how increased traffic demand would affect the outcomes. It is anticipated that the suggested framework will enhance how transportation agencies make high-level decisions about the use of ramp metres.

2.2 Simulation Models using Computer Software

It is possible to evaluate innovative approaches for traffic issue detection and management without interrupting existing traffic networks thanks to computer modelling simulation techniques (Archer, 2000). Several studies have been conducted by (Ferrara, et al., 2013); (Archer, 2000); (Barceló, et al., 2005); (Hadi, et al., 2007); (Holyoak & Stazic, 2009); (Li, et al., 2006); (Ni, 2003); (Zhicai, et al., 2004); (Xu, et al., 2014); (Sheu, 2013) (Helbing, et al., 2002) (Kabit, et al., 2014); (Koorey, et al., 2015) and (Dia, 2011) using computer-based simulation approaches for investigating the effects of ramp metering in specific road networks.

It is possible to assess the effects of Intelligent Transport Systems (ITS) on network performance using both field investigations and traffic simulation(Dia & Cottman, 2004). Field studies typically cost a lot of money to execute, and they don't provide you much freedom to look at other scenarios. A better and more economical method is to use computer modelling, specifically microscopic traffic simulation, which allows the modeller to change the input circumstances and assess the effects on network performance.

The level of modelling detail, the scope of the investigation, and the complexity of the results all influence the modelling strategy that is used. Below, four distinct traffic simulation methodologies are presented in ascending order of the level of model complexity that can be achieved: macroscopic, mesoscopic, microscopic, and nanoscopic.

2.2.1 Macroscopic Simulation Models

Congestion on the roads was a result of the rise in car numbers in previous decades(Gregurić et al., 2014). Urban regions with high densities of people often experience such congestion, which happens every day during the morning and afternoon rush hours. Urban areas have suffered since there isn't enough room to construct new transportation infrastructure. By implementing innovative traffic control techniques from the field of intelligent transportation systems (ITS), the problem of traffic congestion can be resolved. Ramp metering is one of the applied ITS techniques used to boost traffic on urban motorways with lots of on- and off-ramps. Ramp metering is now utilised in conjunction with other control strategies, such as variable speed limit control (VSLC). Such cooperative traffic control systems must be evaluated in simulations using data from actual traffic before being put into use. CTMSIM, which provides macroscopic simulation of highway traffic and local ramp metering techniques, is one of the simulators in use.

2.2.2 Mesoscopic simulation models

There have been established methodologies to model the effects of ramp metering queues on diamond interchange operations(Tian et al., 2004). The techniques are a part of a larger research project that examines how a ramp metering system and a diamond interchange operate together. The approaches were applied in DRIVE, a mesoscopic simulation and analytical model computer model. While still considering stochastic traffic flows, a mesoscopic model offers the benefits of both macroscopic and microscopic models with less computational time. An integrated diamond interchange and ramp metering system can be analysed and evaluated using DRIVE across several cycles. Here, the component relating to the diamond interchange operations is documented, with a focus on the effects of potential queue spillback from ramp metering to the diamond interchange signals.

2.2.3 Microscopic simulation models

It is not until one attempt to make their own traffic microsimulation that the difficulties of developing, calibrating, and verifying one become obvious(Cabannes et al., 2023). This article presents a methodology for building, calibrating, and validating a large-scale microsimulation of any city using a traffic microsimulation of the San Jose Mission district in Fremont, California. Anyone can recreate the simulation or its creation inside the AIMSUN microstimulator using the codes and data that are made publicly available. Using a typical 2019 afternoon six-hour demand, the calibration method enables modelling the movement of 130,000 vehicles via a Fremont subnetwork with more than 4,000 links. Executing the simulation using calibrated data results in a linear regression between the simulated and real data over 83 sensors at 15-minute time intervals, with a slope of 0.976 and an R2 of 0.845.2.5.4.

2.2.4 Nanoscopic simulation models

The identification of crucial scenes and the scenarios that go with them is a necessary condition for scenario-based testing. Critical situations, like collisions, do happen quite seldom(Schütt et al., 2023). As a result, a lot of data needs to be analysed. Another problem is that recorded real-world traffic frequently includes situations with many vehicles, making it difficult to identify which ones are most important for an autonomous vehicle's safety. As a result, we offer the inverse universal traffic quality, a criticality metric for urban traffic that is not dependent on predetermined enemy vehicles or vehicle constellations like intersection trajectories or car-following scenarios. Our measure can be customised to specific scenarios if necessary and is universally relevant for many urban traffic situations, such as crossroads or roundabouts. The suggested metric is also assessed in this study, and its results are compared to other widely used criticality metrics in this area, such as time-to-collision and post-encroachment time.

2.3 Research Gaps and Goals

Many inferences can be made from studying the literature and research discussed in this chapter. First off, there is a serious problem with motorway congestion and the associated financial and environmental costs. This problem is only made worse when significant events shut down one or more lanes of a network of motorways.

Following the loss in roadway capacity, drivers experience severe incident-induced delays that lengthen trip times and slow down travel speeds, ultimately causing significant societal financial and environmental costs. The factors that have the greatest impact on incident impacts include lane obstruction, capacity reduction, and event-induced delay. So, it becomes sense to estimate the effects of these road traffic incidents and come up with strategies for limiting their negative effects.

To accurately measure the effects of ramp metering, Motorway and arterial road networks can be safely and economically modelled using computer simulation. Most studies using this methodology to far seem to agree that the microsimulation automobile following model is the best instrument for analysing these effects. Although there is a substantial volume of research quantifying the financial, environmental, and travel delay effects, there is an even larger body of work in the domain of TIM methods that seek to lessen adverse ramp metering implications. It is proposed that evaluating a wide range of scenarios in numerous locations is the only way to truly evaluate the effects of ramp metering and the efficacy of TIM techniques. The literature also reveals that although there are a number of ITS technologies, VMS re-routing is the most efficient.

Through analysis of existing Motorway ramps the intended purpose of research is given below:

- ❖ Formalization of a traffic network's saturation region. A strong performance metric for a traffic network is the saturation region, which is a generalisation of the saturation flow of a single-on-ramp.
- ❖ Design of traffic-responsive ramp metering policies at the microscopic level that will help in understanding the impacts of different safety and connectivity protocols on the saturation region.

- Examine the performance of the existing motorway ramp in the absence of ramp metering and compare it to the performance of the Motorway by simulating various traffic model scenarios.
- Utilising ramp metering to assess how well nearby intersections and ramps work during peak times of traffic saturation.

Chapter 3

Methodology

The purpose behind choosing the AIMSUN software for the study is discussed in this chapter, methodology through diagram 3, along with the specifics of ramp modelling, traffic control approaches like AIMSUN scenarios, and the modelling procedure.

The approach for this study comprises ramp modelling after the model validation, which is developed according to the scale and high resolution, and before the AIMSUN model is calibrated and verified by DIT standards.

Figure 5 Showing the Research Methodology

Figure 5. Showing the Research Methodology

3.1 Software Selection

The most adaptable, well-liked, and potent traffic analysis tools that can produce remarkably precise results for the ever-increasing complexity of traffic engineering phenomena are microscopic traffic simulators(Barceló, 2005). In the literature review section, several modelling approaches were compared, and the microsimulation approach was found to be the most effective for studying the effects of ramp metering on Bolivar Interchange and evaluating the model in terms of travel times, delays, speeds.
One of the best and most adaptable microsimulation programmes in the world, AIMSUN (Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks), produces driver and vehicle movement data from the model. The vehicle movement parameter is relevant to our research's scope. In the study, Bolivar Interchange Model is used for thorough modelling and simulation for ramp metering on motorways ramp during the morning peak hour.

3.2 Site Location

Site selection is based on the report which is published by Department for Infrastructure and Transport (DIT) on 15 May 2015. This report is known as Concept of Operation it highlighted the major deficiencies related to intelligent transport system (Figure 3) shows the detailed layout of project area and also highlighted the major approached to the Bolivar interchange. Further detailed is given in introduction. The red area shows the location of ramp metering.

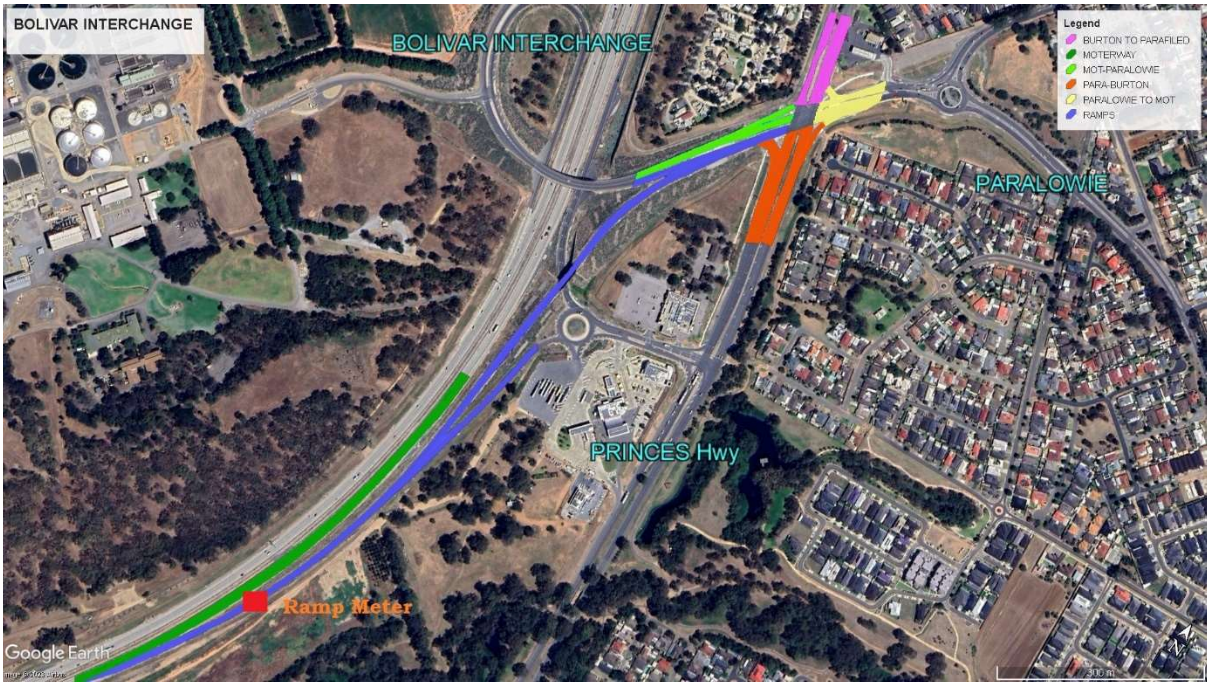


Figure 6 Showing the Study Area

Figure 6. Showing the Study Area

3.3 Data Collection

Traffic data serves as the basis for choices in transportation planning and policy, the gathering of traffic statistics for transportation is crucial. Governments must know how people move around their cities to make these decisions, and transportation research supplies this knowledge. Governments can use this information to improve transportation services and infrastructure, such as public transit systems and roads, by making more valuable decisions. Data collection on traffic and transportation is crucial for businesses across all sectors, not just the government.

By considering all above information for Bolivar Interchange is collected at peak and it was morning time. I have collected the data from 7 am to 9 am at all positions which are highlighted in figure 3 with different colours. This data is collected by recording the video at every point for 15 minutes and then it is predicted for one hour. Below are some glimpses that shows how data is collected.

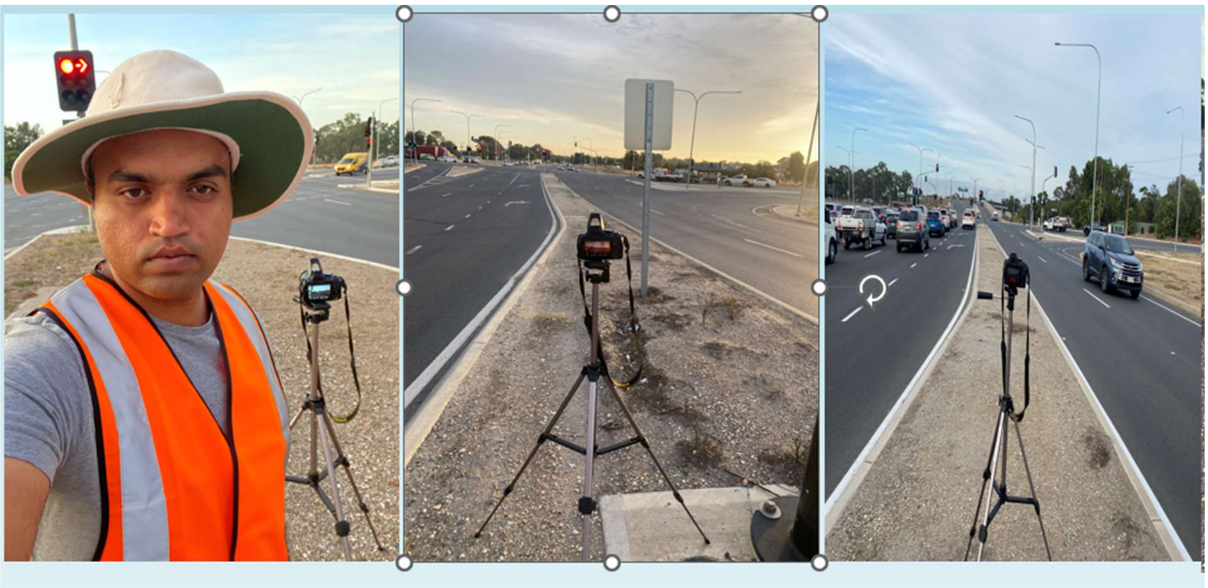


Figure 7 Showing the Data Collection Process

Figure 7. Showing the Data Collection Process

3.4 AIMSUN Model

The adopted approach for the Bolivar Interchange segment traffic event modelling in AIMSUN will be described in this part. Along with the model (Figure 4.) calibration and validation, the comprehensive process of ramp metering creation and traffic management methods utilising the AIMSUN model is explained, demonstrating the models.

Figure 8 Showing AIMSUN Model

Figure 8. Showing AIMSUN Model

3.5 OD Matrix and Validation

Three separate sets of data are frequently needed for traffic flow models: model input, model parameter, and model output(Barceló, 2005). Site data was used to develop an origin-destination (O-D) matrix that included demand data for the traffic simulation divided into light vehicles like cars (Figure 6.) and heavy vehicles trucks (Figure 7.) for the future model. The travel demand between centroids is represented by O-D demand. Additionally, to assess the outputs' accuracy, the output data was validated with observations made in the real world. Validation of model is very important so; GEH value should be less than 5 as in (figure 8.) that the GEH value validate the whole process because of it is within the range.

Table 0-1 Showing the OD Matrix for AIMSUN Model

Bolivar Interchange							
OD for CARS							
ID-NAME	4512	4515	4518	4521	4524	4527	Total
4512	0	0	0	0	0	820	820
4515	0	0	20	116	28	0	164
4518	0	6	0	96	172	18	292
4521	0	132	56	0	408	532	1128
4524	0	14	140	64	0	54	272
4527	640	0	0	0	0	0	640
4557	0	0	0	0	0	60	60
Total	640	152	216	276	608	1484	3376

Figure 9. Showing the OD Matrix for AIMSUN Model

Table 0-2 Showing the OD Matrix for AIMSUN Model

Bolivar Interchange							
OD for TRUCKS							
ID-NAME	**4512**	**4515**	**4518**	**4521**	**4524**	**4527**	**Total**
4512	0	0	0	0	0	272	**272**
4515	0	0	4	8	4	0	**16**
4518	0	4	0	12	116	16	**148**
4521	0	3	8	0	2	8	**21**
4524	0	7	96	12	0	25	**140**
4527	235	0	0	0	0	0	**235**
4557	0	0	0	0	0	4	**4**
Total	**235**	**14**	**108**	**32**	**122**	**325**	**836**

Figure 10. Showing the OD Matrix for AIMSUN Model

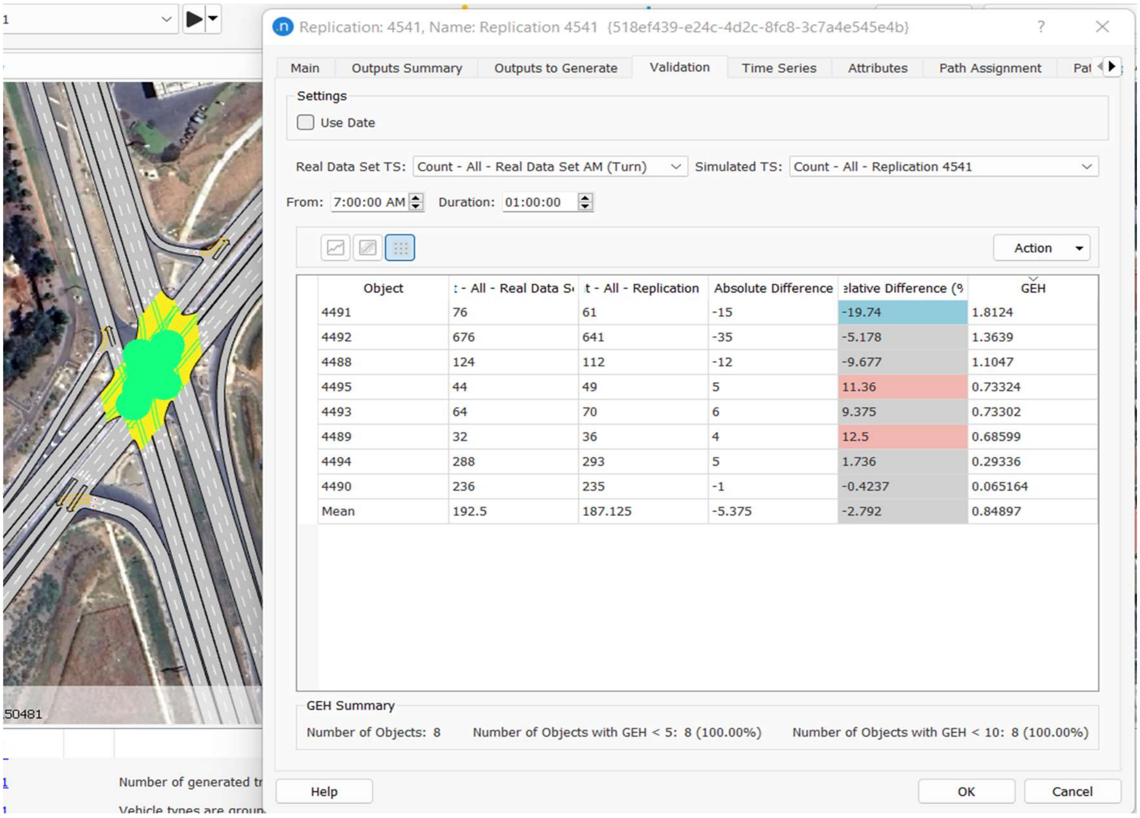


Figure 9 Showing the Calibration and Validation of Model

Figure 11. Showing the Calibration and Validation of Model

3.6 AIMSUN Modelling Scenarios

The scenario object determines what the main input and output objects are for a simulation. It specifies the traffic demand, transit plan, path assignment plan, master control plan, and real data set for validation. It also sets the level of simulation. It can also provide different geometrical configurations and traffic control plans. In this study six scenarios were developed to analyse the ramp metering affects below figure 9 shows the intended scenarios.

1-Existing model

2-Ramp Metering with variable green time

3-Future forecasting up to five years

4-Future forecasting up to ten years

5-Future forecasting up to 20 years

6-Improved model Including geometry of ramp

Figure 10 AIMSUN Modelling Scenarios

Figure 12. AIMSUN Modelling Scenarios

Chapter 4

Results

The outcomes of the AIMSUN microsimulation model are covered in this chapter. According to the amount of traffic on the ramp, the evaluation of the effect of ramp metering has been evaluated in terms of speed, queue length, and delay. Below figure 10 shows the overall data which is being presented in this chapter.

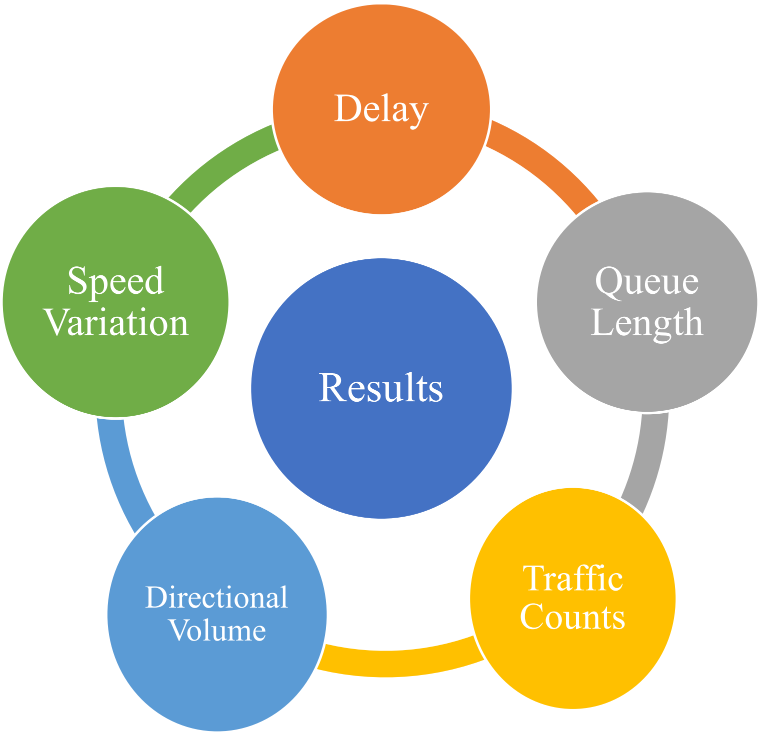


Figure 11 Showing the Results Layout

Figure 13. Showing the Results Layout

4.1 Traffic Counts and Directional Volume

Traffic counts data is collected from each side of the intersection all sides are given below :

1. Ramps and Motorway
2. Paralowie to Motorway
3. Parafield Garden to Burton

4. Burton To Parafield Garden
5. Motorway to Paralowie

As mentioned above, five locations are used to collect the traffic counts data figure 11 shows the entire picture of data. The data of other sites are presented in Appendix A; Figure 12 shows the directional volume of locations and the total volume of traffic vehicles.

Table 0-1 Represents the Vehicles Counts and Classifications

VEHICLE TURNING MOVEMENT SURVEY

BOLIVAR INTERCHANGE

RAMPS AND MOTORWAY

	RAMP LEFT								
15 min Ending	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume
8:50									
9:55	0	0	0	0	0	2	5	7	**28**
9:00	0	0	0	0	0	4	4	8	**32**
9:05	0	0	0	0	1	2	6	9	**36**
Total	**0**	**0**	**0**	**0**	**1**	**8**	**15**	**24**	**96**

	RAMP RIGHT								
15 min Ending	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume
8:50									
9:55	1	0	0	0	0	21	29	51	**204**
9:00	2	0	0	0	0	15	24	41	**164**
9:05	3	0	0	0	0	27	23	53	**212**
Total	**6**	**0**	**0**	**0**	**0**	**63**	**76**	**145**	**580**

	MOTORWAY THROUGH								
15 min Ending	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume
8:50									
9:55	18	1	5	0	0	53	77	154	**616**
9:00	14	0	6	3	1	56	65	145	**580**
9:05	16	3	3	2	0	46	63	133	**532**
Total	**48**	**4**	**14**	**5**	**1**	**155**	**205**	**432**	**1728**

Proposed Hourly Volume

Sr.No	RAMP LEFT			RAMP RIGHT			MOTORWAY THROUGH		
	Description	**Hourly Volume**	**%AGE**	**Description**	**Hourly Volume**	**%AGE**	**Description**	**Hourly Volume**	**%AGE**
1	RIGID	0	0%	RIGID	24	4%	RIGID	192	11%
2	BUS	0	0%	BUS	0	0%	BUS	16	1%
3	ARTICULATED	0	0%	ARTICULATED	0	0%	ARTICULATED	56	3%
4	B-DOUBLE	0	0%	B-DOUBLE	0	0%	B-DOUBLE	20	1%
5	ROAD TRAIN	4	4%	ROAD TRAIN	0	0%	ROAD TRAIN	4	0.23%
6	TOTAL CVs	32	33%	TOTAL CVs	252	43%	TOTAL CVs	620	36%
7	CAR	60	63%	CAR	304	52%	CAR	820	47%
	TOTAL	**96**	**100%**	TOTAL	**580**	**100%**	TOTAL	**1728**	**100%**

Figure 14. Represents the Vehicles Counts and Classifications

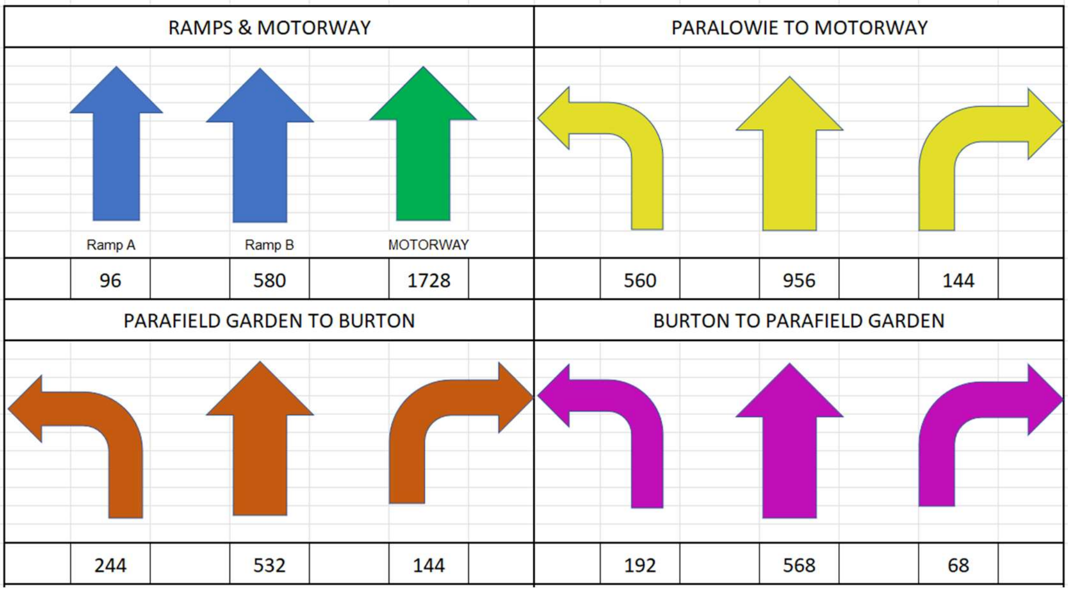
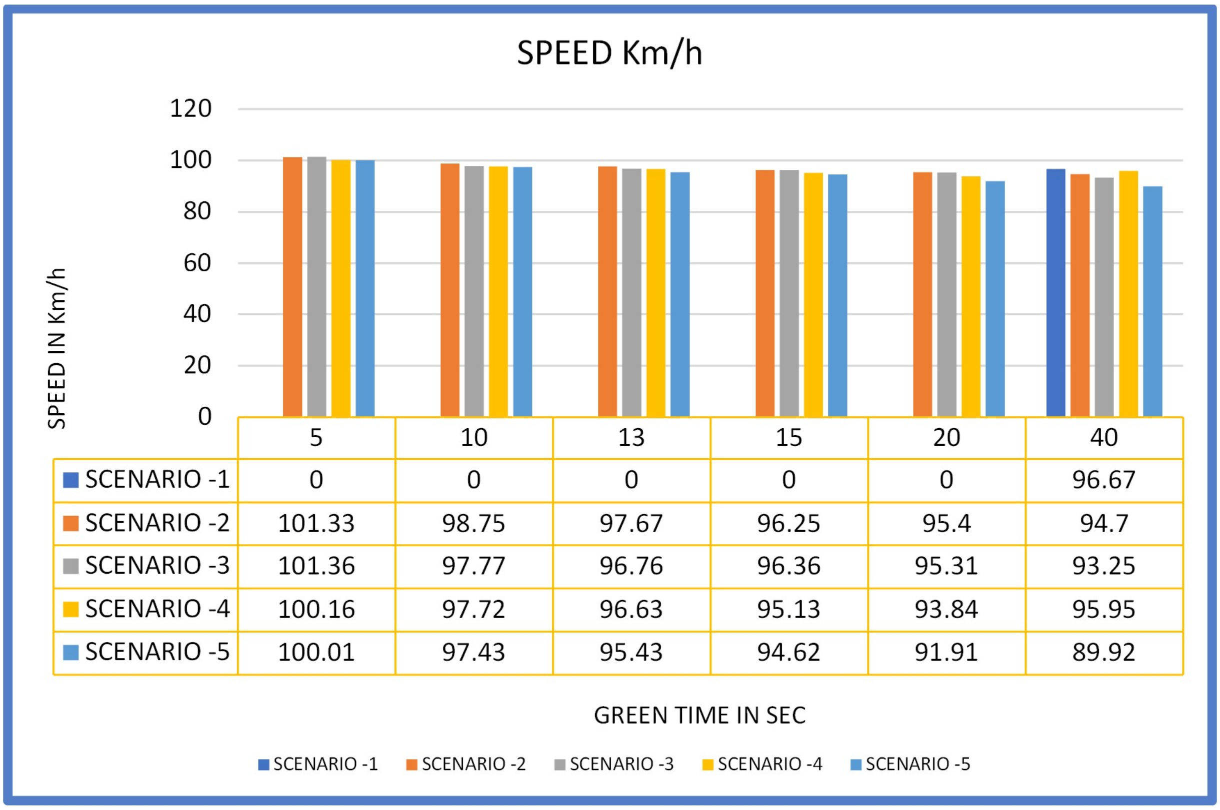


Figure 12 shows the Overall Traffic Volume

Figure 12. Shows the Overall Traffic Volume

4.2 Speed Variations

The current speed of the Motorway is 110 km/h; Figure 13 vertical axis shows the speed, and the horizontal axis shows the green time in seconds, which starts from 5 to 40 seconds. So overall, if we examine the graph, we can conclude that the current speed at merging is almost 94 km/h without the ramp metering. But as we apply the ramp metering trend, the more than 100 km/h speed increases. So, in conclusion, ram metering is mandatory at this location. Appendix B presents the simulation output.



	5	10	13	15	20	40
SCENARIO -1	0	0	0	0	0	96.67
SCENARIO -2	101.33	98.75	97.67	96.25	95.4	94.7
SCENARIO -3	101.36	97.77	96.76	96.36	95.31	93.25
SCENARIO -4	100.16	97.72	96.63	95.13	93.84	95.95
SCENARIO -5	100.01	97.43	95.43	94.62	91.91	89.92

Figure 13 Speed Variations

Figure 13. Speed Variations

4.3 Delay

Figure 14 shows the overall delay in seconds with metering. The horizontal axis shows the ramp metering in seconds which starts from 5 seconds to 40 seconds. But as we examine the graph, the delay increases as time starts from maximum to minimum, and it is expected as saturation on the ramp increases, the delay will also increase. Appendix C shows the comprehensive data related to software.

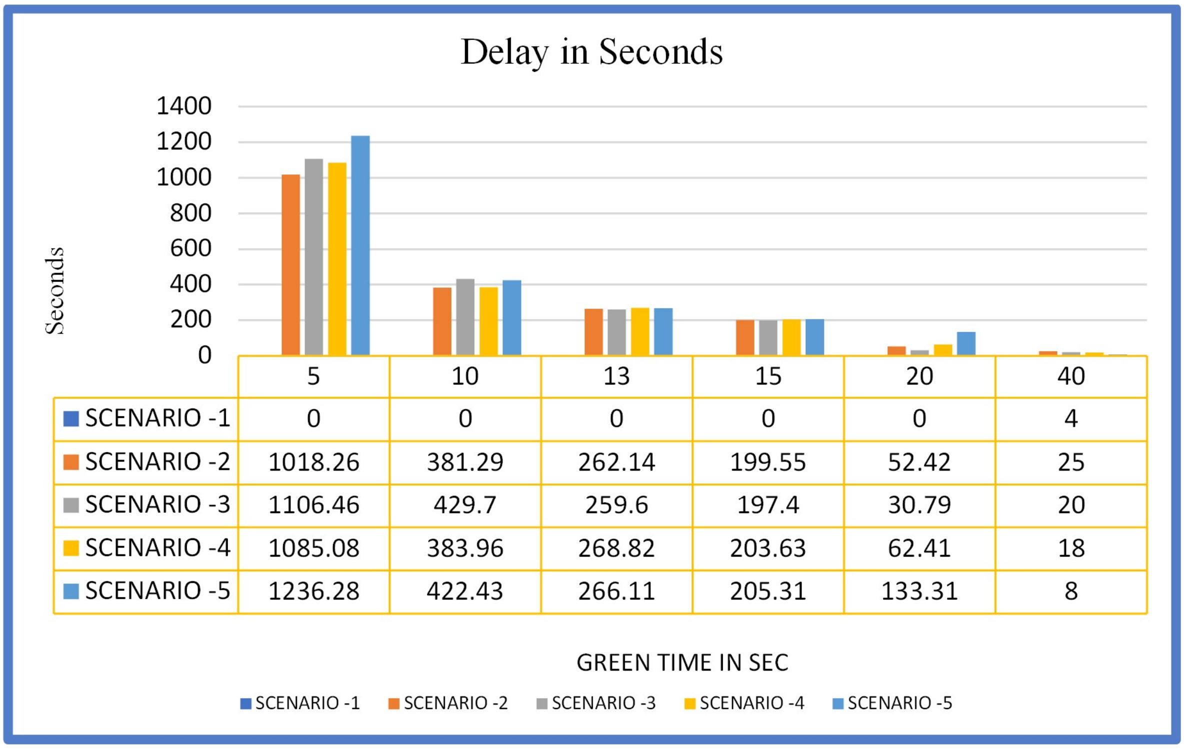
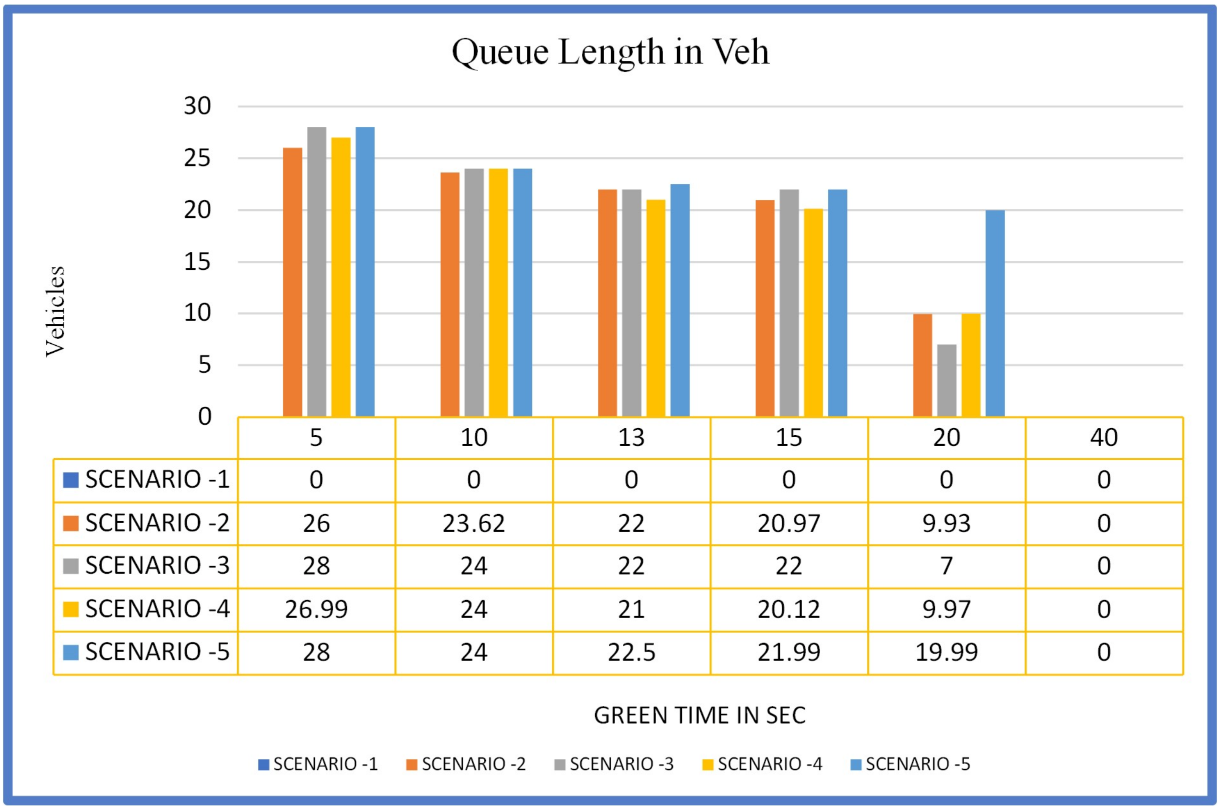


Figure 14 Shows the delay in seconds across the green time.

Figure 14. Shows the delay in seconds across the green time.

4.4 Queue Length

As we apply the ramp metering from 5 seconds to maximum, it is observed that the queue is also increasing, but on the other side, speed on the Motorway improved. So, in peak time, ramp metering is important, balancing the movement on-ramp and Motorway. So, the overall conclusions of this study are presented in the next chapter and simulation output from the software as evidenced in appendix D.



	5	10	13	15	20	40
SCENARIO -1	0	0	0	0	0	0
SCENARIO -2	26	23.62	22	20.97	9.93	0
SCENARIO -3	28	24	22	22	7	0
SCENARIO -4	26.99	24	21	20.12	9.97	0
SCENARIO -5	28	24	22.5	21.99	19.99	0

Figure 15 Shows the Queue Length

Figure 15. Shows the Queue Length

Chapter 5

Discussion

This chapter evaluates the results of the microsimulation, geometry improvement, specifically at merging to the freeway, and ramp modelling from ramp metering scenarios for morning peak (AM) in Bolivar interchange are discussed. The conclusions are drawn based on performance indicators for the road's suitability, such as travel time, queue length, and delay. Additionally, an argument is made for the usefulness and importance of ramp metering in this study.

Ramp metering impacts on freeway ramp performance indicator:

I. Travel time
II. Travel speed
III. Freeway capacity
IV. Accident rate
V. Fuel Consumption
VI. Emission

According to the literature, ramp metering has several advantages, including faster motorway speeds, shorter travel times, fewer delays, increased motorway capacity and throughput, fewer accidents and improved safety, fewer traffic jams, cost-effectiveness, lower emissions and better air quality, lower fuel use and fuel economy, and efficient capacity use.

5.1 Speed improvements

The most frequently mentioned advantage of ramp metering is improved flow on the motorway, as demonstrated by an increase in speeds, a decrease in travel time, or a reduction in delay. Ramp metering regulates traffic demand to prevent forced flow situations from emerging and motorway capacity from being exceeded.

5.2 Reductions in Accidents

An increase in safety, mostly because of fewer accidents in merging zones, is another significant advantage of ramp metering. The fact that accidents don't disrupt traffic as frequently is another advantage of increased safety.

5.3 Congestion Reduction

By controlling traffic demand, enhancing merging effectiveness, and lowering accidents, ramp metering eases congestion. In other words, metering causes some motorway demand to be transferred to less crowded routes and/or times of the day. Effective merging prevents traffic jams and ensures a smooth flow of traffic by preventing many vehicles from trying to merge at once. Effective merging also reduces accidents, which frequently result in heavy traffic congestion.

5.4 Cost Effective

The ramp metering system will continue to be one of most valuable products given the high cost of accidents in terms of property damage, medical and legal expenses, and lost productivity due to congestion.

5.5 Improved Air Quality

Certain vehicle emissions are reduced by improved traffic flow, particularly when stop-and-go situations are minimised.

5.6 Efficient Use of Capacity

Ramp metering promotes the more effective utilisation of available highway capacity. If nearby local streets have spare capacity, it could be beneficial to shift traffic from jam-packed motorways to these local streets to discourage trip patterns with high societal costs. If there is a quick and easy alternative to a jam-packed motorway, drivers should be urged to use it.

5.7 Research Implications

The main goal of this research is to ascertain the impact of ramp metering and to identify potential measures for smooth traffic flow in the northern connector. An investigation has been conducted to ascertain the impacts of ramp metering on motorway ramps and the use of variable green time to reduce the negative effects of unexpected vehicle breakdowns and collisions.

This study offers an emphasis how adding ITS to an existing road network influences how pedestrians and other road users move around. This study is expected to help with the implementation of ramp metering management strategies in motorways to reduce traffic, for optimal planning and operation of motorway network during incident occurrence.

Chapter 6

Conclusion

A ramp metre is a traffic light on an on-ramp to a motorway that controls the flow of traffic onto the motorway. Theoretically, a car is given a green light and permitted to enter the freeway's traffic flow smoothly by taking advantage of any gaps in the mainline traffic.

So, a platoon of cars fighting for the available spaces does not cause a bottleneck, turbulence, or delay. The bottleneck and delay are really transferred to the on-ramp, but the motorway flow is optimised, and the corridor flow is generally better. A metre may be pre-timed, allowing cars to enter every few seconds, or it may be traffic-responsive, watching for available gaps in motorway traffic and line-ups at ramps. Thus, it is crucial to handle ramp management if you want to keep the infrastructure functional and ensure the safety and comfort of other road users. The findings of this study are given below:

Ramp metering is a motorway traffic management approach that boosts speeds (therefore reducing travel times and delays), enhances safety, boosts fuel efficiency and air quality, lessens congestion, and generally results in a more effective use of the current highway infrastructure. The motorway mainline is most affected by these advantages.

Ramp metering raises concerns of equality regarding access to and use of the motorway system and prolongs ramp delays (raising vehicle emissions and fuel consumption). It may also cause vehicle spillback and divert traffic onto the neighbourhood street network.

Many of the detrimental effects of ramp metering are based purely on intuition and lack empirical evidence. The outcomes of field assessments disprove some of the putative harmful effects. With the right planning, design, and promotion, many of the negative effects can be reduced.

When considering the installation of ramp metering, there are a number of additional difficulties that should be taken into account and planned for, the majority of which were at least stated. These consist of:

- Acceptance by public
- Equity
- Public Relations efforts
- Enforcement
- Funding
- System design
- System maintenance

Data shows that ramp metering is necessary at Bolivar interchange it will maintain the motorway speed and make sure safety concerns for merging traffic. I have tried the different green time which range from (5-20) seconds but in my recommendation is it should be between (5-10) seconds is adequate time.

For considering the future performance it is recommended an auxiliary lane for merging traffic to balance the delay on ramp and reduce the emission as well.

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Appendix A

Table 0-1 Demonstrate the Traffic Counts

VEHICLE TURNING MOVEMENT SURVEY

BOLIVAR INTERCHANGE

RAMPS AND MOTORWAY

15 min Ending	RAMP LEFT								
	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume
8:50									
9:55	0	0	0	0	0	2	5	7	28
9:00	0	0	0	0	0	4	4	8	32
9:05	0	0	0	0	1	2	6	9	36
Total	0	0	0	0	1	8	15	24	96

15 min Ending	RAMP RIGHT								
	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume
8:50									
9:55	1	0	0	0	0	21	29	51	204
9:00	2	0	0	0	0	15	24	41	164
9:05	3	0	0	0	0	27	23	53	212
Total	6	0	0	0	0	63	76	145	580

15 min Ending	MOTORWAY THROUGH								
	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume
8:50									
9:55	18	1	5	0	0	53	77	154	616
9:00	14	0	6	3	1	56	65	145	580
9:05	16	3	3	2	0	46	63	133	532
Total	48	4	14	5	1	155	205	432	1728

Proposed Hourly Volume

Sr.No	RAMP LEFT			RAMP RIGHT			MOTORWAY THROUGH		
	Description	Hourly Volume	%AGE	Description	Hourly Volume	%AGE	Description	Hourly Volume	%AGE
1	RIGID	0	0%	RIGID	24	4%	RIGID	192	11%
2	BUS	0	0%	BUS	0	0%	BUS	16	1%
3	ARTICULATED	0	0%	ARTICULATED	0	0%	ARTICULATED	56	3%
4	B-DOUBLE	0	0%	B-DOUBLE	0	0%	B-DOUBLE	20	1%
5	ROAD TRAIN	4	4%	ROAD TRAIN	0	0%	ROAD TRAIN	4	0.23%
6	TOTAL CVs	32	33%	TOTAL CVs	252	43%	TOTAL CVs	620	36%
7	CAR	60	63%	CAR	304	52%	CAR	820	47%
	TOTAL	96	100%	TOTAL	580	100%	TOTAL	1728	100%

Table 2. Demonstrate the Traffic Counts

Table 0-2 Shows the Traffic Counts

VEHICLE TURNING MOVEMENT SURVEY

BOLIVAR INTERCHANGE

PARALOWIE TO MOTORWAY

15 min Ending	LEFT TURN								
	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume
7:45									
7:50	0	0	0	0	0	13	34	47	188
7:55	0	0	0	0	0	11	38	49	196
8:00	0	0	0	0	0	14	30	44	176
Total	0	0	0	0	0	38	102	140	560

15 min Ending	THROUGH								
	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume
7:45									
7:50	1	0	0	0	0	41	71	113	452
7:55	0	0	0	0	0	29	46	75	300
8:00	2	0	0	0	0	0	49	51	204
Total	3	0	0	0	0	70	166	239	956

15 min Ending	RIGHT TURN								
	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume
7:45									
7:50	0	0	0	0	0	8	7	15	60
7:55	1	0	0	0	0	5	3	9	36
8:00	1	0	0	0	0	7	4	12	48
Total	2	0	0	0	0	20	14	36	144

Proposed Hourly Volume

Sr.No	LEFT TURN			THROUGH			RIGHT TURN		
	Description	Hourly Volume	%AGE	Description	Hourly Volume	%AGE	Description	Hourly Volume	%AGE
1	RIGID	0	0%	RIGID	12	1%	RIGID	8	6%
2	BUS	0	0%	BUS	0	0%	BUS	0	0%
3	ARTICULATED	0	0%	ARTICULATED	0	0%	ARTICULATED	0	0%
4	B-DOUBLE	0	0%	B-DOUBLE	0	0%	B-DOUBLE	0	0%
5	ROAD TRAIN	0	0%	ROAD TRAIN	0	0%	ROAD TRAIN	0	0%
6	TOTAL CVs	152	27%	TOTAL CVs	280	29%	TOTAL CVs	80	56%
7	CAR	408	73%	CAR	664	69%	CAR	56	39%
	TOTAL	560	100%	TOTAL	956	100%	TOTAL	144	100%

Table 3. Shows the Traffic Counts

Table 0-3 Shows the traffic counts.

VEHICLE TURNING MOVEMENT SURVEY

BOLIVAR INTERCHANGE

PARAFIELD GARDEN TO BURTON

	LEFT TURN									THROUGH									RIGHT TURN								
15 min Ending	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume
7:20																											
7:25	2	0	0	2	0	10	3	17	**68**	6	0	0	0	0	24	15	45	**180**	2	0	0	0	0	4	0	6	**24**
7:30	2	0	0	0	0	13	6	21	**84**	7	0	0	2	0	33	11	53	**212**	0	0	0	0	0	8	4	12	**48**
7:35	1	0	0	1	0	13	8	23	**92**	9	0	0	0	0	17	9	35	**140**	1	1	0	0	0	4	12	18	**72**
Total	**5**	**0**	**0**	**3**	**0**	**36**	**17**	**61**	**244**	**22**	**0**	**0**	**2**	**0**	**74**	**35**	**133**	**532**	**3**	**1**	**0**	**0**	**0**	**16**	**16**	**36**	**144**

Proposed Hourly Volume

Sr.No	LEFT TURN			THROUGH			RIGHT TURN		
	Description	Hourly Volume	%AGE	Description	Hourly Volume	%AGE	Description	Hourly Volume	%AGE
1	RIGID	20	8%	RIGID	88	17%	RIGID	12	8%
2	BUS	0	0%	BUS	0	0%	BUS	4	3%
3	ARTICULATED	0	0%	ARTICULATED	0	0%	ARTICULATED	0	0%
4	B-DOUBLE	12	5%	B-DOUBLE	8	2%	B-DOUBLE	0	0%
5	ROAD TRAIN	0	0%	ROAD TRAIN	0	0%	ROAD TRAIN	0	0%
6	TOTAL CVs	144	59%	TOTAL CVs	296	56%	TOTAL CVs	64	44%
7	CAR	68	28%	CAR	140	26%	CAR	64	44%
	TOTAL	**244**	**100%**	**TOTAL**	**532**	**100%**	**TOTAL**	**144**	**100%**

Table 3. Shows the traffic counts.

Table 0-4 Traffic counts

VEHICLE TURNING MOVEMENT SURVEY

BOLIVAR INTERCHANGE

BURTON TO PARAFIELD GARDEN

	LEFT TURN									THROUGH									RIGHT TURN								
15 min Ending	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume
8:50																											
9:55	1	0	0	0	0	6	7	14	**56**	7	0	0	3	0	20	9	39	**156**	1	0	0	0	0	3	2	6	**24**
9:00	1	0	0	0	0	0	5	6	**24**	5	0	0	0	0	16	13	34	**136**	0	0	0	0	0	1	3	4	**16**
9:05	1	0	0	0	0	15	12	28	**112**	14	0	0	0	0	34	21	69	**276**	4	0	0	0	0	2	1	7	**28**
Total	**3**	**0**	**0**	**0**	**0**	**21**	**24**	**48**	**192**	**26**	**0**	**0**	**3**	**0**	**70**	**43**	**142**	**568**	**5**	**0**	**0**	**0**	**0**	**6**	**6**	**17**	**68**

Proposed Hourly Volume

Sr.No	LEFT TURN			THROUGH			RIGHT TURN		
	Description	Hourly Volume	%AGE	Description	Hourly Volume	%AGE	Description	Hourly Volume	%AGE
1	RIGID	12	6%	RIGID	104	18%	RIGID	20	29%
2	BUS	0	0%	BUS	0	0%	BUS	0	0%
3	ARTICULATED	0	0%	ARTICULATED	0	0%	ARTICULATED	0	0%
4	B-DOUBLE	0	0%	B-DOUBLE	12	0%	B-DOUBLE	0	0%
5	ROAD TRAIN	0	0%	ROAD TRAIN	0	0%	ROAD TRAIN	0	0%
6	TOTAL CVs	84	44%	TOTAL CVs	280	49%	TOTAL CVs	24	35%
7	CAR	96	50%	CAR	172	30%	CAR	24	35%
	TOTAL	**192**	**100%**	**TOTAL**	**568**	**100%**	**TOTAL**	**68**	**100%**

Table 4. Traffic counts

Table 0-5 shows the traffic counts with Classifications

VEHICLE TURNING MOVEMENT SURVEY																											
BOLIVAR INTERCHANGE																											
MOTORWAY TO PARALOWIE																											
	LEFT TURN									THROUGH									RIGHT TURN								
15 min Ending	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume	RIGID	BUS	ARTICULATED	B-DOUBLE	ROAD TRAIN	TOTAL CVs	CAR	Total Vehicles	Proposed volume
8:35																											
8:40	0	0	0	0	0	4	1	5	**20**	0	0	0	0	0	4	13	17	**68**	0	0	0	0	0	0	3	3	**12**
8:45	0	0	0	0	0	0	1	1	**4**	0	0	0	0	0	9	10	19	**76**	1	0	0	0	0	0	1	2	**8**
8:50	1	0	0	0	0	1	3	5	**20**	2	0	0	0	0	5	6	13	**52**	0	0	0	0	0	2	3	5	**20**
Total	**1**	**0**	**0**	**0**	**0**	**5**	**5**	**11**	**44**	**2**	**0**	**0**	**0**	**0**	**18**	**29**	**49**	**196**	**1**	**0**	**0**	**0**	**0**	**2**	**7**	**10**	**40**

Proposed Hourly Volume									
Sr.No	LEFT TURN			THROUGH			RIGHT TURN		
	Description	Hourly Volume	%AGE	Description	Hourly Volume	%AGE	Description	Hourly Volume	%AGE
1	RIGID	4	9%	RIGID	8	4%	RIGID	4	10%
2	BUS	0	0%	BUS	0	0%	BUS	0	0%
3	ARTICULATED	0	0%	ARTICULATED	0	0%	ARTICULATED	0	0%
4	B-DOUBLE	0	0%	B-DOUBLE	0	0%	B-DOUBLE	0	0%
5	ROAD TRAIN	0	0%	ROAD TRAIN	0	0%	ROAD TRAIN	0	0%
6	TOTAL CVs	20	45%	TOTAL CVs	72	37%	TOTAL CVs	8	20%
7	CAR	20	45%	CAR	116	59%	CAR	28	70%
	TOTAL	**44**	**100%**	**TOTAL**	**196**	**100%**	**TOTAL**	**40**	**100%**

Table 5. shows the traffic counts with Classifications.

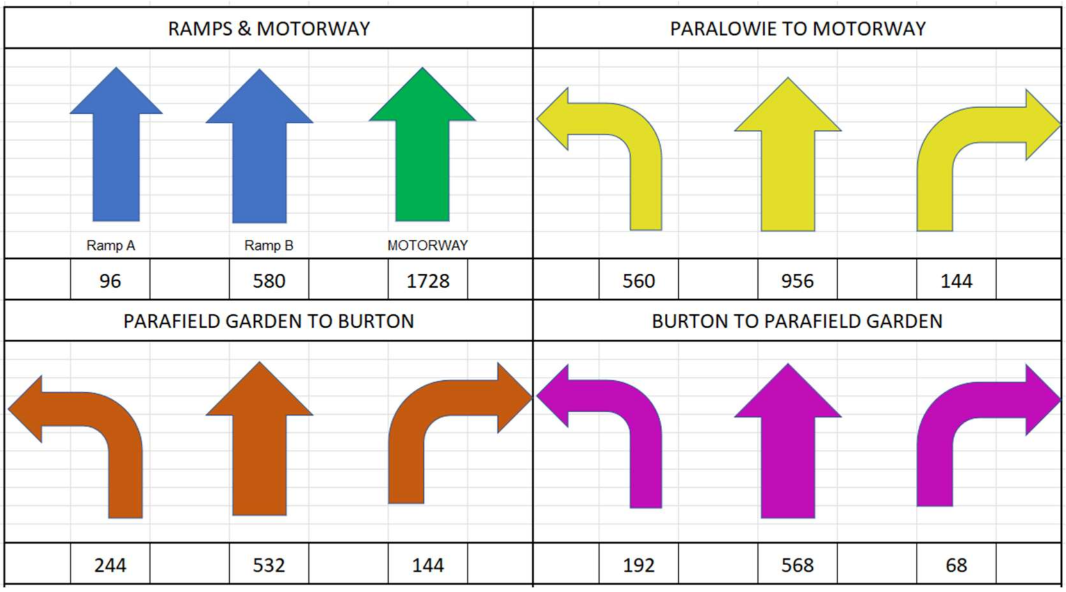

Figure 16 shows the Directional Volume

Figure 16. Shows the Directional Volume

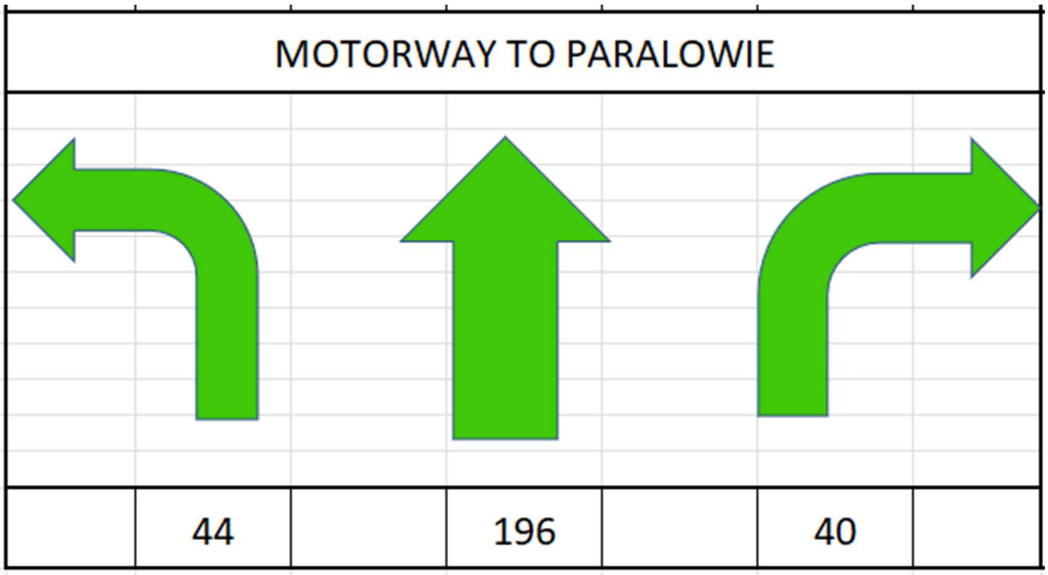

Figure 17 Shows the Directional Volume

Figure 17. Shows the Directional Volume

Table 0-6 AIMSUN Analysis Results for Scenario 1 & 2

BOLIVAR INTERCHANGE RAMP METERING										
AIMSUN SCENARIOS										
RAMP METERING EXISTING SCENARIO - 1										
SR.NO	GREEN TIME SECONDS		MOTORWAY SPEED Km/h			QUEUE LENGTH (VEH)		DELAY TIME (SEC)		REMARKS
	GREEN TIME RANGE SECONDS	GREEN TIME	MOTORWAY SPEED Km/h	AVERAGE SPEED Km/h	MAXIMUM SPEED Km/h	AVE. QUEUE LENGTH (VEH)	MAX. QUEUE LENGTH (VEH)	AVE.DELAY (SEC)	MAX.DELAY (SEC)	
1	40	40	110	93.94	96.67	-	-	1.07	1.5	
RAMP METERING SCENARIO - 2										
SR.NO	GREEN TIME SECONDS		MOTORWAY SPEED Km/h			QUEUE LENGTH (VEH)		DELAY TIME (SEC)		REMARKS
	GREEN TIME RANGE SECONDS	GREEN TIME SECONDS	MOTORWAY SPEED Km/h	AVERAGE SPEED Km/h	MAXIMUM SPEED Km/h	AVE. QUEUE LENGTH (VEH)	MAX. QUEUE LENGTH (VEH)	AVE.DELAY (SEC)	MAX.DELAY (SEC)	
1	40	5	110	99.72	101.33	24	26	764.35	1018.26	
2	40	10	110	97.36	98.75	21.85	23.62	313.81	381.29	
	40	13	110	95.46	97.67	20.32	22	218.71	262.14	
3	40	15	110	94.32	96.25	12.77	20.97	81.01	199.55	
4	40	20	110	93.06	95.4	6	9.93	23.47	52.42	

Table 6. AIMSUN Analysis Results for Scenario 1 & 2

Table 0-7 AIMSUN Analysis Results for Scenario 3

BOLIVAR INTERCHANGE RAMP METERING										
FUTURE FORECASTING UPTO FIVE YEARS SCENARIO - 3										
SR.NO	GREEN TIME SECONDS		MOTORWAY SPEED Km/h			QUEUE LENGTH (VEH)		DELAY TIME (SEC)		REMARKS
	GREEN TIME RANGE SECONDS	GREEN TIME SECONDS	MOTORWAY SPEED Km/h	AVERAGE SPEED Km/h	MAXIMUM SPEED Km/h	AVE. QUEUE LENGTH (VEH)	MAX. QUEUE LENGTH (VEH)	AVE.DELAY (SEC)	MAX.DELAY (SEC)	
1	40	40	110	93.15	95.31	-	-	1.2	1.6	
2	40	5	110	99.79	101.36	25	28	780.4	1106.46	
3	40	10	110	96.97	97.77	22	24	330.62	429.7	
4	40	13	110	95.59	96.76	20	22	212	259.6	
5	40	15	110	93.51	96	18.35	22	153.85	197.4	
6	40	20	110	92.79	95.31	5.82	7	23.26	30.79	

Table 7. AIMSUN Analysis Results for Scenario 3

Table 0-8 AIMSUN Analysis Results for Scenario - 4

BOLIVAR INTERCHANGE RAMP METERING										
FUTURE FORECASTING UPTO TEN YEARS SCENARIO - 4										
SR.NO	GREEN TIME SECONDS		MOTORWAY SPEED Km/h			QUEUE LENGTH (VEH)		DELAY TIME (SEC)		REMARKS
	GREEN TIME RANGE SECONDS	GREEN TIME SECONDS	MOTORWAY SPEED Km/h	AVERAGE SPEED Km/h	MAXIMUM SPEED Km/h	AVE. QUEUE LENGTH (VEH)	MAX. QUEUE LENGTH (VEH)	AVE.DELAY (SEC)	MAX.DELAY (SEC)	
1	40	40	110	93.48	95.95	-	-	1.07	1.25	
2	40	5	110	99.34	100.16	24.46	26.99	759.02	1085.08	
3	40	10	110	96.96	97.72	22.17	24	326.5	383.96	
4	40	13	110	95.05	96.63	20.63	21	219.62	268.82	
5	40	15	110	93.41	95.13	18.84	20.12	162.63	203.63	
6	40	20	110	92.31	93.84	7.17	9.97	38.45	62.41	

Table 8. AIMSUN Analysis Results for Scenario - 4

Table 0-9 AIMSUN Analysis Results for Scenario – 5

BOLIVAR INTERCHANGE RAMP METERING										
FUTURE FORECASTING UPTO 20 YEARS SCENARIO - 5										
SR.NO	GREEN TIME SECONDS		MOTORWAY SPEED Km/h			QUEUE LENGTH (VEH)		DELAY TIME (SEC)		REMARKS
	GREEN TIME RANGE SECONDS	GREEN TIME SECONDS	MOTORWAY SPEED Km/h	AVERAGE SPEED Km/h	MAXIMUM SPEED Km/h	AVE. QUEUE LENGTH (VEH)	MAX. QUEUE LENGTH (VEH)	AVE.DELAY (SEC)	MAX.DELAY (SEC)	
1	40	40	110	89.92	91.84	-	-	0.48	0.536	
2	40	5	110	99.43	100.01	26.5	28	821.95	1236.28	
3	40	10	110	96.62	97.43	22.33	24	334.8	422.43	
4	40	13	110	94.36	95.43	20	22.5	228.5	266.11	
5	40	15	110	93.61	94.62	20.5	21.99	176.56	205.31	
6	40	20	110	90.74	91.91	17.83	19.99	106.58	133.31	

Table 9. AIMSUN Analysis Results for Scenario – 5

Appendix B

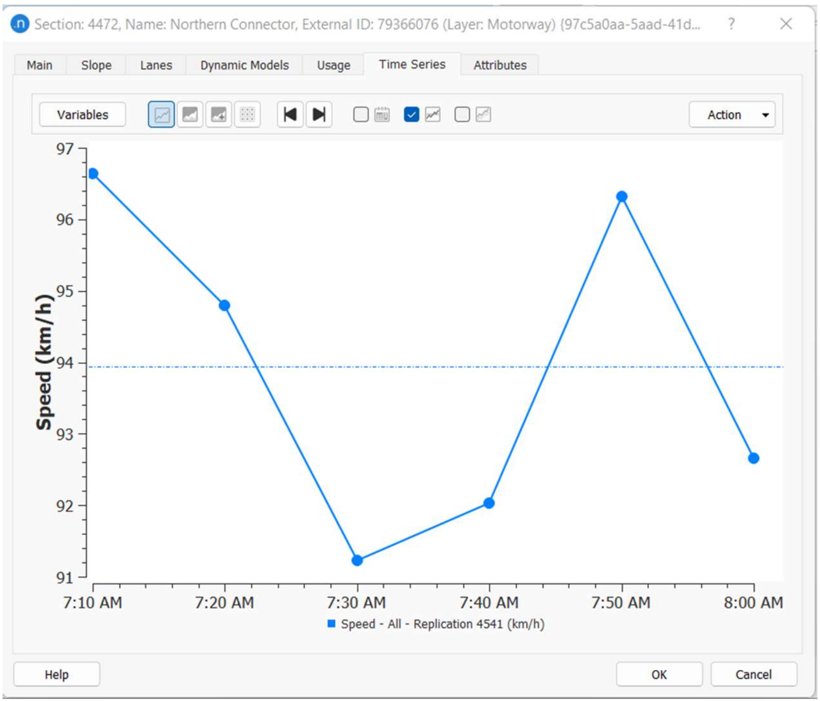

Figure 18 AIMSUN Speed Analysis

Figure 18. AIMSUN Speed Analysis

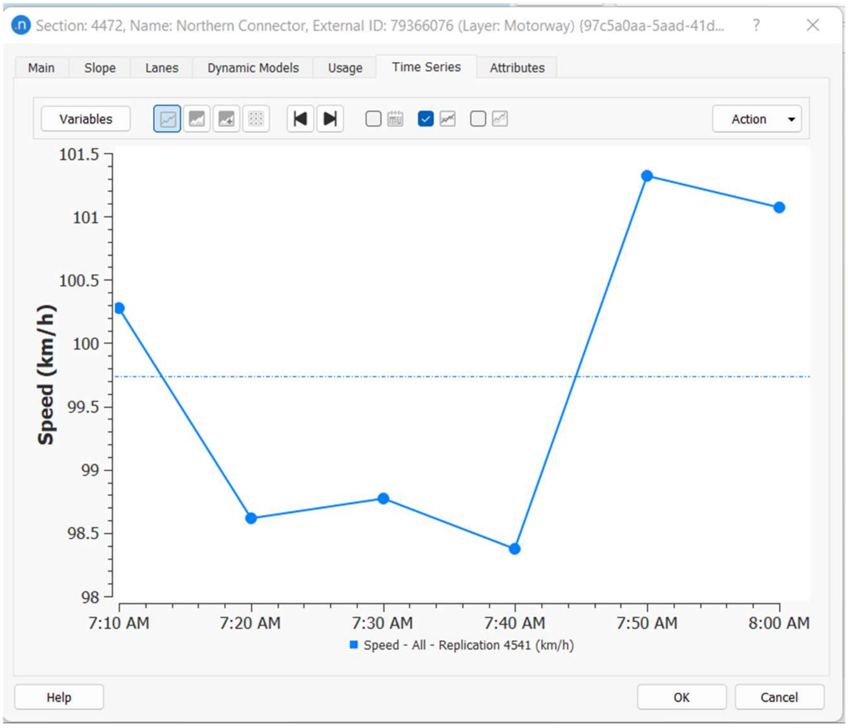

Figure 19 AIMSUN Speed Analysis

Figure 19. AIMSUN Speed Analysis

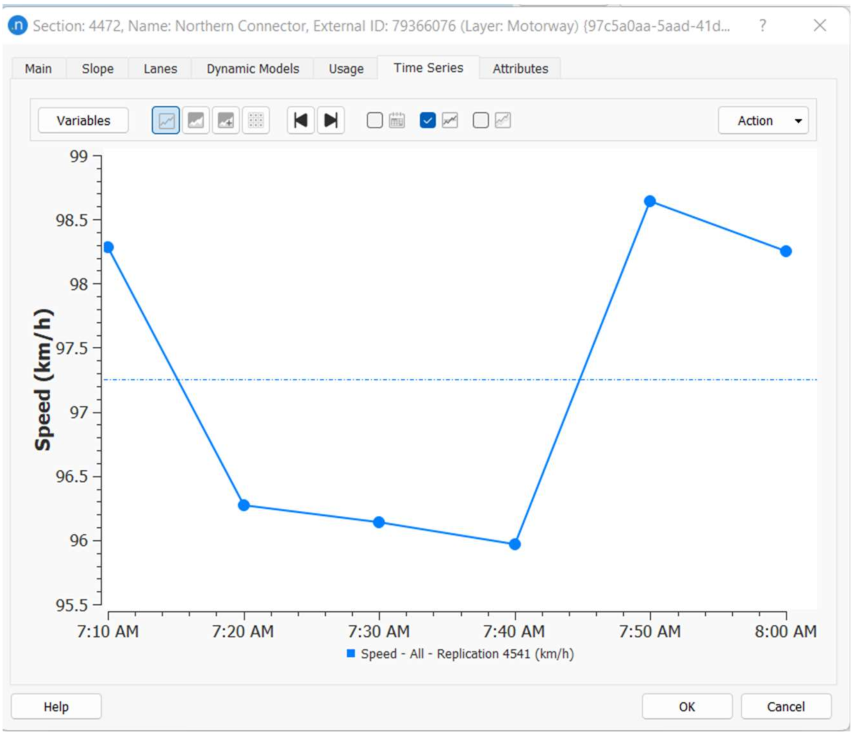

Figure 20 AIMSUN Speed Analysis

Figure 20. AIMSUN Speed Analysis

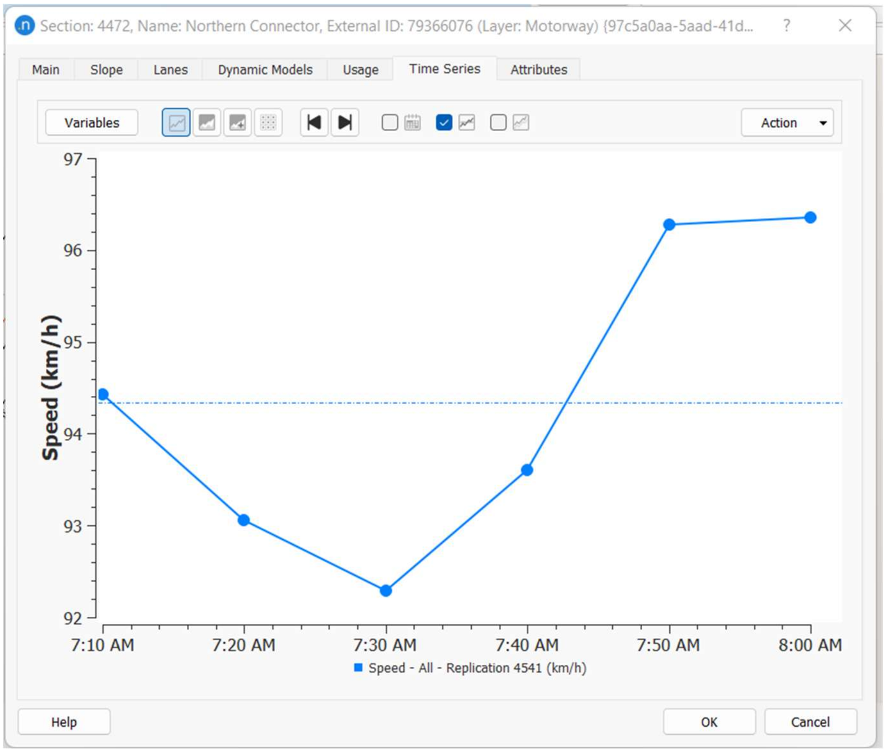

Figure 21 AIMSUN Speed Analysis

Figure 21. AIMSUN Speed Analysis

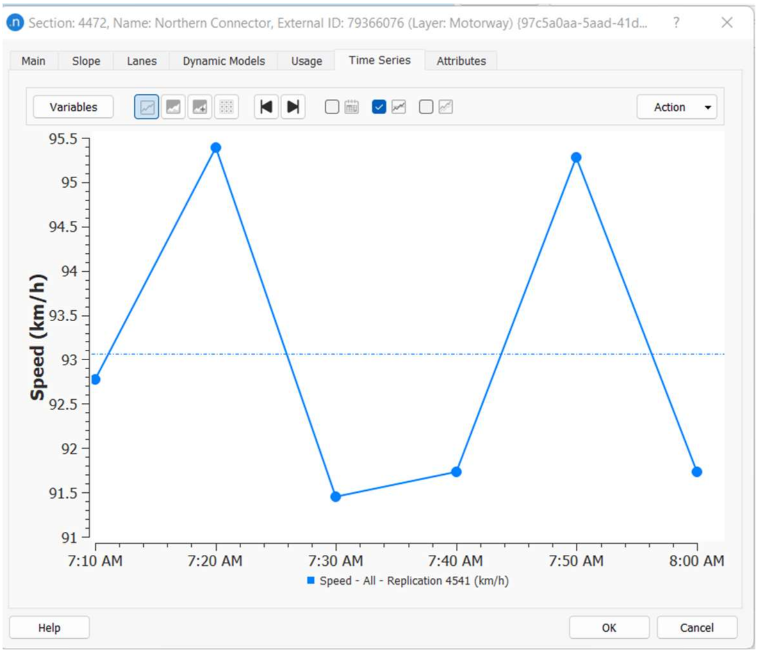

Figure 22 AIMSUN Speed Analysis

Figure 22. AIMSUN Speed Analysis

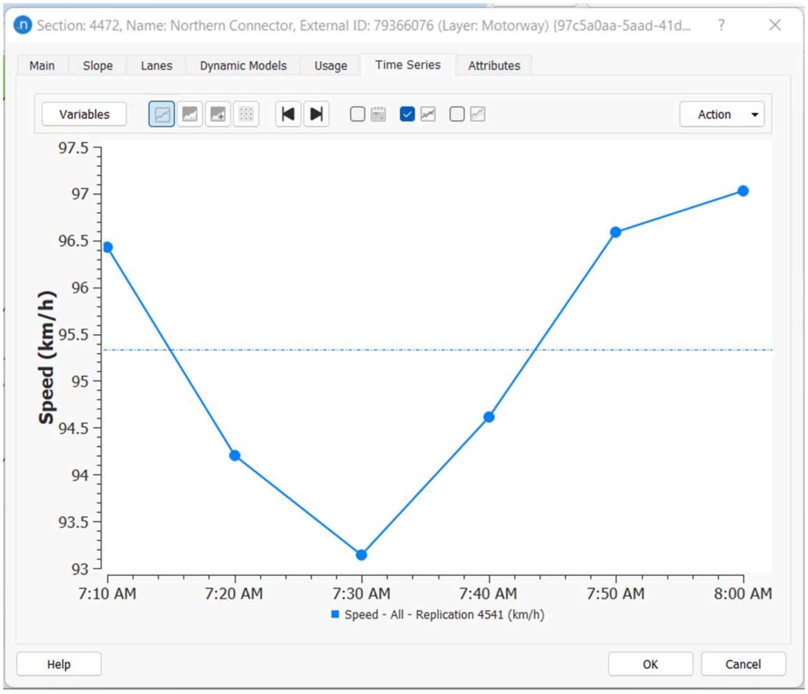

Figure 23 AIMSUN Speed Analysis

Figure 23. AIMSUN Speed Analysis

Appendix C AIMSUN Delay Analysis

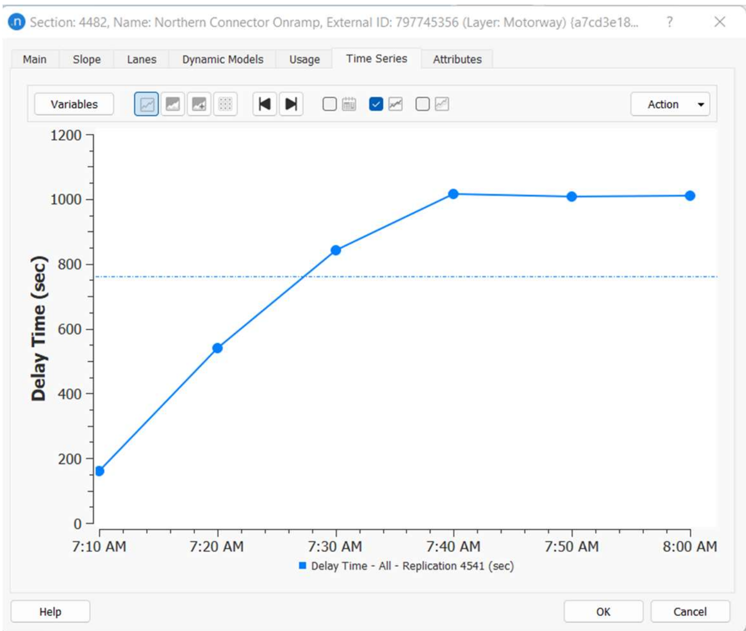

Figure 24 AIMSUN Delay Analysis

Figure 24. AIMSUN Delay Analysis

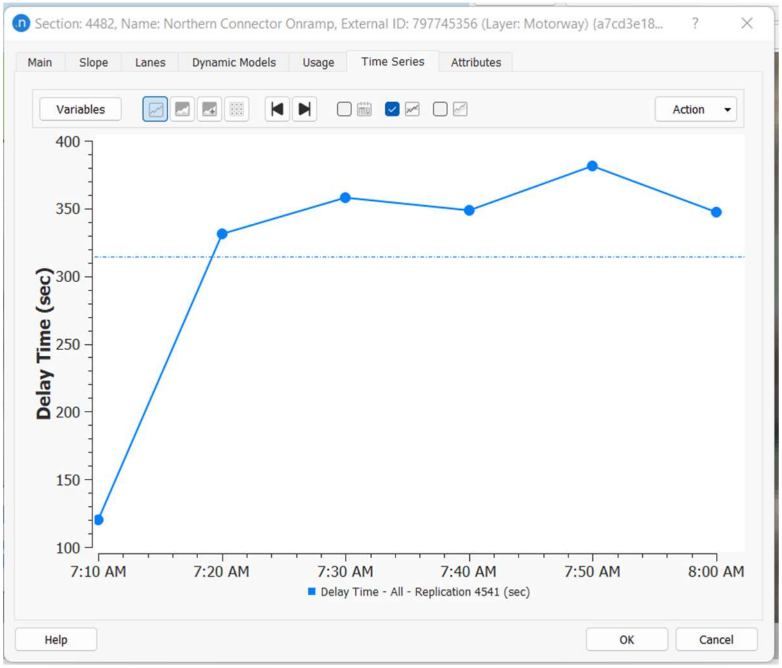

Figure 25 AIMSUN Delay Analysis

Figure 25. AIMSUN Delay Analysis

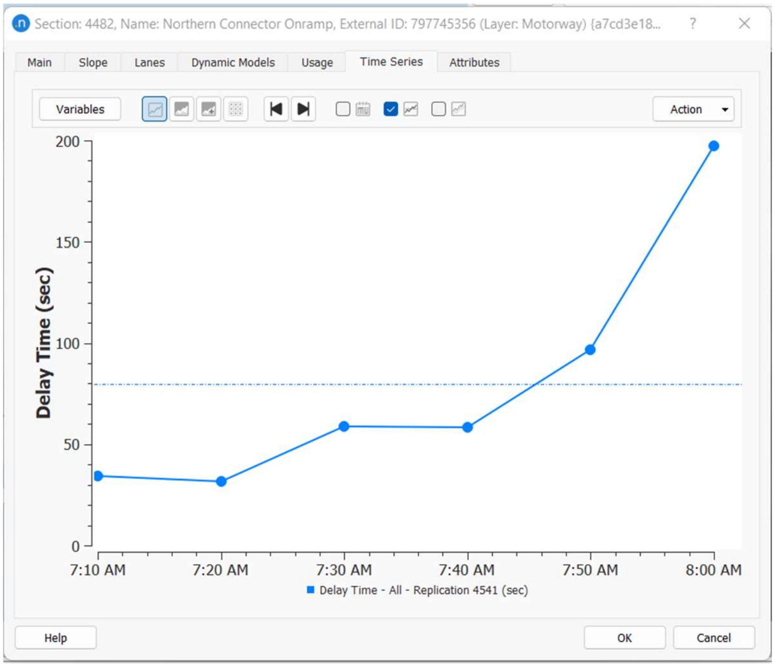

Figure 26 AIMSUN Delay Analysis

Figure 26. AIMSUN Delay Analysis

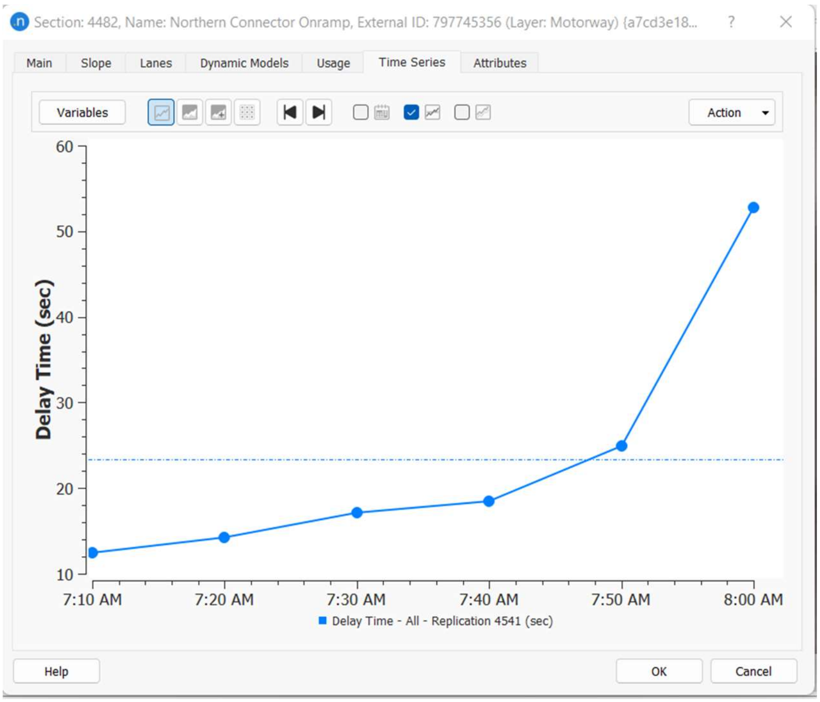

Figure 27 AIMSUN Delay Analysis

Figure 27. AIMSUN Delay Analysis

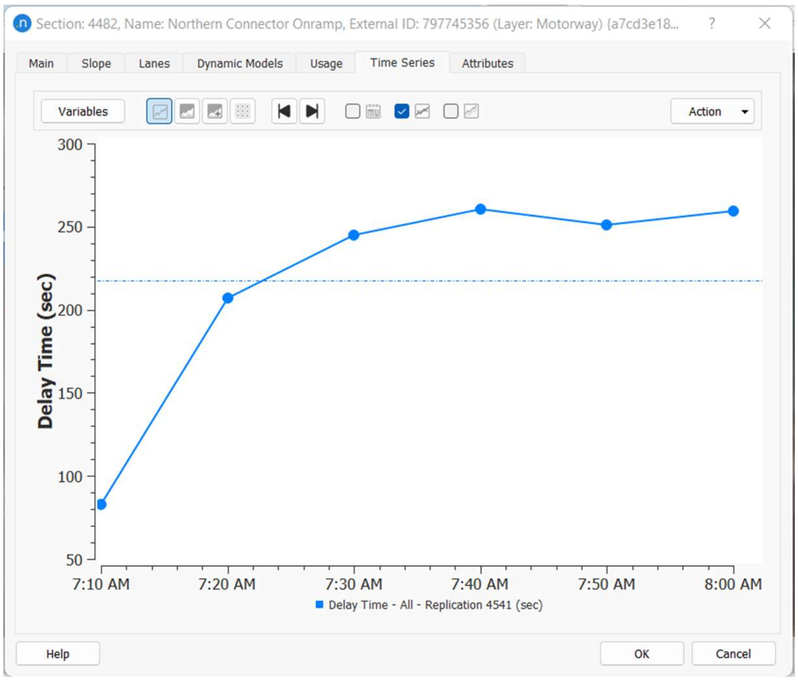

Figure 28 AIMSUN Delay Analysis

Figure 28. AIMSUN Delay Analysis

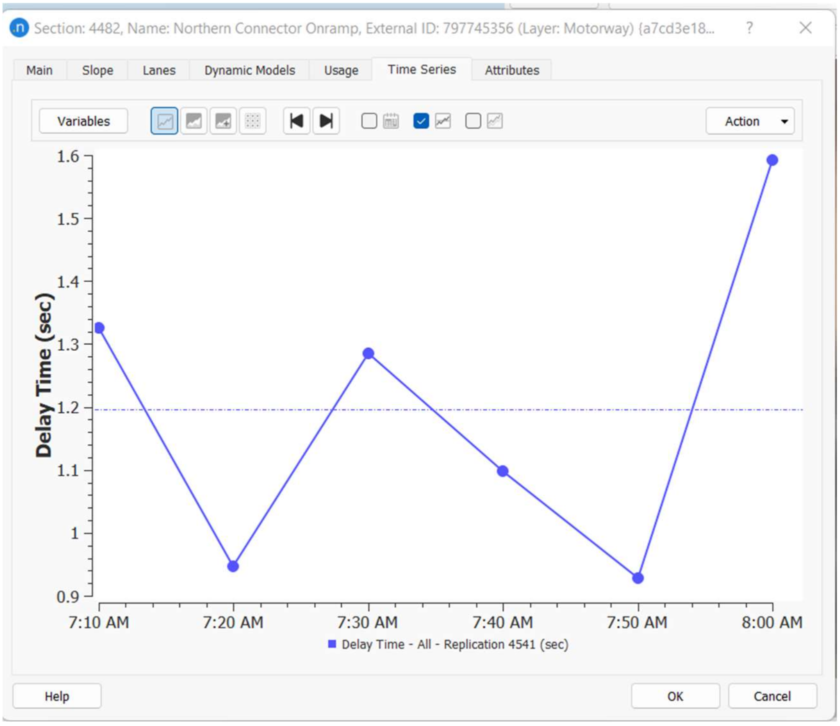

Figure 29 AIMSUN Delay Analysis

Figure 29. AIMSUN Delay Analysis

Appendix D

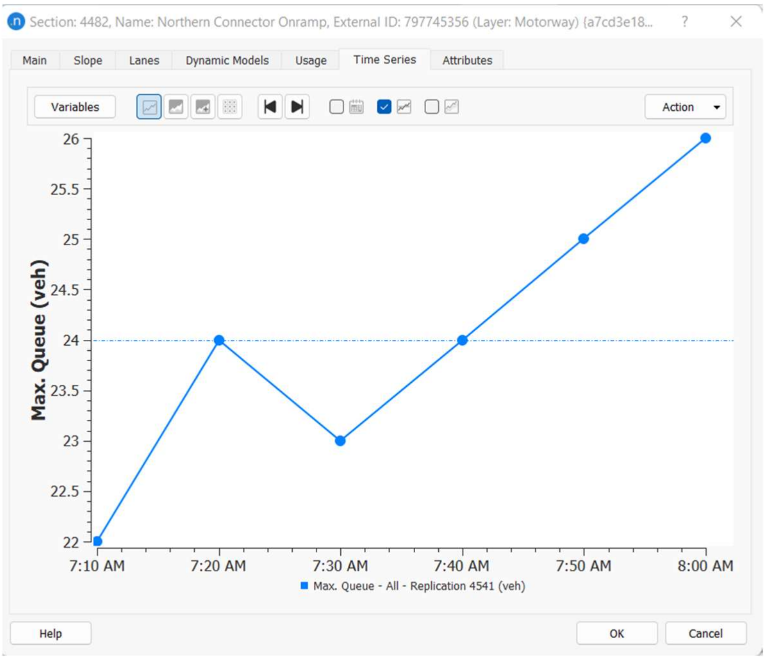

Figure 30 AIMSUN Queue Analysis

Figure 30. AIMSUN Queue Analysis

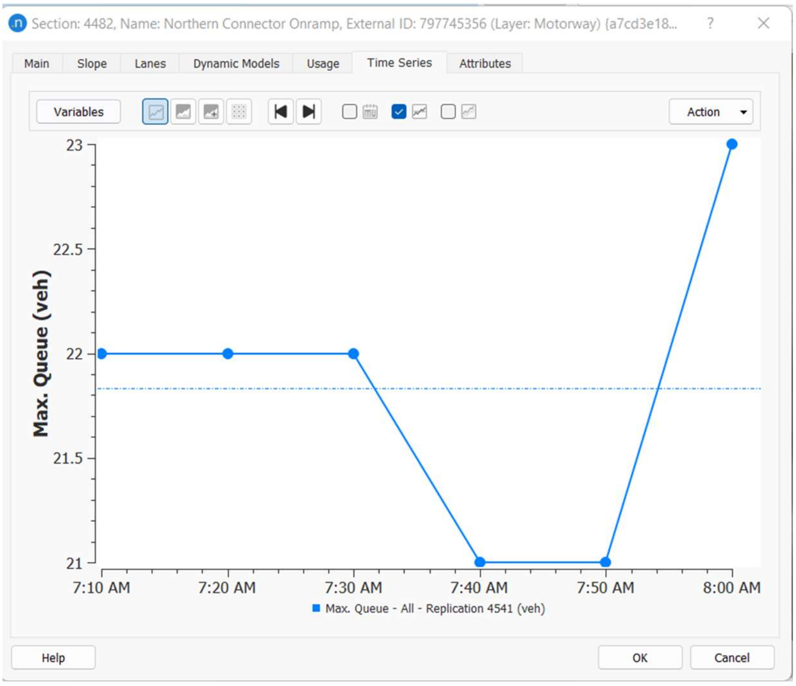

Figure 31 AIMSUN Queue Analysis

Figure 31. AIMSUN Queue Analysis

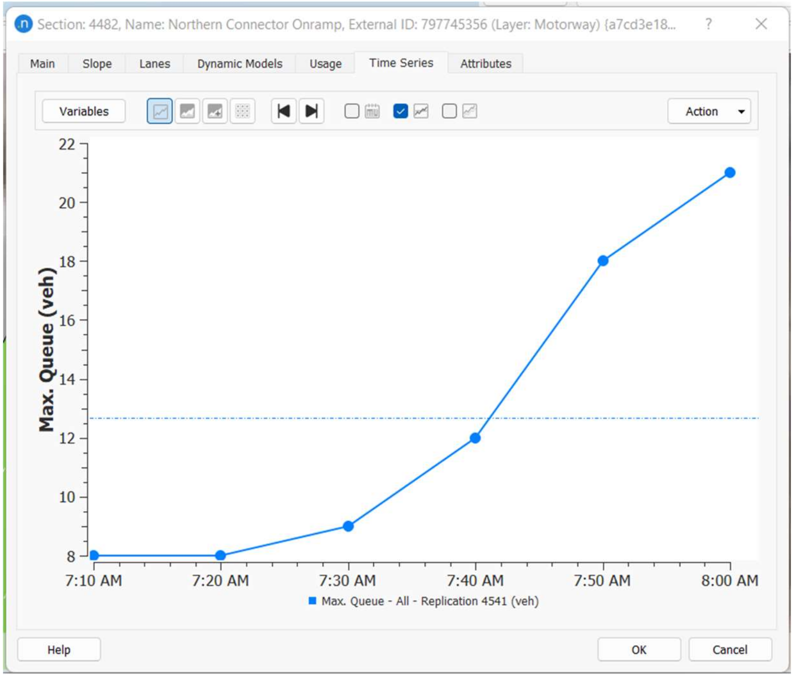

Figure 32 AIMSUN Queue Analysis

Figure 32. AIMSUN Queue Analysis

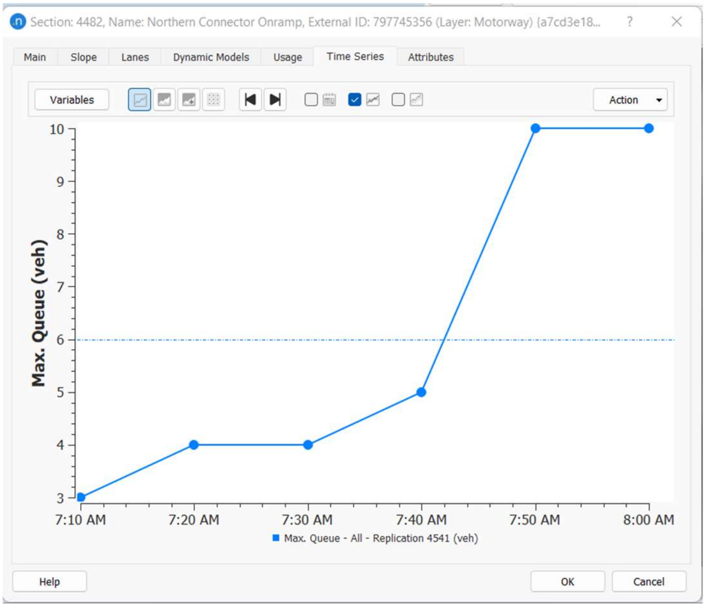

Figure 33 AIMSUN Queue Analysis

Figure 33. AIMSUN Queue Analysis

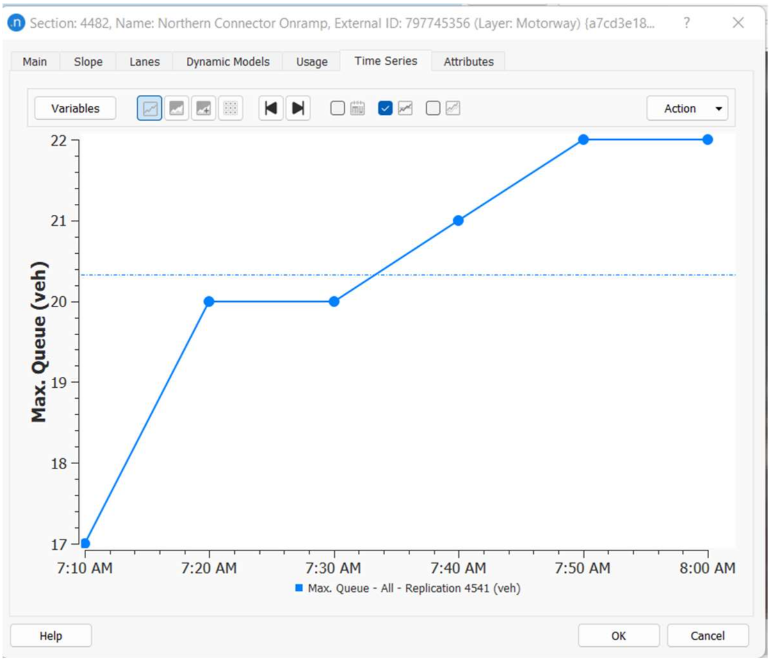

Figure 34 AIMSUN Queue Analysis

Figure 34. AIMSUN Queue Analysis

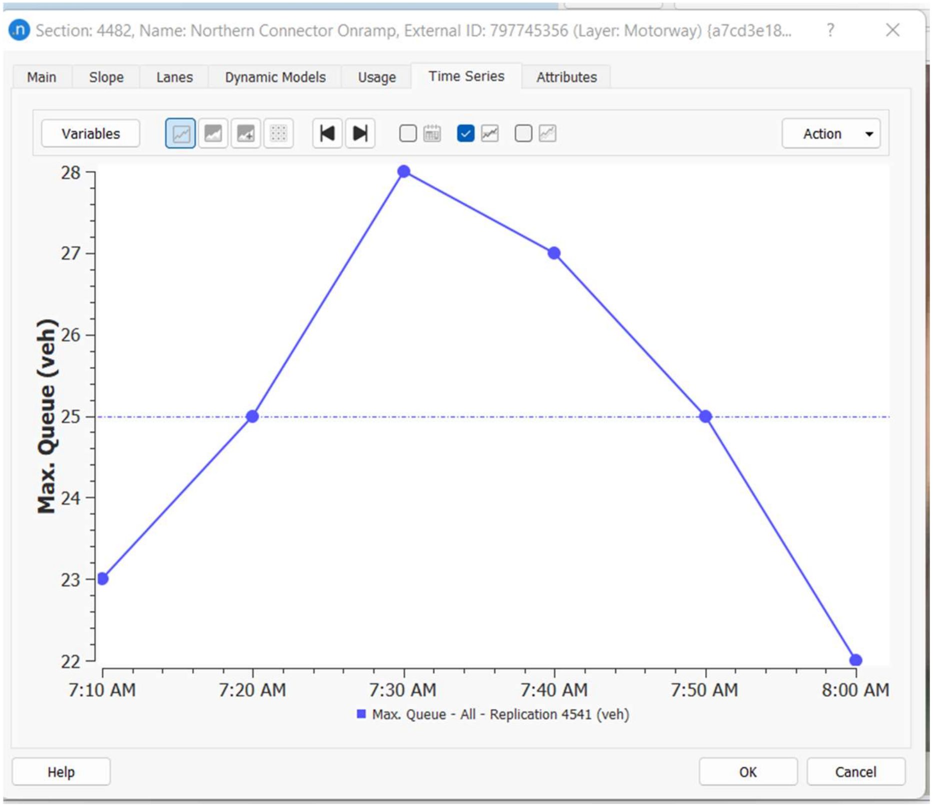

Figure 35 AIMSUN Queue Analysis

Figure 35. AIMSUN Queue Analysis

Project Layout