DEVELOPMENT OF A MODERN TRAFFIC MANAGEMENT SYSTEM TO MITIGATE TRAFFIC CONGESTION ON URBAN ARTERIAL –

A CASE STUDY OF MAIN MARGALLA ROAD

FINAL YEAR PROJECT UG 2020

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This is to certify that

Final Year Project Titled

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ABSTRACT

One of the most recent traffic data published on Islamabad's Main Margalla Road claimed an Average Annual Daily Traffic (AADT) of more than 60,000 on both the North-Bound, and the South-Bound direction (Sulaiman, 2022). The data, compiled by a private firm, called Zeeruk International, as part of a project by Capital Development Authority (CDA), cited several factors for the growing traffic congestion on major urban arterial. One such urban arterial was Main Margalla Road.

This project aims to understand, analyze, and propose a solution to the growing problem of traffic congestion for Islamabad's Main Margalla Road. The project is in line with the Sustainable Development Goal (SDG) 9 and 11. An understanding of the problem is developed by gathering all the relevant information about the Site's traffic data. Once the data collection process has been completed, the analysis phase involves modelling the current traffic conditions on a multi-modal traffic modelling simulation software PTV VISSIM and deriving traffic parameters such as Delays, Queue Length, Emissions, and Fuel Consumption data. Using the split phase optimization technique for all the seven intersections of the Main Margalla Road, a new traffic model is developed. The resulting parameters are compared to see the possible differences.

The findings of this proposal will be presented to the relevant transportation planning authorities in the city, with the aim of developing a more robust traffic management system for the city.

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INTRODUCTION

1.1. General

A country's transportation can give a basic idea about its economy. An efficient transportation system ensures safe travel, passengers' comfort, and reduces travel costs which influences trade routes (Afrin & Yodo, 2020). The rapidly growing population of Pakistan makes its roads vulnerable to untimely congestions and delays. The most common solution for this issue, which is still implemented in Pakistan, is to add more lanes to the sides. This factually worsens the condition in the long run (Cervero, 2020). It not only encourages new drivers to use the road but also creates bottlenecks at certain points like merging lanes or intersections. This effect is called induced demand. The escalated growth in traffic, adverse execution of traffic laws and the decline towards urban cities has resulted in substandard traffic flow on one of the important highways of Islamabad, The Main Margalla Road (Frantzeskakis, 2022). This major arterial, connecting Constitution Avenue and E-11 Sector, facilitates multiple important sectors. Apart from sectors, this road facilitates traffic for multiple important points such as Jinnah Park, Air and Bahria University and Faisal Mosque.

Researchers have highlighted several reasons as to why there is a rise in traffic congestion and delays in Islamabad. Its Modernist, grid-based urban design is one reason (Faiz, 2023), but more so, spiraling rise of urbanization, high growth rate of population, and vehicle registration (Frantzeskakis, 2022), and other factors contribute to it. In the case of Main Margalla Road, the issue is further aggravated due to the expansion of Main Margalla Road (Dawn, 2024), connecting it with Sector D-12, thus increasing the traffic load on it.

1.2. Background

Islamabad's Main Margalla Road is one of the major arterials driving the city's mobility. It starts at one end from F-11 and ends at Constitution Avenue. The road is used by residents of all the E and F Sectors, Islamabad's commercial hubs, residents of the military and navy settlements on Margalla, and then two major universities called the Bahria University, and Air University. Not only that, but it is also connected with other major arterials, such as the Kashmir/Srinagar Highway, Islamabad Expressway, Faisal Avenue, Constitution Avenue, and 9th Avenue.

The increased traffic volume, poor enforcement of traffic laws, and the trend towards urbanization have resulted in substandard traffic flow on one of Islamabad's key highways, the Main Margalla Road (Afrin & Yodo, 2020).

Upon inspecting this road, advanced traffic mitigation techniques have been recommended. One such technique is the Intelligent Transportation System (ITS), which operates using an Advanced Traffic Control and Management System (ATMS). ATMS is a suite of technologies that collect and analyze data to improve traffic flow, safety, and efficiency on roads.

1.3. Problem Statement

The rapid population sprawl has become a major cause for most of the problems over past few years. The trend towards smart cities, suburban development and the location of important areas encourages people to own a private vehicle (Faiz, 2023). Due to the existing regular rectangular urban pattern of Islamabad, there are limited route options, probable congestion at intersections lacking signals and encouragement on personal cars. The bureaucratic hub of Pakistan, Islamabad faces heavy traffic and congestions during the peak hours. The negligence of such growth rates in planning and designing phase of pavement results in imbalance between demand and capacity of the road. The traffic congestion causes delays and extended idle time. This results in large emissions of harmful gases which comprise of NOXs, VOCs and CO (Shah & Zeeshan, 2019). Furthermore, the extreme noise pollution resulting from running engines and continuous honking can cause frustration and psychological meltdown.

1.4. Study Scope

The scope of the study involves the complete site of Islamabad Main Margalla Road. There are a total of 7 Intersections in it. Each Intersection connects the road with another major arterial. The geometric design, signal timings, delays, and other parameters are a part of the study scope for this project. A detailed overview of all the intersections is provided. This is useful as the optimization is carried out on Signalized Intersections.

1.4.1. Pir Sohawa Intersection

It is a pair of intersections; a three-legged one, connecting 7th Avenue with Main Margalla Road and a four legged one, connecting Pir Sohawa and Justice Abdul Rasheed Road. The intersection holds significant value as it inhabits multiple embassies, a zoo and provides access to a scenic spot, Daman-e-Koh.

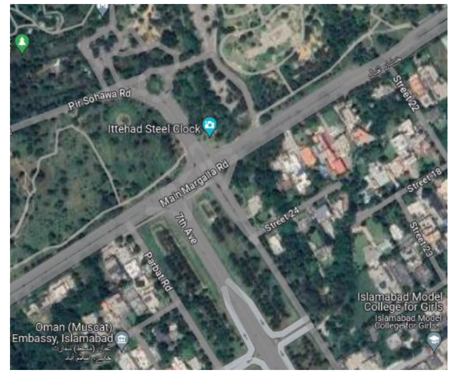


Figure 1-1: Pir Sohawa Intersection – Satellite View

1.4.2. Air University Intersection

This is a pair of intersections; a three-legged one, connecting 9th Avenue with Main Margalla Road and a four-legged service road connecting with Main Margalla Road. Two important universities occupy this intersection: Air University and Bahria University. Huge traffic is observed due to the presence of such important buildings.

Figure 1-2: Air University Intersection – Satellite View

1.4.3. F-8 Intersection

It is a three-legged intersection with an early exit and entry ramp for the 4th direction. This intersection faces heavy traffic coming from F-8 Markaz. The Naval Hospital and Bahria College also contribute to high traffic volumes.

Figure 1-3: F8 Intersection – Satellite View

1.4.4. Faisal Avenue Intersection

It’s a four-legged intersection connecting two major arterials. An enormous amount of traffic is observed here due to the important buildings it houses. Unlike the Centaurus Mall intersection, this intersection lacks a flyover despite lying on the same road. This is a likely cause of traffic congestion at this intersection.

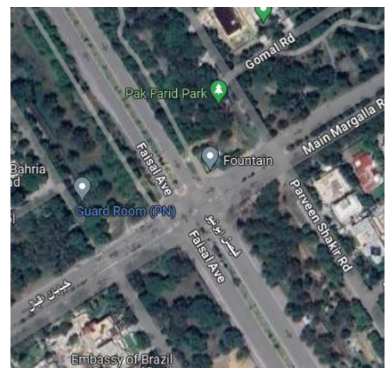


Figure 1-4: Faisal Avenue Intersection – Satellite View

1.4.5. Aurangzeb Intersection

Residing right beside the Faisal Avenue Intersection, is another four-legged intersection. This intersection faces the heavy traffic coming from Faisal Mosque and several other important buildings including a few embassies.

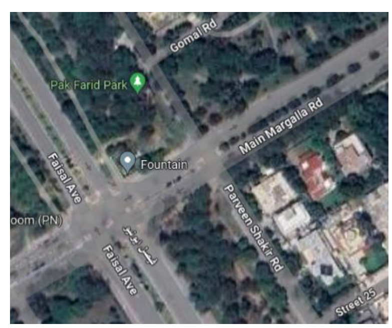


Figure 1-5: Aurangzeb Intersection – Satellite View

1.4.6. Siachen Road Intersection

This is a four-legged intersection which sits on the west side of Pir Sohawa Intersection. Due to this reason, it experiences higher traffic. Other than Model College for Boys or the Embassy of Nepal there aren't any such important buildings in this area that would add on to the already high traffic volumes.

Figure 1-6: Siachen Road Intersection – Satellite View

1.4.7. Kohsar Road

This is a three-legged intersection which connects the F-7 Markaz to Main Margalla Road. Apart from that, a school is also located at the intersection. This is the likely cause of high peak hour volumes.

Figure 1-7: Kohsar Road Intersection – Satellite View

Before performing optimization and signal coordination, a field survey was performed. It gave physical values like travel time, travel distance, cycle length among all signals. There was no automated signal anywhere on this road. The signal coordination technique can be applied for distances within a mile for major roads and highways. In the case of Main Margalla Road, the distances among the signals lie under this threshold so signal coordination technique can be applied.

Travel Nodes	Travel Distance (meters)
Air Uni to F-8	1100
F-8 to Faisal Avenue	800
Faisal Avenue to Aurangzeb	80
Aurangzeb to Kohsar	950
Kohsar to Siachen	400
Siachen to Pir Sohawa	550

1.5. Project Objectives

The key objectives of our project are to:

- Collect data on the existing traffic parameters of the Main Margalla Road using standard data collection methods. It involves collecting parameters such as delays, distances, queue lengths, etc.
- Analyze current traffic demand on Main Margalla Road, Islamabad by using Highway Capacity Manual (HCM).
- Mitigate the traffic congestion on Main Margalla Road, Islamabad using ATMS techniques, split phasing, and signal coordination on PTV VISSIM.
- Design and propose optimized travel time and environmentally friendly network solution by using economic efficiency analysis.
- Identify other possible solutions to tackle increasing traffic volumes.

Chapter 2

LITERATURE REVIEW

2.1 General

A thorough literature review was conducted from the beginning of the Final Year Defense Project. Initial guidance, and framework for the FYDP were provided by our Instructor, who helped us map out important keywords, online resources, access to the library, and a suggestion on the most relevant keywords that could help us navigate the complicated project. Our group picked up a dozen keywords ranging from “Intelligent Transport System ITS”, to “Traffic Mitigation”, and more. During the literature review process, we not only read through important Thesis available at SCEE Library, NICE, but also looked through online available thesis compiled by Masters students worldwide. A range of opensource websites helped us achieve that. Not only this, as per instructions provided to us, our team had to look through a range of similar case studies and practical use of our research that is currently being practiced in the world when it comes to transportation planning. This was an important step of the literature review as it would test our hypothesis for a similar transportation planning framework, with the difference of a site and a location. This chapter discusses in detail the relevant Thesis and relevant case studies that we discovered during our literature review.

2.2 Thesis Review

In this chapter, a comprehensive review of existing theses related to traffic management systems and urban congestion mitigation is presented. The aim is to identify research gaps that can inform and shape the development of a modern traffic management system tailored for urban arterial roads, with a specific focus on the Main Margalla Road case study. By critically analyzing previous academic works, this chapter seeks to uncover areas that have been insufficiently explored or overlooked, thereby providing a solid foundation for the proposed study and ensuring its contribution to the advancement of traffic management strategies.

2.2.1 Real-Time Traffic Performance Measurement of Signalized Intersections Using Connected Vehicle Data: A Simulation-Based Study

This research explores these challenges through a simulation study of a signalized urban arterial corridor in Broward County, Florida. The study includes 17 signalized intersections with varying congestion levels and layouts. Simulations were conducted under various scenarios, considering facility types, congestion levels, CV market penetration rates (1%-25%), and signal timing plans. The research assessed signal performance measures like average delay, queue length, percentage of stopped vehicles, and the number of stops. Sensitivity analysis evaluated the reliability of these measures under different conditions.

The findings demonstrate CV data's potential, even at low market penetration rates, for estimating crucial traffic performance measures and detecting non-recurrent congestion. These insights are directly relevant to the development of a modern traffic management system for the Main Margalla Road case study, offering a foundation for improving urban arterial traffic management and reducing congestion.

2.2.2 Effect of Signal Coordination on the Traffic Operation of Urban Corridor

This study aimed to address the persistent issues faced by road users along a 14 km corridor from Golra intersection on N5 to GHQ intersection, focusing on traffic congestion, delays, and environmental impacts from vehicle emissions and noise. Using on-field data collected through manual counts, signal timing, and link lengths, the analysis was conducted with SYNCHRO software to determine Level of Service (LOS), Intersection Capacity Utilization (ICU), travel delays, and volume-to-capacity ratios. The study considered both current and projected future scenarios, assessing improvements such as lane expansions, signal coordination, and grade separation at feasible intersections. The results highlighted potential reductions in emissions, fuel consumption, and bottlenecks, ultimately suggesting that these measures could enhance traffic flow and user experience.

The findings were directly relevant to the development of a modern traffic management system for the Main Margalla Road, providing a framework for mitigating congestion and improving overall traffic conditions on urban arterial roads.

2.2.3 Traffic Flow Optimization of an Urban Arterial

This research leverages big data and technology to estimate travel time, mobility costs, and their impact on individual savings in Islamabad. Data was collected from BYKEA, Google, and a survey conducted in Islamabad, and the city was divided into multiple zones for analysis. The study found the average travel time in Islamabad to be 35 minutes, increasing to 37 minutes during peak hours. Mobility costs averaged 22.5% of an individual's income, with 12.5% in monetary terms and 10% in time-related costs. Ride-hailing emerged as the most expensive mode of transport, followed by car, public transport, and motorcycle. The study also identified major mobility patterns in the city and provided recommendations for further research.

These findings are relevant to the development of a modern traffic management system for Main Margalla Road, offering insights into travel time, cost efficiency, and mobility patterns that can inform strategies to mitigate traffic congestion on urban arterial roads.

2.2.4 Analysis of Islamabad Signal Free Corridor as a Congestion Mitigation Solution

This was a Masters thesis written by students of NUST with the aim of studying Islamabad Expressway and the traffic analysis and changes observed due to the signal free corridor created in Islamabad Expressway from Faisal Avenue till T Chowk, Rawat. The project was relevant as it helped us gauged the possibility of considering and simulating a signal free geometric design in the Margalla Road and running the comparison results with the existing conditions.

The major deviation between our project and the one being discussed is that the sites are different. Ours being Main Margalla Road while the thesis focused on Islamabad Expressway. This also creates limitation for the design renovation and rework due to lack of adequate space near the margalla road to expand it.

2.2.5 Effects of Signal Optimization vs Signal Free Corridor in a Network (Chairing Cross to Katchery Chowk)

This was the most relevant thesis to our project, as there is a direct comparison between signal free corridor and signal optimized corridors. The content helped us draft our framework, methodology, data collection procedure, data analysis and comparison tools, and more.

2.3 International Use Cases

The chapter is dedicated to some of the most renowned international use-cases where a similar technology was employed for transportation modelling, mapping, management, and more.

2.3.1 Implementation of Real-Time Traffic Management System by Hungarian Public Roads Utilizing PTV Optima Software

Hungarian Public Roads (Magyar Közút), a preeminent state enterprise in Hungary, manages and maintains an extensive network of approximately 31,000 kilometers of national public roads. A critical challenge encountered by the organization pertains to the necessity for consistent and error-free real-time data regarding current and imminent traffic situations. Such data is imperative for providing operators with a comprehensive overview of traffic conditions, predicting incidents, and enabling timely and appropriate responses (Attila, 2023).

In response to this challenge, Hungarian Public Roads implemented PTV Optima, a sophisticated real-time traffic management software. The selection of PTV Optima was predicated on its advanced functionalities, which include traffic forecasting, decision support for traffic management, and Key Performance Indicator (KPI) calculations.

A paramount consideration during the implementation phase was the assurance of error-free and reliable data integration into PTV Optima. To address this, Főmterv, an engineering consultancy engaged by Hungarian Public Roads, undertook the task of updating an existing traffic model using historical data sourced from Inrix, processed within the PTV Visum software environment. This updated model was subsequently transformed into a dynamic simulation traffic forecast model tailored for PTV Optima, encompassing approximately 9,000 kilometers of the high-level road network.

Furthermore, PTV Group developed customized Application Programming Interfaces (APIs) that facilitated the integration of Hungarian Public Roads' proprietary real-time data. This was augmented by real-time speed data provided by Inrix. The synthesis of these real-time data sources with the foundational traffic model ensures the execution of highly accurate traffic forecast calculations.

Currently, Hungarian Public Roads receives comprehensive real-time information concerning incidents across its entire road network. Additionally, PTV Optima is employed to rigorously test various traffic management strategies, thereby facilitating the implementation of the most effective measures. By leveraging real-time data from multiple sources, PTV Optima empowers the organization to evaluate the reliability of different strategies, thereby optimizing traffic management and enhancing operational efficiency.

2.3.2 Utilization of multi-modal traffic simulation software in real-time for Traffic Management by ITS Vienna Region

A precise forecast of the anticipated traffic situation is critical for enhancing mobility management, ultimately benefiting all street users (Fiby, 2022). Accordingly, PTV Optima software has been integrated into the traffic control center of the ITS Vienna Region.

ITS Vienna Region serves as the competence center for intelligent transport systems (ITS) across the three Austrian states in and around Vienna. The organization is responsible for collecting and processing digital traffic data to develop services aimed at improving traffic efficiency, safety, and sustainability.

Analysis of Current and Future Traffic Situations

To acquire real-time traffic information, ITS Vienna Region employs PTV Optima, PTV's sophisticated traffic management tool. This software amalgamates reliable offline traffic modeling with real-time data and advanced algorithms, considering responses to unplanned traffic delays and known disturbances such as accidents and construction sites.

Utilizing data from PTV Optima, ITS Vienna Region calculates and visualizes both current and future traffic situations. These results, updated every five minutes, benefit all connected systems of ITS Vienna Region, including the national journey planner AnachB.

Hans Fiby, Head of ITS Vienna Region, asserts, *"We have been working with PTV products to evaluate traffic levels in Vienna for many years now. In 2014, we decided to replace the previous 'PTV Traffic Platform' with PTV Optima to enhance our services. High-quality information about the traffic situation forms the basis for well-grounded decisions in the operational headquarters. Up-to-date and comprehensive data is crucial for traffic management and control. This is why ITS Vienna Region relies on PTV Optima."*

Offline Data Provision and Model Integration

For offline data provision, PTV Optima utilizes a classical traffic demand model developed with PTV Visum software. This model incorporates all types of road users and their interactions, covering an area of 2,700 square kilometers, divided into 1,096 zones, and encompassing nearly 150,000 streets and 50,000 traffic arteries.

Single Source Solution Approach

To ensure the quality and reliability of its services, ITS Vienna Region adheres to a single source solution provided by PTV. This comprehensive approach includes long-term data storage, the offline model, and the data fusion and forecast engine.

The forecasts generated by PTV Optima also support the Austrian national route planner, based on PTV HyperPath, enabling drivers to plan their routes and avoid existing or anticipated traffic congestion. Additionally, the software's ability to compare various scenarios enhances the decision-making process for traffic operators, further optimizing traffic management and operational efficiency.

2.4 Local Use Cases

2.4.1 Pak-USAID Karachi Metropolitan ITS Project

The PAK-USAID Karachi Metropolitan ITS Project was a collaborative initiative between the University of Mississippi (UM), USA, and Nadirshaw Eduljee Dinshaw (NED), Pakistan. The primary goal of this project was to enhance traffic flow, reduce vehicular emissions, mitigate road accidents, and lower public health costs through the implementation of Intelligent Transportation Systems (ITS) video surveillance. The project successfully integrated modern geo-spatial technologies and scientific models to improve traffic flow and air quality. By combining traffic flow parameters with real-time traffic data, the project established an efficient Traffic Management System (TMS).

Moreover, the project involved the creation of a geo-referenced road network database using Geographic Information Systems (GIS), providing a robust framework for traffic management. Contributions to the city government focused on road safety and traffic engineering issues, aiming to optimize traffic flow management through ITS. A significant achievement of the project was the development of an indigenous vehicle-mounted traffic data collection system and video traffic data extraction software, which facilitated comprehensive and accurate traffic monitoring and analysis.

2.4.2 Urban Traffic Control System Implementation by RDA for Murree Road

The Rawalpindi Development Authority (RDA) has initiated an Urban Traffic Control (UTC) System on Murree Road with the objective of enhancing the traffic signal system. This project involves the installation of 16 SCATS-compatible UTC controllers along Murree Road, extending from Marrir Hassan Chowk to Faizabad, with each traffic controller having an expected operational lifespan of ten years. The total projected cost for the execution of this initiative is 36 million PKR.

The traffic management system will be centrally controlled, incorporating the installation of loop detectors and surveillance cameras at key intersections to facilitate real-time data collection. A dedicated room within the RDA office will serve as the centralized control center for traffic monitoring and management. Additionally, physical improvements to certain intersections are included in the project scope. This initiative is anticipated to reduce traffic congestion by 30-40%. Future includes expanding the system to integrate more major roads within the city for enhanced centralized control and security purposes.

2.4.3 Islamabad Shelves Traffic Signal Automation Project

The Capital Development Authority (CDA) of Islamabad initiated a project aimed at automating traffic signals to optimize signal phasing and timing using sensors, thereby reducing delays for commuters at intersections. This project was designed to enhance traffic flow by dynamically adjusting traffic signal timings based on real-time traffic conditions.

The primary objective of the automated traffic signal system was to enable adaptive signal phasing and timing. This system was designed to allocate longer green phases to approaches with heavy traffic while shortening or skipping phases for approaches with minimal or no traffic. Additionally, the system could modify the traffic signal control strategy according to the time of day and day of the week, ensuring optimal traffic management under varying conditions. To facilitate comprehensive traffic monitoring across the city, video cameras and pavement-embedded sensors were to be installed. Furthermore, the system included a provision to turn off traffic lights late at night in areas with light traffic, conserving energy and reducing unnecessary delays.

2.5 Intelligent Transportation System

2.5.1 Introduction

Intelligent Transportation System (ITS) technology represents a significant advancement in modern transportation management, encompassing a wide range of applications that utilize communication, control, and information technologies to improve the efficiency, safety, and sustainability of transportation networks (Klugl & Bazzan, 2022). ITS integrates various systems such as traffic management, public transportation, and emergency response through advanced data collection and processing capabilities. This integration facilitates real-time monitoring and control of transportation systems, enabling dynamic responses to traffic conditions and improving overall traffic flow.

The importance of ITS technology lies in its ability to address numerous challenges associated with urban transportation, including traffic congestion, accidents, and environmental impact (Qureshi & Abdullah, 2013). By leveraging technologies such as sensors, cameras, and communication networks, ITS provides accurate and timely information to traffic managers, commuters, and other stakeholders. This information is crucial for optimizing traffic signal timings, managing public transportation schedules, and coordinating emergency responses. Consequently, ITS contributes to reduced travel times, lower vehicle emissions, and enhanced road safety, ultimately improving the quality of life for urban populations.

Furthermore, the implementation of ITS technology supports long-term strategic goals related to urban planning and development. It enables more efficient use of existing infrastructure, delaying the need for costly expansions and upgrades (Guevara & Cheein, 2020). Additionally, ITS facilitates the collection of vast amounts of data, which can be analyzed to identify trends and inform future transportation policies. This data-driven approach ensures that transportation systems are resilient and adaptable to changing conditions, fostering sustainable urban growth (Yilmaz & Haydari, 2020). As cities continue to expand and face increasing transportation demands, the adoption of ITS technology becomes indispensable for maintaining efficient, safe, and sustainable transportation networks.

2.5.2 Traffic Management

Intelligent Transportation System (ITS) technology encompasses a broad spectrum of applications that enhance the efficiency, safety, and sustainability of transportation networks. One prominent use case is in traffic management, where ITS technologies such as adaptive traffic signal control systems, real-time traffic monitoring, and predictive analytics are employed to optimize traffic flow and reduce congestion. These systems utilize data from various sensors, cameras, and GPS devices to adjust signal timings dynamically based on current traffic conditions. By reducing stop-and-go traffic, these systems not only improve travel times but also decrease fuel consumption and vehicular emissions, contributing to a cleaner environment.

Public Transportation

In the realm of public transportation, ITS technologies are pivotal in improving service reliability and passenger satisfaction. Advanced systems such as Automatic Vehicle Location (AVL) and Passenger Information Systems (PIS) provide real-time updates on bus and train locations, arrival times, and service disruptions. These systems enhance the operational efficiency of public transit agencies by facilitating better route planning, scheduling, and fleet management. For passengers, access to real-time information reduces waiting times and enhances the overall travel experience, encouraging greater use of public transport and reducing the reliance on private vehicles.

Road Safety

ITS technology also plays a crucial role in enhancing road safety. Applications such as collision avoidance systems, intelligent speed adaptation, and automated incident detection are instrumental in preventing accidents and mitigating their impacts (Sharma, Singh, & Gehlot, 2022). These technologies use data from in-vehicle sensors and roadside equipment to monitor driving behavior, road conditions, and potential hazards. For instance, collision avoidance systems can warn drivers of imminent collisions and even take corrective actions to prevent accidents. Similarly, intelligent speed adaptation ensures that vehicles adhere to speed limits, thereby reducing the likelihood of speed-related accidents.

Freight and Logistics

Freight and logistics industries significantly benefit from ITS technologies as well. Fleet management systems that incorporate GPS tracking, route optimization, and telematics improve the efficiency of freight operations by providing real-time visibility into vehicle locations, conditions, and performance. These systems enable logistics companies to optimize delivery routes, reduce fuel consumption, and ensure timely deliveries (Kadlubek & Grabowska, 2021). Additionally, ITS technologies facilitate better asset management by monitoring vehicle health and scheduling preventive maintenance, thereby reducing downtime and extending the lifespan of transportation assets.

Toll Roads and Parking Facilities

Furthermore, ITS applications extend to the management of toll roads and parking facilities. Electronic toll collection systems streamline toll payments by allowing vehicles to pass through toll booths without stopping, thus reducing traffic congestion and improving the efficiency of toll road operations. Smart parking solutions, which include real-time parking availability information and automated payment systems, enhance the user experience and optimize the use of parking spaces. These systems reduce the time drivers spend searching for parking, thereby decreasing traffic congestion and emissions in urban areas.

2.5.3 Conclusion

In conclusion, the practical industry applications of ITS technology are vast and varied, addressing critical needs in traffic management, public transportation, road safety, freight logistics, and infrastructure management. By leveraging advanced data collection, processing, and communication technologies, ITS provides innovative solutions that enhance the efficiency, safety, and sustainability of transportation systems. As urban populations continue to grow and transportation demands increase, the deployment of ITS technologies will be essential in creating resilient, adaptable, and sustainable transportation networks for the future.

Chapter 3

OPTIMIZING TRAFFIC FLOW ON MARGALLA ROAD, ISLAMABAD

General

In this chapter, we will discuss the optimization process implemented for seven intersections along Margalla Road in Islamabad, stretching from the D12 roundabout to the Pir Sohawa Intersection. While the LOS for most of the time is quite satisfactory, the situation gets worse as the peak hours approach (Ahsan, Zaidi, & Khattak, 2023) There are long queues, resulting in increased delay times, which eventually not only increases fuel consumption but also has a hazardous impact on the environment due to the increased emission of NOX, VOX, and CO as the vehicles at the intersection waiting for their turn.

3.1 Optimization Process

One of the major reasons for the rising traffic congestion in urban arterials is that signals are not well coordinated. The majority of the time, as the first few vehicles from the previous intersection reach the next intersection, they get a red signal. This situation, known as lack of signal coordination, leads to queue formation that spills back onto the previous intersection, creating a domino effect that disrupts traffic flow throughout the entire corridor.

To overcome this challenge, we implemented two primary traffic signal optimization techniques: signal coordination and split phasing.

3.1.1 Signal Coordination

Signal coordination aims to synchronize traffic signals across multiple intersections, creating a "green wave" for approaching vehicles. This ensures vehicles traveling at a specific speed receive a green light at each intersection, minimizing stops and delays. Implementing signal coordination requires collecting various data points, including:

- **Road and Lane Lengths**: Knowing the physical dimensions of the road and lanes is essential for calculating travel times between intersections.

- **Speed Limits:** Posted speed limits along the road segment are factored into travel time calculations.

- **Traffic Volume Data:** Understanding traffic volume patterns, including peak hours and dominant traffic directions, is crucial for optimizing signal timings.

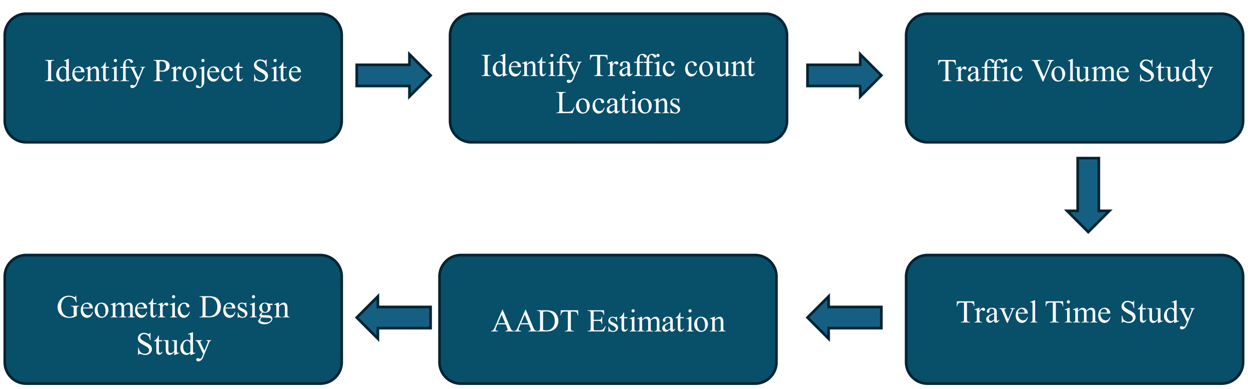
3.2 Data Collection for Signal Coordination

A comprehensive data collection framework was developed to produce accurate data free of anomalies and inconsistencies. The data collection process aimed to collect the following information:

- Traffic Volume
- Travel Time
- AADT/Traffic Demand
- Future Traffic forecasting till 2030
- Geometric Design
- Peak Hours

3.2.1 Data Collection Methodology

The flow chart below highlights how the data was collected. The specific details on collection methods is described afterwards.



Our project members employed the use of every available resource and equipment to collect data. Video Recording Cameras, Stopwatches for measuring counts, and Pen and Paper technique for maintaining record.

The data was collected normally close to morning and evening peak hours, i.e. 8 am to 11 am during the morning hours on business days, while 4 pm to 7 pm for evening peak hours for business days as well as the weekends.

One limitation encountered during the process was the fact that Main Margalla Road itself is a very lengthy road, with security considerations, and seven different intersections all working simultaneously. Thus, it would've been impractical and impossible to measure all of the seven intersections at one time. A better approach to counter the situation was to measure the intersections one by one, but also compare the results with the online available data on traffic counts for the road, as well as data available at the University. The past data was adjusted for yearly growth at 4% which portrayed an accurate picture for verifying our results.

A critical parameter for signal coordination is the travel time it takes a vehicle to reach an intersection from the previous one as it turns green. This travel time can be efficiently calculated using the following formula:

Travel Time (seconds) = Distance (meters) / Speed (meters per second)

Google Earth perhaps is the most convenient software, that can be used efficiently to calculate the distance between any two places. Opening the Google Earth software, searching for the location, and using the polygon feature, draw a line between two points. Then using the earth scale, you can calculate the distance between the locations.

3.3 F8 Markaz Intersection - A Coordinated Approach

The F8 Markaz Intersection is a three-legged junction on Margalla Road, providing access to Kohistan Road and the F8 Markaz. Due to its simple geometry, a more sophisticated optimization strategy called split phasing (discussed later) would be less effective here. Therefore, signal coordination was the primary method employed.

Traffic on Margalla Road typically flows at a speed of 65 km/hr., which translates to approximately 18.06 meters per second (m/s). To determine the travel time for vehicles approaching the Air University and Faisal Avenue intersections, we measured the distances using Google Earth and applied the travel time formula.

For instance, if the distance between the Air University Intersection and F8 Markaz Intersection is 2,050 meters, the travel time would be:

Travel Time = 2,050 meters / 18.06 m/s = 113.5 seconds

This calculation is repeated for all approaches to the intersection, allowing us to determine the optimal green time allocation for each direction during the signal cycle. While calculating travel times, a safety buffer is typically added to account for variations in vehicle speeds and driver behavior.

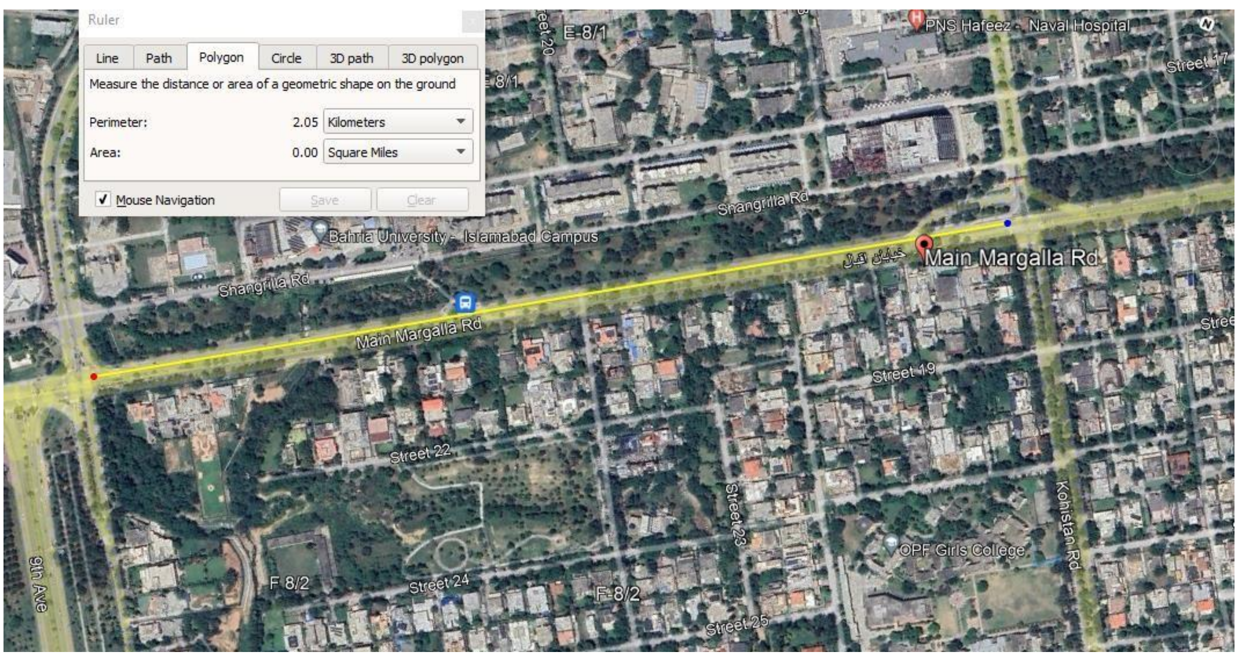


Figure 3-1: F8 Markaz Intersection - Eastbound

For the eastbound, the distance for the approaching vehicle to travel from Air University to the F8 Intersection is 2.05 km. Using the time formula, we figured out that the time required by a 65 km/hr. vehicle to reach the intersection from the East Bound will be 113 seconds.

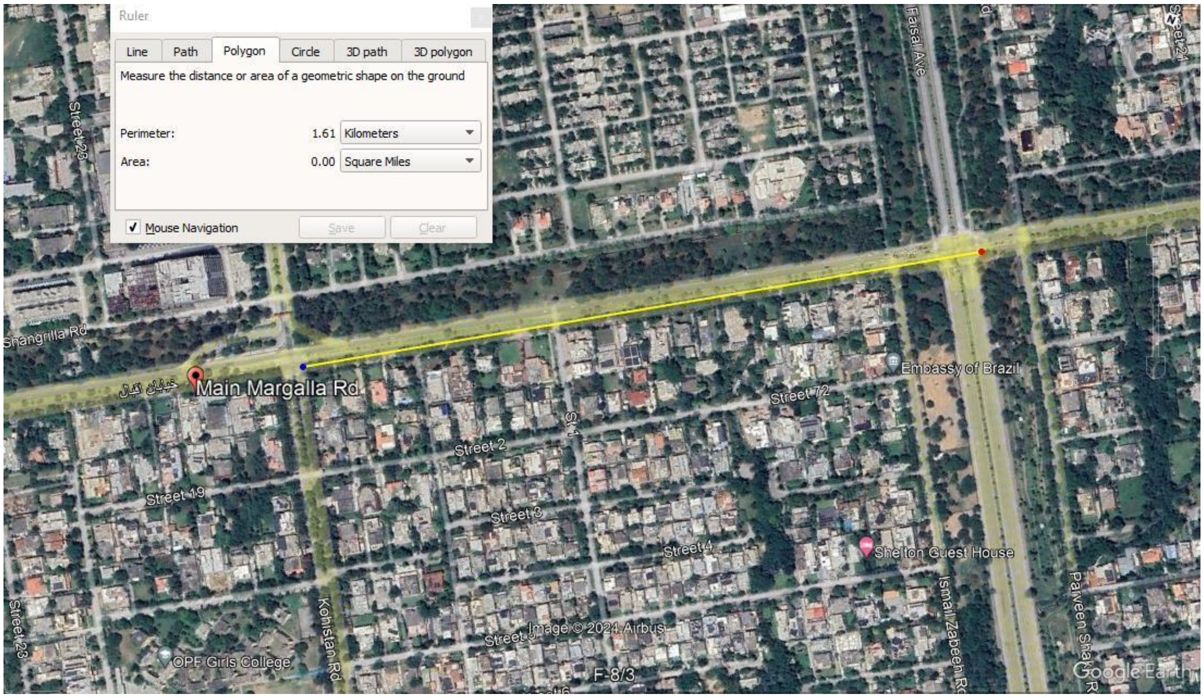


Figure 3-2: F8 Markaz Intersection - Westbound

Similarly, the time required for the westbound vehicles to approach the Faisal Avenue intersection to the F8 Markaz will be 86 seconds.

3.4 Time-Based Cycle Length for Signal Coordination

The cycle Length for the F8 Markaz Intersection before optimization was 99 seconds, which is kept the same after the signal coordination, as otherwise, even the reduction in the queue length wouldn’t been enough to reduce the delay times. Using the PTV VISSIM Version where we plotted 1 km from each side of the intersection, here are the signal timings before and after the optimization:

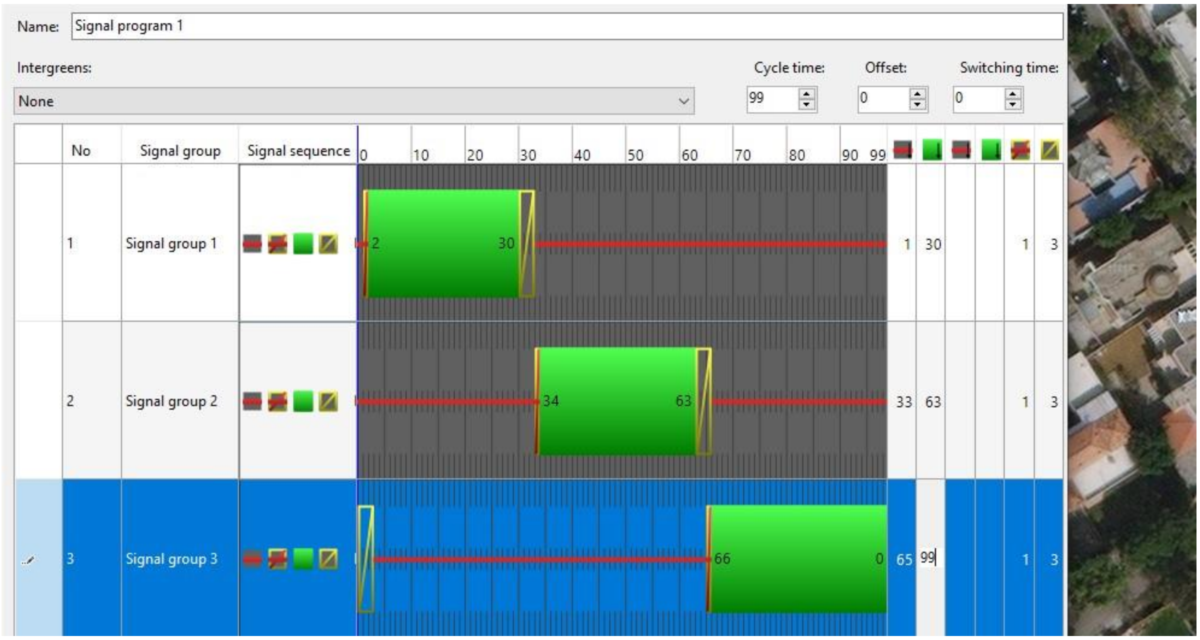


Figure 3-3: F8 Markaz Intersection - Uncoordinated

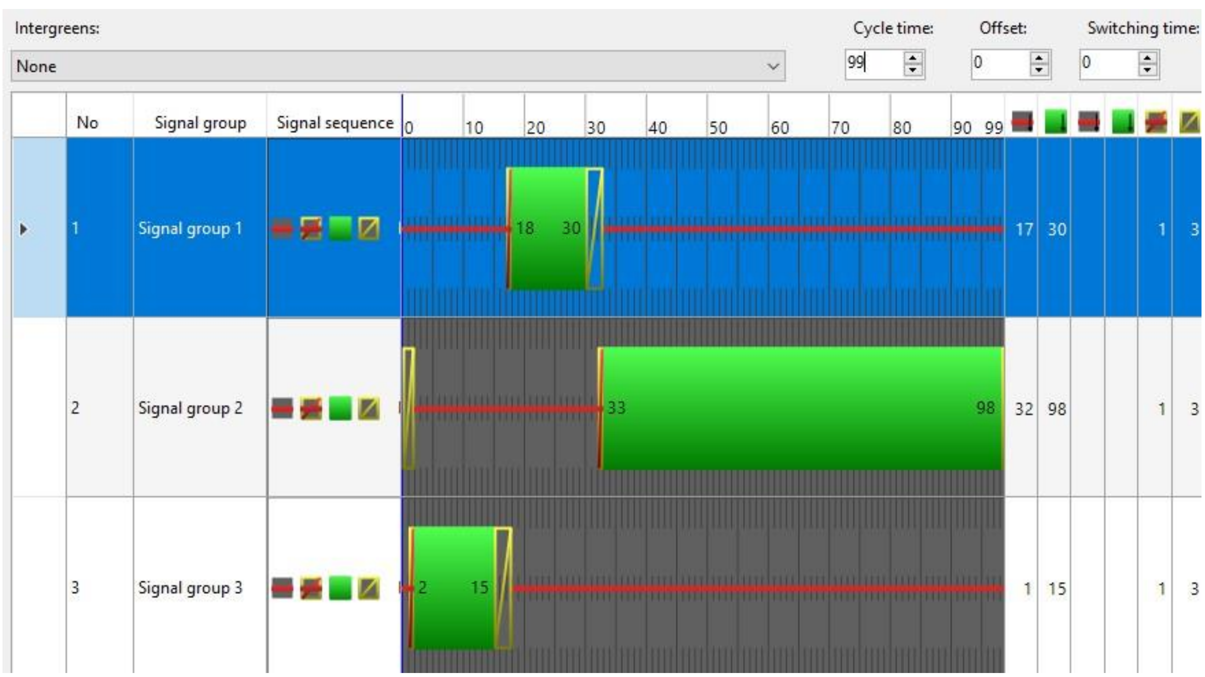


Figure 3-4: F8 Markaz Intersection - Coordinated

3.5 Split-Phasing Technique to Mitigate Congestion

To increase the efficiency of a road network, signal coordination alone cannot serve the purpose. Therefore, the second optimization method that can be adopted alongside signal coordination is a split-phasing method (Dogar, Khattak, Jamal, & Gohar, 2021). Currently, most intersections in Pakistan, including those on Margalla Road, utilize fixed three-phase or four-phase signal systems.

These systems allocate a predetermined amount of green time to each direction during a cycle, regardless of actual traffic volumes. This approach has limitations:

- **Inefficient Green Time Allocation:** Lanes with low traffic volume receive the same green time as those with high volume, leading to unnecessary waiting for low-volume lanes.
- **Increased Red-Light Running:** Drivers frustrated by long waits at red lights might resort to red-light running, creating safety hazards.
- **Exacerbated Congestion:** Inefficient green time allocation can contribute to longer queues and delays, especially during peak hours.

Split phasing addresses these limitations by dynamically allocating green time based on traffic demand. This method involves dividing the signal cycle into multiple phases, each allowing specific traffic movements that do not conflict with each other to proceed simultaneously.

3.6 Split-Phasing Technique for Air – University Intersection

The Air University Intersection presents a unique challenge due to its high traffic volume and the use of two separate signal programs: a three-phase system and a four-phase system. While signal coordination, as implemented at the F8 Markaz Intersection, can be applied here, significant congestion mitigation requires a more sophisticated approach – split phasing.

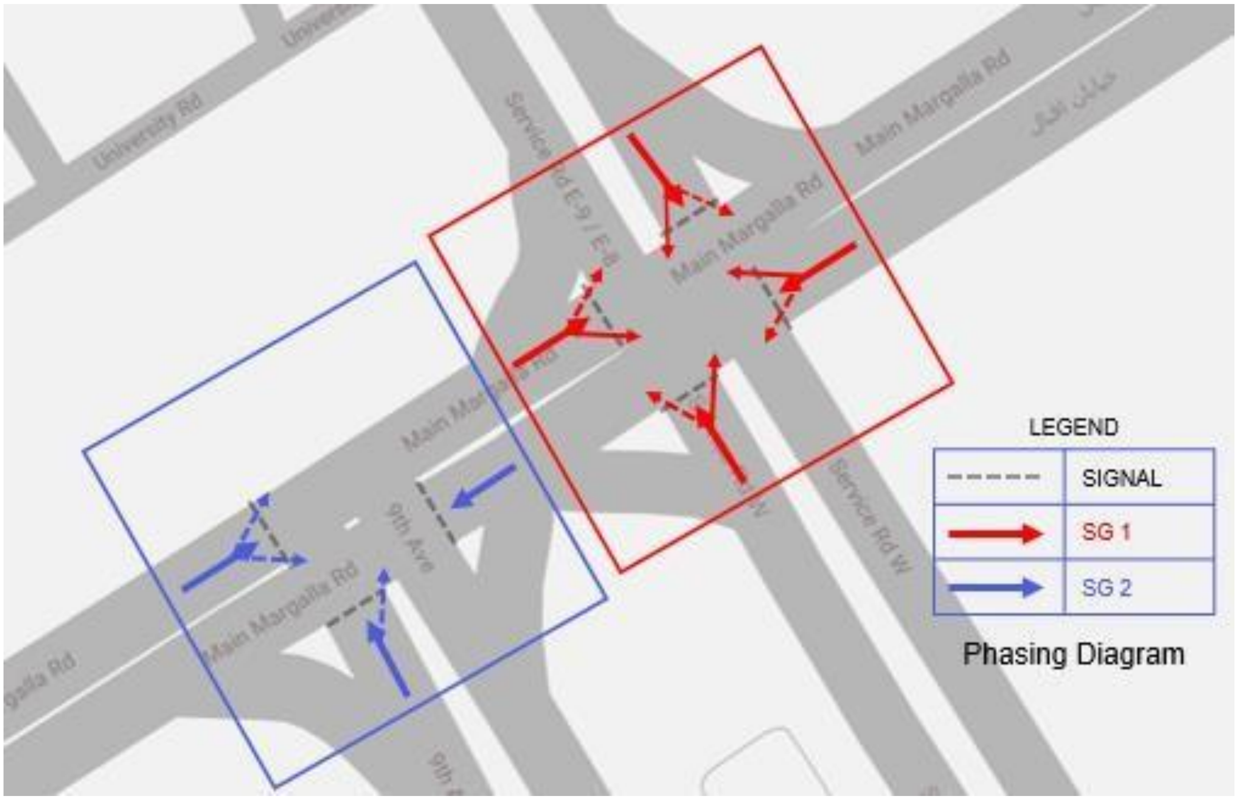
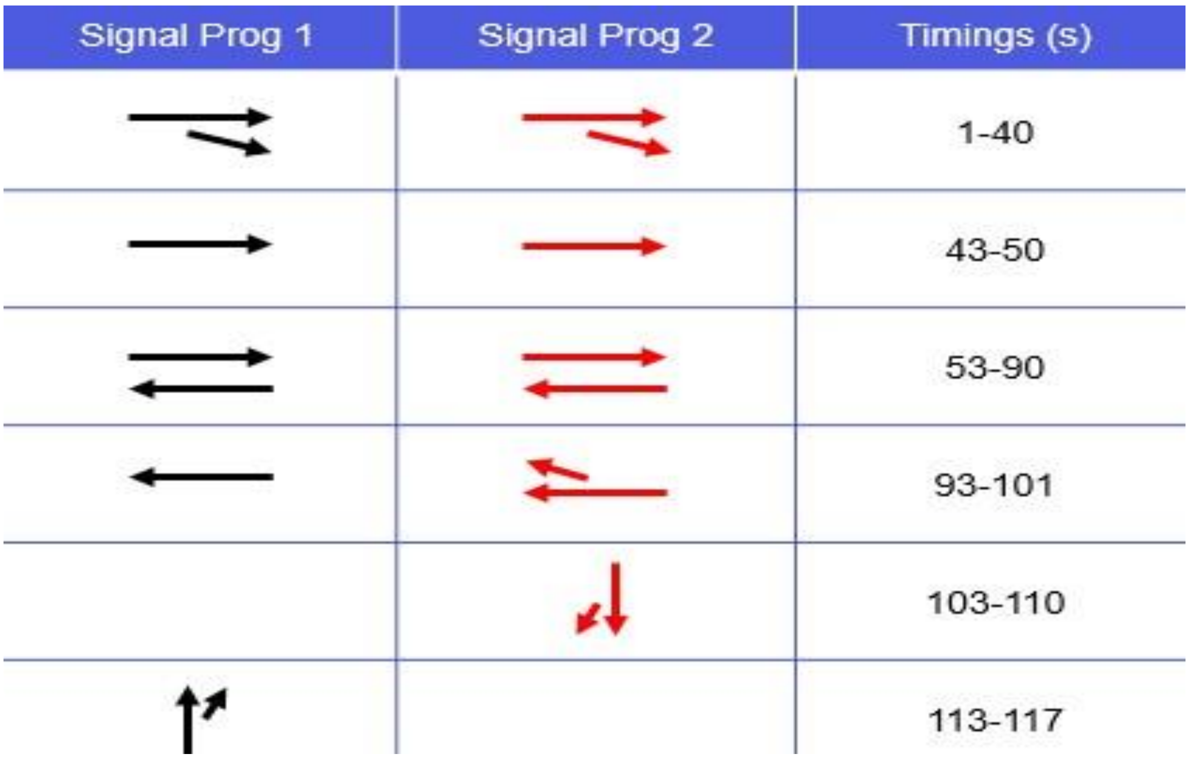


Figure 3-5: Split Phasing Design of 9th Avenue Intersection

These two signals work individually, as three-phased and four-phased signal systems. While, the coordination of these signals will be the same as that of the F8 Markaz intersection, as mentioned earlier, however to bring significant improvement in LOS, we need to change the phasing into split phasing, so we can provide more time to the thru traffic of eastbound and westbound which are heavier as compare to the remaining movements including the north and southbound.

In the Splits phasing method, the total cycle time of the two signal programs is kept the same which is 117 seconds. However, by allowing the non-conflicting movements together, a better way is proposed to mitigate congestion and bring efficiency. Here is the phasing system proposed for the Air University intersection, for a smooth and better flow of traffic:



Signal Prog 1	Signal Prog 2	Timings (s)
		1-40
		43-50
		53-90
		93-101
		103-110
		113-117

Figure 3-6: Improved Design for Split Phasing Optimization

Chapter 4

OPTIMIZED VISSIM ANALYSIS OF MARGALLA ROAD, ISLAMABAD

General

In this chapter, we present the results of the optimization strategies applied to Margalla Road, Islamabad. The primary focus is on the outcomes of signal coordination and split phasing implemented at seven major intersections along the route, from the D12 roundabout to Pir Sohawa. Using Vissim simulation software, we evaluated the performance of these strategies by comparing traffic conditions before and after optimization.

4.1. Introduction

The optimization of traffic flow on Margalla Road was essential to alleviate congestion and improve overall efficiency. The selected strategies, signal coordination and split phasing, were tailored to address the unique traffic dynamics and challenges posed by each intersection along the corridor. This chapter details the methodology used for evaluating the effectiveness of these strategies, followed by a comprehensive analysis of the simulation results.

4.2. Methodology

To assess the impact of the optimization strategies, a detailed simulation model of Margalla Road was developed using PTV Vissim. The model incorporated existing traffic data, including vehicle counts, signal timings, and intersection layouts. Two scenarios were simulated:

1. **Pre-Optimization Scenario**: This scenario represented the baseline conditions before any optimization was applied. It included the existing traffic signal timings and intersection configurations.
2. **Post-Optimization Scenario**: In this scenario, signal coordination and split phasing were implemented as per the optimization strategies designed in Chapter 3. The objective was to improve traffic flow and reduce delays at the major intersections.

The key performance indicators (KPIs) used to evaluate the effectiveness of the optimization included average travel time, queue lengths, and intersection delays. Data was collected for both scenarios during peak and off-peak hours to ensure a comprehensive analysis.

4.3. Analysis Results

The results from the Vissim simulations are presented in the following sections. For each intersection, we compare the traffic performance before and after optimization, highlighting the improvements achieved through the implemented strategies.

4.3.1. Air University Intersection Analysis

3600	S...	Ti	Movement	QLen	QLenMax	Vehs(...	Pers(All)	LOS(All)	LOSVal...	VehDelay(...	PersDelay(...	StopDelay(...	Stops(All)	EmissionsCO	Emissi...	Emissions...	FuelConsumption
17	7	0	1: Air University Intersection - 11: Service NB@4...	97.31	371.22	1	1	LOS_A	1	0.67	0.67	0.00	0.00	0.457	0.089	0.106	0.007
18	7	0	1: Air University Intersection - 11: Service NB@4...	6.34	19.43	1	1	LOS_A	1	0.01	0.01	0.00	0.00	0.308	0.060	0.071	0.004
19	7	0	1: Air University Intersection - 10015@8.4 - 3: E...	0.00	0.00	0	0	LOS_A									
20	7	0	1: Air University Intersection	18.71	371.22	80	80	LOS_B	2	13.54	13.54	7.44	0.50	74.593	14.513	17.288	1.067
21	7	1	1: Air University Intersection - 1: EB@263.7 - 3:...	223.04	325.52	14	14	LOS_F	6	109.06	109.06	84.05	2.36	44.607	8.679	10.338	0.638
22	7	1	1: Air University Intersection - 1: EB@263.7 - 6...	14.59	28.26	10	10	LOS_F	6	80.69	80.69	64.84	1.40	22.638	4.404	5.247	0.324
23	7	1	1: Air University Intersection - 1: EB@263.7 - 10:...	223.04	325.52	2	2	LOS_F	6	87.44	87.44	68.86	2.00	5.569	1.083	1.291	0.080
24	7	1	1: Air University Intersection - 1: EB@263.7 - 12:...	223.04	325.52	18	18	LOS_E	5	71.99	71.99	58.76	1.11	36.028	7.010	8.350	0.515
25	7	1	1: Air University Intersection - 5: 9th NB@152.8...	1.31	3.33	1	1	LOS_E	5	71.43	71.43	61.29	2.00	2.502	0.487	0.580	0.036
26	7	1	1: Air University Intersection - 5: 9th NB@152.8...	0.00	0.00	11	11	LOS_A	1	0.56	0.56	0.00	0.00	4.464	0.869	1.035	0.064
27	7	1	1: Air University Intersection - 5: 9th NB@152.8...	0.00	0.00	0	0	LOS_A									
28	7	1	1: Air University Intersection - 5: 9th NB@152.8...	1.31	3.33	0	0	LOS_A									
29	7	1	1: Air University Intersection - 7@80.8 - 4: WB@...	3.37	11.47	0	0	LOS_A									
30	7	1	1: Air University Intersection - 7@80.8 - 10: Serv...	3.37	11.47	1	1	LOS_D	4	36.87	36.87	29.40	1.00	1.353	0.263	0.313	0.019
31	7	1	1: Air University Intersection - 7@80.8 - 12: 9th...	3.37	11.47	0	0	LOS_A									
32	7	1	1: Air University Intersection - 8: WB@328.8 - 4:...	402.15	420.60	39	39	LOS_E	5	77.55	77.55	66.95	1.08	86.188	16.769	19.975	1.233
33	7	1	1: Air University Intersection - 8: WB@328.8 - 6...	402.15	420.60	1	1	LOS_F	6	80.13	80.13	69.83	1.00	2.020	0.393	0.468	0.029
34	7	1	1: Air University Intersection - 8: WB@328.8 - 1...	314.56	333.01	0	0	LOS_A									
35	7	1	1: Air University Intersection - 8: WB@328.8 - 1...	402.15	420.60	7	7	LOS_E	5	78.65	78.65	67.89	1.14	15.698	3.054	3.638	0.225
36	7	1	1: Air University Intersection - 11: Service NB@4...	1.83	18.62	1	1	LOS_A	1	0.13	0.13	0.00	0.00	0.422	0.082	0.098	0.006
37	7	1	1: Air University Intersection - 11: Service NB@4...	473.30	491.78	1	1	LOS_D	4	49.89	49.89	43.71	1.00	1.561	0.304	0.362	0.022
38	7	1	1: Air University Intersection - 11: Service NB@4...	3.67	18.62	4	4	LOS_D	4	43.13	43.13	35.57	1.00	5.595	1.089	1.297	0.080
39	7	1	1: Air University Intersection - 10015@8.4 - 3: E...	0.00	0.00	0	0	LOS_A									
40	7	1	1: Air University Intersection	119.66	491.78	110	110	LOS_E	5	70.88	70.88	58.67	1.18	229.234	44.601	53.127	3.279
41	7	2	1: Air University Intersection - 1: EB@263.7 - 3:...	300.32	323.98	14	14	LOS_F	6	142.59	142.59	114.57	2.79	54.941	10.690	12.733	0.786
42	7	2	1: Air University Intersection - 1: EB@263.7 - 6...	9.49	26.64	5	5	LOS_F	6	102.06	102.06	85.87	2.00	14.345	2.791	3.325	0.205
43	7	2	1: Air University Intersection - 1: EB@263.7 - 10:...	300.32	323.98	2	2	LOS_F	6	182.99	182.99	158.48	3.50	9.748	1.897	2.259	0.139
44	7	2	1: Air University Intersection - 1: EB@263.7 - 12:...	300.32	323.98	22	22	LOS_F	6	92.48	92.48	75.45	2.05	59.731	11.622	13.843	0.855
45	7	2	1: Air University Intersection - 5: 9th NB@152.8...	7.85	13.03	2	2	LOS_E	5	79.26	79.26	64.11	1.50	4.842	0.942	1.122	0.069
46	7	2	1: Air University Intersection - 5: 9th NB@152.8...	0.00	0.00	23	23	LOS_A	1	1.08	1.08	0.00	0.00	9.507	1.850	2.203	0.136
47	7	2	1: Air University Intersection - 5: 9th NB@152.8...	2.42	7.02	1	1	LOS_D	4	48.72	48.72	42.63	1.00	1.675	0.326	0.388	0.024
48	7	2	1: Air University Intersection - 5: 9th NB@152.8...	7.85	13.03	1	1	LOS_F	6	96.47	96.47	84.98	2.00	2.829	0.550	0.656	0.040

Figure 4-1: Air University Intersection - Unoptimized

r: 4620	Tim...	Movement	QLen	QLenMax	Vehs(All)	Pers(All)	LOS(All)	LOSVal(All)	VehDelay(...	PersDela...	StopDelay(...	Stops(All)	EmissionsCO	Emissions...	EmissionsV...	FuelConsu...
17	0-1...	1: Air University - 11: Service NB@64.2...	3.70	34.11	2	2	LOS_A	1	8.28	8.28	6.03	0.50	1.587	0.309	0.368	0.023
18	0-1...	1: Air University - 11: Service NB@64.2...	7.45	19.53	0	0	LOS_A									
19	0-1...	1: Air University - 14@8.8 - 3: EB@72.5	0.00	0.00	0	0	LOS_A									
20	0-1...	1: Air University - 14@8.8 - 10: Service...	0.00	0.00	0	0	LOS_A									
21	0-1...	1: Air University - 10005@3.5 - 4: WB@...	0.00	0.00	13	13	LOS_A	1	0.61	0.61	0.00	0.00	5.199	1.012	1.205	0.074
22	0-1...	1: Air University	25.62	420.44	67	67	LOS_B	2	10.57	10.57	7.84	0.30	53.147	10.341	12.317	0.760
23	12...	1: Air University - 1: EB@253.4 - 3: EB@...	165.01	259.95	23	23	LOS_C	3	24.76	24.76	12.83	0.96	31.593	6.147	7.322	0.452
24	12...	1: Air University - 1: EB@253.4 - 6@55.1	96.41	190.79	12	12	LOS_B	2	13.68	13.68	3.43	0.42	10.859	2.113	2.517	0.155
25	12...	1: Air University - 1: EB@253.4 - 10: Ser...	165.01	259.95	2	2	LOS_D	4	39.81	39.81	31.15	1.00	3.216	0.626	0.745	0.046
26	12...	1: Air University - 1: EB@253.4 - 12: 9th...	165.46	260.40	21	21	LOS_D	4	43.45	43.45	31.91	1.29	34.983	6.806	8.108	0.500
27	12...	1: Air University - 5: 9th NB@168.1 - 3:...	7.18	13.79	1	1	LOS_A	1	0.04	0.04	0.00	0.00	0.595	0.116	0.138	0.009
28	12...	1: Air University - 5: 9th NB@168.1 - 6...	0.00	0.00	0	0	LOS_A									
29	12...	1: Air University - 5: 9th NB@168.1 - 10:...	7.18	13.79	0	0	LOS_A									
30	12...	1: Air University - 7@54.2 - 3: EB@72.5	0.00	0.00	0	0	LOS_A									
31	12...	1: Air University - 7@54.2 - 4: WB@69.8	251.29	461.52	1	1	LOS_D	4	51.02	51.02	42.72	3.00	2.471	0.481	0.573	0.035
32	12...	1: Air University - 7@54.2 - 10: Service...	3.66	7.41	1	1	LOS_E	5	72.15	72.15	64.38	1.00	1.820	0.354	0.422	0.026
33	12...	1: Air University - 7@54.2 - 12: 9th SB@...	0.00	0.00	0	0	LOS_A									
34	12...	1: Air University - 8: WB@345.8 - 4: WB...	251.29	461.52	32	32	LOS_F	6	134.11	134.11	112.36	2.63	120.298	23.406	27.880	1.721
35	12...	1: Air University - 8: WB@345.8 - 6@55.1	401.90	418.20	2	2	LOS_F	6	165.62	165.62	141.88	3.00	8.708	1.694	2.018	0.125
36	12...	1: Air University - 8: WB@345.8 - 10: Se...	330.08	346.36	2	2	LOS_E	5	65.21	65.21	50.34	2.00	4.592	0.893	1.064	0.066
37	12...	1: Air University - 8: WB@345.8 - 12: 9t...	330.08	346.36	6	6	LOS_F	6	131.85	131.85	108.55	3.00	22.613	4.400	5.241	0.324
38	12...	1: Air University - 11: Service NB@64.2...	1.71	7.45	1	1	LOS_C	3	26.84	26.84	21.14	1.00	1.272	0.248	0.295	0.018
39	12...	1: Air University - 11: Service NB@64.2...	251.29	461.52	1	1	LOS_A	1	0.07	0.07	0.00	0.00	0.475	0.092	0.110	0.007
40	12...	1: Air University - 11: Service NB@64.2...	2.85	7.45	5	5	LOS_D	4	52.04	52.04	43.51	1.00	7.923	1.541	1.836	0.113
41	12...	1: Air University - 14@8.8 - 3: EB@72.5	0.00	0.00	0	0	LOS_A									
42	12...	1: Air University - 14@8.8 - 10: Service...	0.00	0.00	0	0	LOS_A									
43	12...	1: Air University - 10005@3.5 - 4: WB@...	0.00	0.00	11	11	LOS_A	1	0.92	0.92	0.00	0.00	4.426	0.861	1.026	0.063
44	12...	1: Air University	101.74	461.52	121	121	LOS_E	5	63.56	63.56	49.96	1.47	255.087	49.631	59.119	3.649
45	24...	1: Air University - 1: EB@253.4 - 3: EB@...	300.03	327.01	14	14	LOS_E	5	57.60	57.60	37.02	1.79	31.498	6.128	7.300	0.451
46	24...	1: Air University - 1: EB@253.4 - 6@55.1	230.86	257.84	8	8	LOS_D	4	36.25	36.25	20.76	1.12	12.255	2.384	2.840	0.175
47	24...	1: Air University - 1: EB@253.4 - 10: Ser...	300.03	327.01	3	3	LOS_F	6	96.67	96.67	73.44	2.33	9.032	1.757	2.093	0.129

Figure 4-2: Air University Intersection – Optimized

4.3.2. F8-Markaz Intersection Analysis

er: 1776	Si...	TimeInt	Movement	QLen	QLenMax	Vehs(...	Pers(All)	LOS(All)	LOSVal(...	VehDela...	PersDelay(...	StopDelay(...	Stops(All)	Emissions...	Emissions...	EmissionsVOC	FuelConsumption
7	10	0-99	1: F8 MARKAZ - 10012@2...	0.00	0.00	1	1	LOS_A	1	0.02	0.02	0.00	0.00	0.164	0.032	0.038	0.002
8	10	0-99	1: F8 MARKAZ	2.73	37.54	63	63	LOS_A	1	3.52	3.52	1.74	0.08	25.212	4.905	5.843	0.361
9	10	99-198	1: F8 MARKAZ - 1: F8 EB...	3.91	12.88	13	13	LOS_A	1	3.08	3.08	2.50	0.08	5.417	1.054	1.255	0.077
10	10	99-198	1: F8 MARKAZ - 1: F8 EB...	3.95	12.88	1	1	LOS_C	3	31.48	31.48	25.78	1.00	1.179	0.229	0.273	0.017
11	10	99-198	1: F8 MARKAZ - 6: F8 WB...	242.20	417.91	32	32	LOS_E	5	60.30	60.30	38.67	1.19	55.549	10.808	12.874	0.795
12	10	99-198	1: F8 MARKAZ - 6: F8 WB...	211.81	387.52	0	0	LOS_A									
13	10	99-198	1: F8 MARKAZ - 8: F8 NB...	39.70	96.60	6	6	LOS_D	4	40.00	40.00	30.20	1.00	8.263	1.608	1.915	0.118
14	10	99-198	1: F8 MARKAZ - 8: F8 NB...	22.38	71.59	22	22	LOS_A	1	4.80	4.80	0.98	0.09	8.929	1.737	2.069	0.128
15	10	99-198	1: F8 MARKAZ - 10012@2...	0.00	0.00	2	2	LOS_A	1	0.01	0.01	0.00	0.00	0.329	0.064	0.076	0.005
16	10	99-198	1: F8 MARKAZ	74.85	417.91	76	76	LOS_C	3	30.88	30.88	19.72	0.63	79.856	15.537	18.507	1.142
17	10	198-297	1: F8 MARKAZ - 1: F8 EB...	6.23	18.08	13	13	LOS_A	1	4.76	4.76	3.88	0.08	5.750	1.119	1.333	0.082
18	10	198-297	1: F8 MARKAZ - 1: F8 EB...	6.28	18.08	5	5	LOS_A	1	4.21	4.21	2.38	0.20	2.393	0.466	0.555	0.034
19	10	198-297	1: F8 MARKAZ - 6: F8 WB...	469.97	504.96	34	34	LOS_F	6	82.17	82.17	58.55	2.06	83.338	16.215	19.314	1.192
20	10	198-297	1: F8 MARKAZ - 6: F8 WB...	462.18	504.95	9	9	LOS_E	5	56.28	56.28	41.40	1.33	15.244	2.966	3.533	0.218
21	10	198-297	1: F8 MARKAZ - 8: F8 NB...	126.77	171.16	5	5	LOS_F	6	83.95	83.95	64.37	2.00	12.177	2.369	2.822	0.174
22	10	198-297	1: F8 MARKAZ - 8: F8 NB...	101.71	146.15	4	4	LOS_D	4	48.46	48.46	32.54	1.75	6.922	1.347	1.604	0.099
23	10	198-297	1: F8 MARKAZ - 10012@2...	0.00	0.00	1	1	LOS_A	1	0.00	0.00	0.00	0.00	0.169	0.033	0.039	0.002
24	10	198-297	1: F8 MARKAZ	167.58	504.96	71	71	LOS_E	5	56.29	56.29	40.53	1.42	125.776	24.471	29.150	1.799
25	10	297-396	1: F8 MARKAZ - 1: F8 EB...	1.70	23.23	8	8	LOS_A	1	7.83	7.83	6.75	0.12	4.067	0.791	0.943	0.058
26	10	297-396	1: F8 MARKAZ - 1: F8 EB...	1.71	23.23	12	12	LOS_B	2	14.07	14.07	9.71	0.33	8.193	1.594	1.899	0.117
27	10	297-396	1: F8 MARKAZ - 6: F8 WB...	499.62	504.89	18	18	LOS_E	5	68.63	68.63	51.38	1.28	34.980	6.806	8.107	0.500
28	10	297-396	1: F8 MARKAZ - 6: F8 WB...	490.89	500.34	4	4	LOS_B	2	18.84	18.84	9.76	0.50	3.105	0.604	0.720	0.044
29	10	297-396	1: F8 MARKAZ - 8: F8 NB...	151.77	171.36	3	3	LOS_F	6	110.28	110.28	83.53	3.00	9.792	1.905	2.269	0.140
30	10	297-396	1: F8 MARKAZ - 8: F8 NB...	126.76	146.35	10	10	LOS_F	6	100.84	100.84	77.23	2.80	30.488	5.932	7.066	0.436
31	10	297-396	1: F8 MARKAZ - 10012@2...	0.00	0.00	2	2	LOS_A	1	0.01	0.01	0.00	0.00	0.329	0.064	0.076	0.005
32	10	297-396	1: F8 MARKAZ	181.78	504.89	57	57	LOS_D	4	50.55	50.55	37.85	1.18	90.596	17.627	20.997	1.296

Figure 4-3: F8 Markaz Intersection - Unoptimized

er: 259	SimRun	TimeInt	Movement	QLen	QLenMax	Vehs(All)	Pers(All)	LOS(All)	LO...	VehDela...	PersDelay...	StopDel...	Stops(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	FuelConsumption
1	29	0-99	1: f8 markaz - 1: F8 EB@30.9 - 3: F...	10.41	19.88	8	8	LOS_A	1	0.35	0.35	0.00	0.00	2.317	0.451	0.537	0.033
2	29	0-99	1: f8 markaz - 1: F8 EB@30.9 - 7: F...	10.41	19.88	4	4	LOS_D	4	44.62	44.62	38.89	1.00	5.330	1.037	1.235	0.076
3	29	0-99	1: f8 markaz - 6: F8 WB@35.0 - 4: F...	0.00	0.00	31	31	LOS_A	1	1.48	1.48	0.00	0.00	9.405	1.830	2.180	0.135
4	29	0-99	1: f8 markaz - 6: F8 WB@35.0 - 7: F...	0.00	0.00	5	5	LOS_A	1	0.58	0.58	0.00	0.00	1.270	0.247	0.294	0.018
5	29	0-99	1: f8 markaz - 8: F8 NB@154.7 - 3:...	10.67	27.21	0	0	LOS_A									
6	29	0-99	1: f8 markaz - 8: F8 NB@154.7 - 4:...	1.79	16.64	24	24	LOS_A	1	2.47	2.47	0.09	0.12	8.180	1.592	1.896	0.117
7	29	0-99	1: f8 markaz	5.72	27.21	72	72	LOS_A	1	4.02	4.02	2.19	0.10	26.693	5.193	6.186	0.382
8	29	99-198	1: f8 markaz - 1: F8 EB@30.9 - 3: F...	0.08	5.24	14	14	LOS_A	1	1.83	1.83	0.69	0.14	5.277	1.027	1.223	0.075
9	29	99-198	1: f8 markaz - 1: F8 EB@30.9 - 7: F...	0.08	5.24	1	1	LOS_A	1	0.21	0.21	0.00	0.00	0.275	0.054	0.064	0.004
10	29	99-198	1: f8 markaz - 6: F8 WB@35.0 - 4: F...	0.00	0.00	59	59	LOS_A	1	5.08	5.08	0.00	0.02	21.523	4.188	4.988	0.308
11	29	99-198	1: f8 markaz - 6: F8 WB@35.0 - 7: F...	0.00	0.00	5	5	LOS_A	1	1.86	1.86	0.00	0.00	1.346	0.262	0.312	0.019
12	29	99-198	1: f8 markaz - 8: F8 NB@154.7 - 3:...	36.99	96.77	4	4	LOS_D	4	43.42	43.42	38.18	0.75	5.065	0.986	1.174	0.072
13	29	99-198	1: f8 markaz - 8: F8 NB@154.7 - 4:...	28.91	86.20	21	21	LOS_A	1	6.10	6.10	0.59	0.10	7.951	1.547	1.843	0.114
14	29	99-198	1: f8 markaz	16.49	96.77	104	104	LOS_A	1	6.12	6.12	1.68	0.08	41.287	8.033	9.569	0.591
15	29	198-297	1: f8 markaz - 1: F8 EB@30.9 - 3: F...	8.86	20.67	1	1	LOS_A	1	0.00	0.00	0.00	0.00	0.297	0.058	0.069	0.004
16	29	198-297	1: f8 markaz - 1: F8 EB@30.9 - 7: F...	8.86	20.67	0	0	LOS_A									
17	29	198-297	1: f8 markaz - 6: F8 WB@35.0 - 4: F...	0.00	0.00	10	10	LOS_A	1	3.22	3.22	0.00	0.00	3.251	0.633	0.754	0.047
18	29	198-297	1: f8 markaz - 6: F8 WB@35.0 - 7: F...	0.00	0.00	1	1	LOS_A	1	0.98	0.98	0.00	0.00	0.247	0.048	0.057	0.004
19	29	198-297	1: f8 markaz - 8: F8 NB@154.7 - 3:...	104.22	109.26	2	2	LOS_E	5	64.27	64.27	53.64	1.00	3.344	0.651	0.775	0.048
20	29	198-297	1: f8 markaz - 8: F8 NB@154.7 - 4:...	93.75	98.91	1	1	LOS_E	5	67.18	67.18	59.81	1.00	1.663	0.324	0.385	0.024
21	29	198-297	1: f8 markaz	51.71	109.26	15	15	LOS_B	2	15.26	15.26	11.14	0.20	8.827	1.717	2.046	0.126

Figure 4-4: F8 Markaz Intersection – Optimized

4.3.3. Faisal Mosque Intersection Analysis

ber: 624	Si...	Timel...	Movement	QLen	QLenMax	Vehs(All)	Pers(All)	LOS(All)	LOS...	VehDelay(...	PersDela...	Stop...	Stops(All)	EmissionsCO	Emissions...	Emissions...	FuelConsumption
16	21	0-94	1: Faisal Mosque	9.29	78.47	44	44	LOS_C	3	21.99	21.99	16.02	0.52	37.757	7.346	8.751	0.540
17	21	94-188	1: Faisal Mosque - 1: Faisal EB@174.2 - 7@20.4	3.67	19.19	9	9	LOS_B	2	11.92	11.92	6.97	0.44	6.193	1.205	1.435	0.089
18	21	94-188	1: Faisal Mosque - 1: Faisal EB@174.2 - 8@37.7	0.00	0.00	0	0	LOS_A									
19	21	94-188	1: Faisal Mosque - 1: Faisal EB@174.2 - 10@16.5	3.67	19.19	1	1	LOS_A	1	0.08	0.08	0.00	0.00	0.347	0.067	0.080	0.005
20	21	94-188	1: Faisal Mosque - 1: Faisal EB@174.2 - 10033@2.2	3.67	19.19	0	0	LOS_A									
21	21	94-188	1: Faisal Mosque - 2: Faisal SB@134.6 - 6@30.2	41.32	65.66	1	1	LOS_E	5	59.63	59.63	53.39	1.00	1.627	0.317	0.377	0.023
22	21	94-188	1: Faisal Mosque - 2: Faisal SB@134.6 - 7@20.4	11.03	32.59	5	5	LOS_C	3	22.74	22.74	13.50	1.20	5.815	1.131	1.348	0.083
23	21	94-188	1: Faisal Mosque - 2: Faisal SB@134.6 - 10@16.5	41.32	65.66	10	10	LOS_E	5	67.54	67.54	58.94	1.00	17.824	3.468	4.131	0.255
24	21	94-188	1: Faisal Mosque - 2: Faisal SB@134.6 - 10033@2.2	11.03	32.59	0	0	LOS_A									
25	21	94-188	1: Faisal Mosque - 3: Faisal WB@30.9 - 6@30.2	96.31	209.84	20	20	LOS_E	5	76.33	76.33	62.37	1.40	41.250	8.026	9.560	0.590
26	21	94-188	1: Faisal Mosque - 3: Faisal WB@30.9 - 8@37.7	96.31	209.84	0	0	LOS_A									
27	21	94-188	1: Faisal Mosque - 3: Faisal WB@30.9 - 10@16.5	76.56	188.89	5	5	LOS_F	6	84.08	84.08	72.22	1.40	10.507	2.044	2.435	0.150
28	21	94-188	1: Faisal Mosque - 4: Faisal NB@146.1 - 6@30.2	69.67	118.34	6	6	LOS_A	1	8.51	8.51	0.00	0.00	2.448	0.476	0.567	0.035
29	21	94-188	1: Faisal Mosque - 4: Faisal NB@146.1 - 7@20.4	105.95	154.62	8	8	LOS_E	5	63.98	63.98	49.63	1.38	15.378	2.992	3.564	0.220
30	21	94-188	1: Faisal Mosque - 4: Faisal NB@146.1 - 8@37.7	105.95	154.62	2	2	LOS_F	6	84.70	84.70	71.71	2.00	4.901	0.954	1.136	0.070
31	21	94-188	1: Faisal Mosque - 4: Faisal NB@146.1 - 10033@2.2	105.95	154.62	0	0	LOS_A									
32	21	94-188	1: Faisal Mosque	50.56	209.84	67	67	LOS_D	4	54.26	54.26	43.61	1.06	105.996	20.623	24.566	1.516
33	21	188-...	1: Faisal Mosque - 1: Faisal EB@174.2 - 7@20.4	5.62	19.56	10	10	LOS_B	2	11.23	11.23	6.90	0.50	7.104	1.382	1.647	0.102
34	21	188-...	1: Faisal Mosque - 1: Faisal EB@174.2 - 8@37.7	0.00	0.00	0	0	LOS_A									
35	21	188-...	1: Faisal Mosque - 1: Faisal EB@174.2 - 10@16.5	5.62	19.56	0	0	LOS_A									
36	21	188-...	1: Faisal Mosque - 1: Faisal EB@174.2 - 10033@2.2	5.62	19.56	0	0	LOS_A									
37	21	188-...	1: Faisal Mosque - 2: Faisal SB@134.6 - 6@30.2	102.33	148.02	2	2	LOS_F	6	98.15	98.15	81.51	2.00	5.149	1.002	1.193	0.074
38	21	188-...	1: Faisal Mosque - 2: Faisal SB@134.6 - 7@20.4	69.26	114.94	0	0	LOS_A									
39	21	188-...	1: Faisal Mosque - 2: Faisal SB@134.6 - 10@16.5	102.33	148.02	10	10	LOS_F	6	101.55	101.55	86.02	1.80	26.180	5.094	6.067	0.375
40	21	188-...	1: Faisal Mosque - 2: Faisal SB@134.6 - 10033@2.2	69.26	114.94	0	0	LOS_A									
41	21	188-...	1: Faisal Mosque - 3: Faisal WB@30.9 - 6@30.2	195.59	215.97	18	18	LOS_F	6	93.20	93.20	79.14	1.39	41.332	8.042	9.579	0.591
42	21	188-...	1: Faisal Mosque - 3: Faisal WB@30.9 - 8@37.7	195.59	215.97	1	1	LOS_E	5	72.88	72.88	52.97	1.00	1.872	0.364	0.434	0.027
43	21	188-...	1: Faisal Mosque - 3: Faisal WB@30.9 - 10@16.5	174.64	195.02	5	5	LOS_F	6	96.48	96.48	82.41	1.80	12.668	2.465	2.936	0.181
44	21	188-...	1: Faisal Mosque - 4: Faisal NB@146.1 - 6@30.2	138.73	152.05	0	0	LOS_A									
45	21	188-...	1: Faisal Mosque - 4: Faisal NB@146.1 - 7@20.4	174.94	188.33	7	7	LOS_F	6	137.49	137.49	111.30	3.14	26.297	5.116	6.095	0.376
46	21	188-...	1: Faisal Mosque - 4: Faisal NB@146.1 - 8@37.7	174.94	188.33	0	0	LOS_A									
47	21	188-...	1: Faisal Mosque - 4: Faisal NB@146.1 - 10033@2.2	174.94	188.33	0	0	LOS_A									
48	21	188-...	1: Faisal Mosque	107.64	215.97	53	53	LOS_F	6	95.37	95.37	79.06	1.58	120.685	23.481	27.970	1.737

Faisal Mosque Intersection – Unoptimized

umb...	Si	Timel...	Movement	QLen	QLenMax	Vehs(All)	Per...	LOS(All)	LOSVal(...	VehDelay...	PersDelay...	StopDelay...	Stops...	EmissionsCO	EmissionsNOx	EmissionsVOC	FuelConsumption
19	1	94-188	1: Faisal Mosque - 1: Faisal EB@183.7 - 10@3.5	12.35	37.42	0	0	LOS_A									
20	1	94-188	1: Faisal Mosque - 1: Faisal EB@183.7 - 10033...	12.35	37.42	0	0	LOS_A									
21	1	94-188	1: Faisal Mosque - 2: Faisal SB@138.3 - 6@21.5	39.19	84.86	2	2	LOS_D	4	43.51	43.51	37.70	1.00	2.736	0.532	0.634	0.039
22	1	94-188	1: Faisal Mosque - 2: Faisal SB@138.3 - 7@19.2	13.87	52.10	2	2	LOS_D	4	48.31	48.31	42.15	1.00	2.743	0.534	0.636	0.039
23	1	94-188	1: Faisal Mosque - 2: Faisal SB@138.3 - 10@3.5	39.19	84.86	14	14	LOS_D	4	45.11	45.11	36.97	0.93	19.561	3.806	4.533	0.280
24	1	94-188	1: Faisal Mosque - 2: Faisal SB@138.3 - 10033...	13.87	52.10	0	0	LOS_A									
25	1	94-188	1: Faisal Mosque - 3: Faisal WB@31.0 - 6@21.5	6.14	19.64	26	26	LOS_C	3	32.14	32.14	22.93	0.54	26.229	5.103	6.079	0.375
26	1	94-188	1: Faisal Mosque - 3: Faisal WB@31.0 - 8@33.1	6.14	19.64	1	1	LOS_E	5	64.80	64.80	48.78	1.00	1.749	0.340	0.405	0.025
27	1	94-188	1: Faisal Mosque - 3: Faisal WB@31.0 - 10@3.5	0.00	0.00	8	8	LOS_C	3	24.10	24.10	16.43	0.50	6.620	1.288	1.534	0.095
28	1	94-188	1: Faisal Mosque - 4: Faisal NB@159.0 - 7@19.2	102.83	151.65	7	7	LOS_E	5	79.92	79.92	60.83	1.71	15.756	3.066	3.652	0.225
29	1	94-188	1: Faisal Mosque - 4: Faisal NB@159.0 - 8@33.1	102.83	151.65	0	0	LOS_A									
30	1	94-188	1: Faisal Mosque - 4: Faisal NB@159.0 - 10033...	102.83	151.65	0	0	LOS_A									
31	1	94-188	1: Faisal Mosque - 10009@0.3 - 6@21.5	79.66	128.44	6	6	LOS_A	1	6.61	6.61	1.01	0.17	2.509	0.488	0.581	0.036
32	1	94-188	1: Faisal Mosque	31.98	151.65	76	76	LOS_D	4	38.08	38.08	28.67	0.78	90.985	17.702	21.087	1.302
33	1	188-...	1: Faisal Mosque - 1: Faisal EB@183.7 - 7@19.2	11.05	31.09	12	12	LOS_C	3	34.74	34.74	22.49	0.83	14.195	2.762	3.290	0.203
34	1	188-...	1: Faisal Mosque - 1: Faisal EB@183.7 - 8@33.1	1.67	8.21	0	0	LOS_A									
35	1	188-...	1: Faisal Mosque - 1: Faisal EB@183.7 - 10@3.5	11.05	31.09	1	1	LOS_E	5	77.62	77.62	72.28	1.00	1.898	0.369	0.440	0.027
36	1	188-...	1: Faisal Mosque - 1: Faisal EB@183.7 - 10033...	11.05	31.09	0	0	LOS_A									
37	1	188-...	1: Faisal Mosque - 2: Faisal SB@138.3 - 6@21.5	85.51	134.00	3	3	LOS_D	4	54.27	54.27	45.88	1.00	4.594	0.894	1.065	0.066
38	1	188-...	1: Faisal Mosque - 2: Faisal SB@138.3 - 7@19.2	52.80	101.24	6	6	LOS_E	5	71.63	71.63	60.52	1.67	12.491	2.430	2.895	0.179
39	1	188-...	1: Faisal Mosque - 2: Faisal SB@138.3 - 10@3.5	85.51	134.00	11	11	LOS_E	5	67.61	67.61	59.49	1.00	19.116	3.719	4.430	0.273
40	1	188-...	1: Faisal Mosque - 2: Faisal SB@138.3 - 10033...	52.80	101.24	0	0	LOS_A									
41	1	188-...	1: Faisal Mosque - 3: Faisal WB@31.0 - 6@21.5	9.94	27.47	27	27	LOS_D	4	35.91	35.91	27.22	0.67	30.362	5.907	7.037	0.434
42	1	188-...	1: Faisal Mosque - 3: Faisal WB@31.0 - 8@33.1	9.94	27.47	3	3	LOS_C	3	24.65	24.65	17.77	0.33	2.518	0.490	0.584	0.036
43	1	188-...	1: Faisal Mosque - 3: Faisal WB@31.0 - 10@3.5	0.05	5.32	6	6	LOS_F	6	83.61	83.61	68.16	1.83	13.730	2.671	3.182	0.196
44	1	188-...	1: Faisal Mosque - 4: Faisal NB@159.0 - 7@19.2	175.11	186.57	8	8	LOS_F	6	149.62	149.62	119.98	2.88	30.144	5.865	6.986	0.431
45	1	188-...	1: Faisal Mosque - 4: Faisal NB@159.0 - 8@33.1	175.11	186.57	0	0	LOS_A									
46	1	188-...	1: Faisal Mosque - 4: Faisal NB@159.0 - 10033...	175.11	186.57	0	0	LOS_A									
47	1	188-...	1: Faisal Mosque - 10009@0.3 - 6@21.5	151.90	163.36	0	0	LOS_A									
48	1	188-...	1: Faisal Mosque	61.01	186.57	77	77	LOS_E	5	59.39	59.39	47.46	1.14	129.190	25.136	29.941	1.848
49	1	282-...	1: Faisal Mosque - 1: Faisal EB@183.7 - 7@19.2	24.41	38.65	0	0	LOS_A									
50	1	282-...	1: Faisal Mosque - 1: Faisal EB@183.7 - 8@33.1	6.45	15.77	0	0	LOS_A									

Fig 4.6 Faisal Mosque Intersection – Optimized

4.3.4. Aurangzeb Road Intersection Analysis

: 741	Si...	Timel...	Movement	QLen	QLenMax	Vehs(All)	Pers(All)	LOS(All)	LOS...	VehDelay(...	PersDela...	Stop...	Stops(All)	EmissionsCO	Emissions...	Emissions...	FuelConsumption
22	22	94-188	1: Aurangzeb Intersection - 12: Aurangzeb road S...	20.29	34.88	1	1	LOS_E	5	74.04	74.04	66.28	1.00	1.751	0.341	0.406	0.025
23	22	94-188	1: Aurangzeb Intersection - 13: Aur EB@0.8 - 11:...	2.43	11.83	5	5	LOS_C	3	22.52	22.52	11.21	1.40	6.337	1.233	1.469	0.091
24	22	94-188	1: Aurangzeb Intersection - 13: Aur EB@0.8 - 14@...	2.43	11.83	11	11	LOS_C	3	26.50	26.50	18.34	0.91	12.016	2.338	2.785	0.172
25	22	94-188	1: Aurangzeb Intersection - 13: Aur EB@0.8 - 17@...	2.43	11.83	6	6	LOS_E	5	61.00	61.00	49.58	0.83	9.522	1.853	2.207	0.136
26	22	94-188	1: Aurangzeb Intersection - 16: AUR WB@111.4 -...	130.05	157.53	17	17	LOS_F	6	113.86	113.86	89.52	2.24	50.048	9.737	11.599	0.716
27	22	94-188	1: Aurangzeb Intersection - 16: AUR WB@111.4 -...	130.05	157.53	1	1	LOS_F	6	126.70	126.70	101.97	3.00	3.474	0.676	0.805	0.050
28	22	94-188	1: Aurangzeb Intersection - 16: AUR WB@111.4 -...	100.09	127.19	4	4	LOS_F	6	86.60	86.60	61.51	1.75	9.413	1.831	2.182	0.135
29	22	94-188	1: Aurangzeb Intersection - 18: AUR NB@59.6 - 3:...	86.08	90.79	2	2	LOS_F	6	120.68	120.68	109.55	2.00	5.629	1.095	1.305	0.081
30	22	94-188	1: Aurangzeb Intersection - 18: AUR NB@59.6 - 1...	86.08	90.79	1	1	LOS_E	5	66.85	66.85	57.51	1.00	1.636	0.318	0.379	0.023
31	22	94-188	1: Aurangzeb Intersection - 18: AUR NB@59.6 - 1...	86.08	90.79	0	0	LOS_A									
32	22	94-188	1: Aurangzeb Intersection - 10032@11.5 - 3: Faisa...	130.05	157.53	0	0	LOS_A									
33	22	94-188	1: Aurangzeb Intersection - 10032@11.5 - 11: Aur...	130.05	157.53	0	0	LOS_A									
34	22	94-188	1: Aurangzeb Intersection - 10032@11.5 - 17@29.5	100.07	127.16	0	0	LOS_A									
35	22	94-188	1: Aurangzeb Intersection - 10033@5.8 - 11: Aura...	2.43	11.83	0	0	LOS_A									
36	22	94-188	1: Aurangzeb Intersection - 10033@5.8 - 14@28.4	2.43	11.83	0	0	LOS_A									
37	22	94-188	1: Aurangzeb Intersection - 10033@5.8 - 17@29.5	2.43	11.83	0	0	LOS_A									
38	22	94-188	1: Aurangzeb Intersection	62.71	157.53	53	53	LOS_E	5	70.88	70.88	54.81	1.51	105.723	20.570	24.502	1.512
39	22	188-...	1: Aurangzeb Intersection - 12: Aurangzeb road S...	19.73	33.99	2	2	LOS_F	6	84.41	84.41	71.71	1.00	3.835	0.746	0.889	0.055
40	22	188-...	1: Aurangzeb Intersection - 12: Aurangzeb road S...	0.00	0.00	3	3	LOS_D	4	45.42	45.42	37.97	0.67	3.433	0.668	0.796	0.049
41	22	188-...	1: Aurangzeb Intersection - 12: Aurangzeb road S...	19.73	33.99	1	1	LOS_F	6	87.13	87.13	76.90	1.00	1.903	0.370	0.441	0.027
42	22	188-...	1: Aurangzeb Intersection - 13: Aur EB@0.8 - 11:...	3.17	39.03	2	2	LOS_C	3	23.24	23.24	14.57	1.00	2.141	0.417	0.496	0.031
43	22	188-...	1: Aurangzeb Intersection - 13: Aur EB@0.8 - 14@...	3.17	39.03	11	11	LOS_C	3	34.32	34.32	23.99	1.27	15.285	2.974	3.542	0.219
44	22	188-...	1: Aurangzeb Intersection - 13: Aur EB@0.8 - 17@...	3.17	39.03	5	5	LOS_F	6	125.09	125.09	102.54	2.80	16.965	3.301	3.932	0.243
45	22	188-...	1: Aurangzeb Intersection - 16: AUR WB@111.4 -...	126.30	146.68	18	18	LOS_F	6	148.79	148.79	119.10	3.22	70.870	13.789	16.425	1.014
46	22	188-...	1: Aurangzeb Intersection - 16: AUR WB@111.4 -...	126.30	146.68	0	0	LOS_A									
47	22	188-...	1: Aurangzeb Intersection - 16: AUR WB@111.4 -...	96.82	116.33	1	1	LOS_F	6	146.03	146.03	116.43	4.00	4.099	0.798	0.950	0.059
48	22	188-...	1: Aurangzeb Intersection - 18: AUR NB@59.6 - 3:...	81.56	88.19	1	1	LOS_F	6	194.57	194.57	177.79	3.00	4.390	0.854	1.018	0.063
49	22	188-...	1: Aurangzeb Intersection - 18: AUR NB@59.6 - 1...	81.56	88.19	2	2	LOS_F	6	136.95	136.95	120.08	2.00	6.516	1.268	1.510	0.093
50	22	188-...	1: Aurangzeb Intersection - 18: AUR NB@59.6 - 1...	81.56	88.19	1	1	LOS_F	6	140.52	140.52	125.64	2.00	3.137	0.610	0.727	0.045

Fig 4.7 Aurangzeb Road Intersection - Unoptimized

Numb...	Si	TimeInt	Movement	QLen	QLenMax	Vehs(All)	Per...	LOS(All)	LOSVal(...	VehDelay...	PersDelay...	StopDelay...	Stops...	EmissionsCO	EmissionsNOx	EmissionsVOC	FuelConsumption
2	1	0-94	1: Aurangzeb Road - 12: Aurangzeb road SB 1...	4.67	18.70	0	0	LOS_A									
3	1	0-94	1: Aurangzeb Road - 12: Aurangzeb road SB 1...	26.23	50.24	1	1	LOS_E	5	73.55	73.55	64.73	1.00	1.830	0.356	0.424	0.026
4	1	0-94	1: Aurangzeb Road - 13: Aur EB@9.1 - 11: Aura...	12.77	19.48	0	0	LOS_A									
5	1	0-94	1: Aurangzeb Road - 13: Aur EB@9.1 - 14@28.3	12.77	19.48	0	0	LOS_A									
6	1	0-94	1: Aurangzeb Road - 13: Aur EB@9.1 - 17@34.8	12.77	19.48	0	0	LOS_A									
7	1	0-94	1: Aurangzeb Road - 16: AUR WB@110.7 - 3: F...	69.12	147.05	31	31	LOS_C	3	20.37	20.37	5.90	1.68	42.041	8.180	9.743	0.601
8	1	0-94	1: Aurangzeb Road - 16: AUR WB@110.7 - 11:...	69.12	147.05	1	1	LOS_C	3	22.21	22.21	5.89	2.00	1.530	0.298	0.355	0.022
9	1	0-94	1: Aurangzeb Road - 16: AUR WB@110.7 - 17...	48.01	115.18	4	4	LOS_C	3	24.06	24.06	4.76	1.50	5.314	1.034	1.232	0.076
10	1	0-94	1: Aurangzeb Road - 18: AUR NB@54.0 - 3: Fai...	15.42	58.29	0	0	LOS_A									
11	1	0-94	1: Aurangzeb Road - 18: AUR NB@54.0 - 11: A...	37.74	90.24	1	1	LOS_E	5	55.74	55.74	48.89	1.00	1.465	0.285	0.340	0.021
12	1	0-94	1: Aurangzeb Road - 18: AUR NB@54.0 - 14@2...	37.74	90.24	0	0	LOS_A									
13	1	0-94	1: Aurangzeb Road - 10032@10.7 - 3: Faisal W...	69.12	147.05	0	0	LOS_A									
14	1	0-94	1: Aurangzeb Road - 10032@10.7 - 11: Aurang...	69.12	147.05	0	0	LOS_A									
15	1	0-94	1: Aurangzeb Road - 10032@10.7 - 17@34.8	52.55	115.00	0	0	LOS_A									
16	1	0-94	1: Aurangzeb Road	33.31	147.05	38	38	LOS_C	3	23.14	23.14	8.46	1.63	52.197	10.156	12.097	0.747
17	1	94-188	1: Aurangzeb Road - 12: Aurangzeb road SB 1...	61.68	86.98	2	2	LOS_F	6	138.36	138.36	121.57	2.50	6.589	1.282	1.527	0.094
18	1	94-188	1: Aurangzeb Road - 12: Aurangzeb road SB 1...	30.02	55.45	0	0	LOS_A									
19	1	94-188	1: Aurangzeb Road - 12: Aurangzeb road SB 1...	61.68	86.98	1	1	LOS_F	6	109.87	109.87	85.96	3.00	3.193	0.621	0.740	0.046
20	1	94-188	1: Aurangzeb Road - 13: Aur EB@9.1 - 11: Aura...	11.66	32.53	5	5	LOS_D	4	54.33	54.33	40.99	1.20	8.099	1.576	1.877	0.116
21	1	94-188	1: Aurangzeb Road - 13: Aur EB@9.1 - 14@28.3	11.66	32.53	11	11	LOS_D	4	51.70	51.70	41.88	1.09	16.627	3.235	3.854	0.238
22	1	94-188	1: Aurangzeb Road - 13: Aur EB@9.1 - 17@34.8	11.66	32.53	3	3	LOS_E	5	59.59	59.59	45.18	1.33	5.169	1.006	1.198	0.074
23	1	94-188	1: Aurangzeb Road - 16: AUR WB@110.7 - 3: F...	100.15	146.91	36	36	LOS_E	5	64.00	64.00	40.89	1.75	72.909	14.185	16.897	1.043
24	1	94-188	1: Aurangzeb Road - 16: AUR WB@110.7 - 11:...	100.15	146.91	0	0	LOS_A									
25	1	94-188	1: Aurangzeb Road - 16: AUR WB@110.7 - 17...	74.56	115.04	3	3	LOS_E	5	68.10	68.10	45.42	2.00	6.667	1.297	1.545	0.095
26	1	94-188	1: Aurangzeb Road - 18: AUR NB@54.0 - 3: Fai...	53.20	60.00	0	0	LOS_A									
27	1	94-188	1: Aurangzeb Road - 18: AUR NB@54.0 - 11: A...	85.15	91.96	0	0	LOS_A									
28	1	94-188	1: Aurangzeb Road - 18: AUR NB@54.0 - 14@2...	85.15	91.96	0	0	LOS_A									
29	1	94-188	1: Aurangzeb Road - 10032@10.7 - 3: Faisal W...	100.15	146.91	0	0	LOS_A									
30	1	94-188	1: Aurangzeb Road - 10032@10.7 - 11: Aurang...	100.15	146.91	0	0	LOS_A									
31	1	94-188	1: Aurangzeb Road - 10032@10.7 - 17@34.8	74.40	114.86	0	0	LOS_A									
32	1	94-188	1: Aurangzeb Road	61.35	146.91	61	61	LOS_E	5	64.16	64.16	44.89	1.62	119.123	23.177	27.608	1.704
33	1	188-282	1: Aurangzeb Road - 12: Aurangzeb road SB 1...	49.25	81.64	3	3	LOS_F	6	90.95	90.95	68.91	2.33	7.847	1.527	1.819	0.112

Fig 4.8 Aurangzeb Intersection – Optimized

4.3.5. Siachen Road Intersection Analysis

ber: 637	Si...	TimeInt	Movement	QLen	QLenMax	Vehs...	Pers(All)	LOS(All)	LO...	VehD...	PersDel...	StopDelay(...	Stop...	EmissionsCO	EmissionsNOx	EmissionsVOC	FuelConsumption
22	8	74-148	1: SIACHEN RD - 7: Siachen NB@42.8 - 15@9.6	11.43	31.45	1	1	LOS_E	5	56.95	56.95	51.11	1.00	1.484	0.289	0.344	0.02
23	8	74-148	1: SIACHEN RD - 9: Siachen WB@38.7 - 2@21.2	267.40	286.92	0	0	LOS_A									
24	8	74-148	1: SIACHEN RD - 9: Siachen WB@38.7 - 6: B WB...	267.40	286.92	16	16	LOS_F	6	81.57	81.57	65.15	2.12	39.127	7.613	9.068	0.56
25	8	74-148	1: SIACHEN RD - 9: Siachen WB@38.7 - 8@30.8	267.40	286.92	1	1	LOS_E	5	65.25	65.25	49.47	1.00	1.706	0.332	0.395	0.02
26	8	74-148	1: SIACHEN RD	48.84	286.92	50	50	LOS_D	4	39.21	39.21	29.57	1.14	67.868	13.205	15.729	0.97
27	8	148-222	1: SIACHEN RD - 1: Siachen EB@363.3 - 2@21.2	140.28	190.72	6	6	LOS_D	4	39.77	39.77	31.89	1.00	7.806	1.519	1.809	0.11
28	8	148-222	1: SIACHEN RD - 1: Siachen EB@363.3 - 8@30.8	161.95	212.39	5	5	LOS_D	4	38.23	38.23	30.18	1.00	6.527	1.270	1.513	0.09
29	8	148-222	1: SIACHEN RD - 1: Siachen EB@363.3 - 15@9.6	161.95	212.39	14	14	LOS_D	4	38.68	38.68	30.42	1.00	17.951	3.493	4.160	0.25
30	8	148-222	1: SIACHEN RD - 3: Siachen SB@58.0 - 6: B WB...	3.69	13.56	2	2	LOS_C	3	23.92	23.92	18.08	1.00	2.092	0.407	0.485	0.03
31	8	148-222	1: SIACHEN RD - 3: Siachen SB@58.0 - 8@30.8	0.00	0.00	0	0	LOS_A									
32	8	148-222	1: SIACHEN RD - 3: Siachen SB@58.0 - 15@9.6	0.00	0.00	2	2	LOS_A	1	1.36	1.36	0.00	0.00	0.467	0.091	0.108	0.00
33	8	148-222	1: SIACHEN RD - 7: Siachen NB@42.8 - 2@21.2	1.02	6.71	1	1	LOS_B	2	18.73	18.73	9.71	1.00	0.959	0.187	0.222	0.01
34	8	148-222	1: SIACHEN RD - 7: Siachen NB@42.8 - 6: B WB...	0.00	0.00	4	4	LOS_A	1	0.00	0.00	0.00	0.00	0.697	0.136	0.162	0.01
35	8	148-222	1: SIACHEN RD - 7: Siachen NB@42.8 - 15@9.6	1.02	6.71	0	0	LOS_A									
36	8	148-222	1: SIACHEN RD - 9: Siachen WB@38.7 - 2@21.2	271.00	287.38	0	0	LOS_A									
37	8	148-222	1: SIACHEN RD - 9: Siachen WB@38.7 - 6: B WB...	271.00	287.38	15	15	LOS_F	6	129.31	129.31	104.12	2.80	52.121	10.141	12.080	0.74
38	8	148-222	1: SIACHEN RD - 9: Siachen WB@38.7 - 8@30.8	271.00	287.38	1	1	LOS_E	5	66.74	66.74	49.86	1.00	1.666	0.324	0.386	0.02
39	8	148-222	1: SIACHEN RD	82.56	287.38	50	50	LOS_E	5	60.94	60.94	48.51	1.42	89.800	17.472	20.812	1.28
40	8	222-296	1: SIACHEN RD - 1: Siachen EB@363.3 - 2@21.2	256.66	352.00	5	5	LOS_E	5	67.08	67.08	51.31	1.60	9.678	1.883	2.243	0.13
41	8	222-296	1: SIACHEN RD - 1: Siachen EB@363.3 - 8@30.8	278.33	373.67	2	2	LOS_E	5	76.73	76.73	60.33	2.00	4.647	0.904	1.077	0.06
42	8	222-296	1: SIACHEN RD - 1: Siachen EB@363.3 - 15@9.6	278.33	373.67	15	15	LOS_E	5	65.40	65.40	50.41	1.53	29.155	5.672	6.757	0.41
43	8	222-296	1: SIACHEN RD - 3: Siachen SB@58.0 - 6: B WB...	9.92	19.94	1	1	LOS_D	4	38.59	38.59	34.12	1.00	1.268	0.247	0.294	0.01
44	8	222-296	1: SIACHEN RD - 3: Siachen SB@58.0 - 8@30.8	0.00	0.00	0	0	LOS_A									
45	8	222-296	1: SIACHEN RD - 3: Siachen SB@58.0 - 15@9.6	0.00	0.00	1	1	LOS_A	1	0.03	0.03	0.00	0.00	0.207	0.040	0.048	0.00
46	8	222-296	1: SIACHEN RD - 7: Siachen NB@42.8 - 2@21.2	10.14	25.99	2	2	LOS_D	4	35.86	35.86	27.44	1.00	2.486	0.484	0.576	0.03
47	8	222-296	1: SIACHEN RD - 7: Siachen NB@42.8 - 6: B WB...	0.00	0.00	5	5	LOS_B	2	12.30	12.30	9.09	0.40	2.729	0.531	0.632	0.03
48	8	222-296	1: SIACHEN RD - 7: Siachen NB@42.8 - 15@9.6	10.14	25.99	0	0	LOS_A									
49	8	222-296	1: SIACHEN RD - 9: Siachen WB@38.7 - 2@21.2	276.19	283.16	0	0	LOS_A									
50	8	222-296	1: SIACHEN RD - 9: Siachen WB@38.7 - 6: B WB...	276.19	283.16	14	14	LOS_F	6	144.66	144.66	121.62	2.64	50.076	9.743	11.606	0.71
51	8	222-296	1: SIACHEN RD - 9: Siachen WB@38.7 - 8@30.8	276.19	283.16	0	0	LOS_A									
52	8	222-296	1: SIACHEN RD	118.75	373.67	45	45	LOS_F	6	81.48	81.48	66.01	1.71	100.513	19.556	23.295	1.43
53	8	296-370	1: SIACHEN RD - 1: Siachen EB@363.3 - 2@21.2	447.71	504.75	4	4	LOS_F	6	106.15	106.15	88.73	2.00	10.966	2.134	2.541	0.15
54	8	296-370	1: SIACHEN RD - 1: Siachen EB@363.3 - 8@30.8	459.99	504.22	5	5	LOS_F	6	85.22	85.22	70.14	1.80	11.639	2.265	2.697	0.16
55	8	296-370	1: SIACHEN RD - 1: Siachen EB@363.3 - 15@9.6	459.99	504.22	12	12	LOS_F	6	87.04	87.04	71.41	1.67	27.887	5.426	6.463	0.39
56	8	296-370	1: SIACHEN RD - 3: Siachen SB@58.0 - 6: B WB...	9.04	19.02	3	3	LOS_E	5	62.99	62.99	56.74	1.00	4.881	0.950	1.131	0.07

Fig 4.9 Siachen Road Intersection - Unoptimized

: 637	Si	TimeInt	Movement	QLen	QLenMax	Vehs(All)	Pers(All)	LOS(All)	LO...	VehDela...	PersDelay(...	StopD...	Stops(All)	EmissionsCO	EmissionsN...	EmissionsVOC	FuelConsumption
10	2	0-74	1: SIACHEN RD - 9: Siachen WB@38.1 - 2@16.3	43.90	171.78	1	1	LOS_A	1	0.01	0.01	0.00	0.00	0.319	0.062	0.074	0.005
11	2	0-74	1: SIACHEN RD - 9: Siachen WB@38.1 - 6: B W...	43.90	171.78	15	15	LOS_A	1	2.16	2.16	0.00	0.00	4.715	0.917	1.093	0.067
12	2	0-74	1: SIACHEN RD - 9: Siachen WB@38.1 - 8@20.4	27.67	141.28	1	1	LOS_A	1	0.00	0.00	0.00	0.00	0.282	0.055	0.065	0.004
13	2	0-74	1: SIACHEN RD	12.44	171.78	30	30	LOS_A	1	5.17	5.17	3.06	0.13	12.145	2.363	2.815	0.174
14	2	74-148	1: SIACHEN RD - 1: Siachen EB@370.8 - 2@16.3	32.54	83.47	4	4	LOS_C	3	22.62	22.62	15.04	1.00	4.205	0.818	0.975	0.060
15	2	74-148	1: SIACHEN RD - 1: Siachen EB@370.8 - 8@20.4	32.54	83.47	9	9	LOS_B	2	19.74	19.74	11.73	0.89	8.650	1.683	2.005	0.124
16	2	74-148	1: SIACHEN RD - 1: Siachen EB@370.8 - 15@1...	32.54	83.47	18	18	LOS_B	2	19.08	19.08	11.32	0.61	14.951	2.909	3.465	0.214
17	2	74-148	1: SIACHEN RD - 3: Siachen SB@62.6 - 6: B W...	4.39	12.37	1	1	LOS_D	4	42.19	42.19	37.69	1.00	1.284	0.250	0.298	0.018
18	2	74-148	1: SIACHEN RD - 3: Siachen SB@62.6 - 8@20.4	0.00	0.00	0	0	LOS_A									
19	2	74-148	1: SIACHEN RD - 3: Siachen SB@62.6 - 15@10.8	0.00	0.00	2	2	LOS_A	1	0.04	0.04	0.00	0.00	0.418	0.081	0.097	0.006
20	2	74-148	1: SIACHEN RD - 7: Siachen NB@53.3 - 2@16.3	13.58	31.43	2	2	LOS_C	3	25.60	25.60	18.55	0.50	1.607	0.313	0.372	0.023
21	2	74-148	1: SIACHEN RD - 7: Siachen NB@53.3 - 6: B W...	2.69	11.50	2	2	LOS_B	2	12.91	12.91	7.81	0.50	1.166	0.227	0.270	0.017
22	2	74-148	1: SIACHEN RD - 7: Siachen NB@53.3 - 15@1...	13.58	31.43	1	1	LOS_E	5	61.44	61.44	55.48	1.00	1.550	0.302	0.359	0.022
23	2	74-148	1: SIACHEN RD - 9: Siachen WB@38.1 - 2@16.3	153.63	173.53	0	0	LOS_A									
24	2	74-148	1: SIACHEN RD - 9: Siachen WB@38.1 - 6: B W...	153.63	173.53	16	16	LOS_D	4	54.70	54.70	46.84	1.00	24.500	4.767	5.678	0.351
25	2	74-148	1: SIACHEN RD - 9: Siachen WB@38.1 - 8@20.4	123.14	143.03	2	2	LOS_D	4	54.51	54.51	37.99	1.00	2.975	0.579	0.690	0.043
26	2	74-148	1: SIACHEN RD	47.14	173.53	57	57	LOS_C	3	31.17	31.17	23.52	0.79	61.250	11.917	14.195	0.876
27	2	148-222	1: SIACHEN RD - 1: Siachen EB@370.8 - 2@16.3	129.86	207.72	9	9	LOS_D	4	44.23	44.23	33.92	1.00	12.090	2.352	2.802	0.173
28	2	148-222	1: SIACHEN RD - 1: Siachen EB@370.8 - 8@20.4	129.86	207.72	3	3	LOS_D	4	40.74	40.74	32.44	1.00	3.925	0.764	0.910	0.056
29	2	148-222	1: SIACHEN RD - 1: Siachen EB@370.8 - 15@1...	129.86	207.72	19	19	LOS_D	4	38.20	38.20	27.55	1.00	24.434	4.754	5.663	0.350
30	2	148-222	1: SIACHEN RD - 3: Siachen SB@62.6 - 6: B W...	5.58	13.37	2	2	LOS_D	4	35.12	35.12	29.60	1.00	2.338	0.455	0.542	0.033
31	2	148-222	1: SIACHEN RD - 3: Siachen SB@62.6 - 8@20.4	0.00	0.00	0	0	LOS_A									
32	2	148-222	1: SIACHEN RD - 3: Siachen SB@62.6 - 15@10.8	0.00	0.00	2	2	LOS_A	1	0.35	0.35	0.00	0.00	0.442	0.086	0.102	0.006
33	2	148-222	1: SIACHEN RD - 7: Siachen NB@53.3 - 2@16.3	1.40	6.68	2	2	LOS_C	3	22.54	22.54	14.38	1.00	1.948	0.379	0.452	0.028
34	2	148-222	1: SIACHEN RD - 7: Siachen NB@53.3 - 6: B W...	0.00	0.00	6	6	LOS_A	1	5.47	5.47	2.64	0.17	1.920	0.374	0.445	0.027
35	2	148-222	1: SIACHEN RD - 7: Siachen NB@53.3 - 15@1...	1.40	6.68	0	0	LOS_A									
36	2	148-222	1: SIACHEN RD - 9: Siachen WB@38.1 - 2@16.3	158.01	168.67	0	0	LOS_A									
37	2	148-222	1: SIACHEN RD - 9: Siachen WB@38.1 - 6: B W...	158.01	168.67	16	16	LOS_F	6	108.78	108.78	89.71	2.19	45.936	8.937	10.646	0.657
38	2	148-222	1: SIACHEN RD - 9: Siachen WB@38.1 - 8@20.4	127.51	138.18	0	0	LOS_A									
39	2	148-222	1: SIACHEN RD	60.34	207.72	59	59	LOS_D	4	53.14	53.14	41.78	1.20	92.794	18.054	21.506	1.328
40	2	222-296	1: SIACHEN RD - 1: Siachen EB@370.8 - 2@16.3	185.58	254.33	9	9	LOS_D	4	46.90	46.90	35.06	1.22	13.602	2.647	3.152	0.195
41	2	222-296	1: SIACHEN RD - 1: Siachen EB@370.8 - 8@20.4	185.58	254.33	5	5	LOS_D	4	41.91	41.91	32.67	1.00	6.643	1.292	1.540	0.095

Fig 4.10 Siachen Road Intersection – Optimized

4.3.6. Pir Sohawa Intersection Analysis

: 9...	TimeInt	Movement	QLen	QLenMax	Vehs(All)	Pers(All)	LOS(All)	LOSVal...	VehD...	PersDelay(All)	StopDelay(All)	Stops(All)	EmissionsCO	Emissions...	EmissionsVOC	FuelConsumption
49	184-276	1: PIRSOHAWA - 2: EB@13.6 - 6@69.8	14.62	32.76	4	4	LOS_B	2	18.13	18.13	12.14	0.50	3.718	0.723	0.862	0.053
50	184-276	1: PIRSOHAWA - 2: EB@13.6 - 8@28.7	14.62	32.76	16	16	LOS_D	4	50.45	50.45	41.37	1.06	26.034	5.065	6.034	0.372
51	184-276	1: PIRSOHAWA - 2: EB@13.6 - 13@33.1	14.62	32.76	2	2	LOS_D	4	38.14	38.14	26.83	1.00	2.930	0.570	0.679	0.042
52	184-276	1: PIRSOHAWA - 2: EB@13.6 - 15@43.2	14.62	32.76	6	6	LOS_C	3	26.93	26.93	20.84	0.83	6.599	1.284	1.529	0.094
53	184-276	1: PIRSOHAWA - 7: SB@24.8 - 3@30.1	1.59	6.28	2	2	LOS_A	1	3.79	3.79	0.00	0.00	0.846	0.165	0.196	0.012
54	184-276	1: PIRSOHAWA - 7: SB@24.8 - 8@28.7	0.00	0.00	1	1	LOS_A	1	0.01	0.01	0.00	0.00	0.192	0.037	0.045	0.003
55	184-276	1: PIRSOHAWA - 7: SB@24.8 - 13@33.1	1.59	6.28	1	1	LOS_E	5	56.85	56.85	47.20	1.00	1.547	0.301	0.359	0.022
56	184-276	1: PIRSOHAWA - 7: SB@24.8 - 15@43.2	1.59	6.28	0	0	LOS_A									
57	184-276	1: PIRSOHAWA - 9: WB@269.7 - 3@30.1	296.85	302.09	12	12	LOS_F	6	165.35	165.35	132.84	3.92	55.368	10.773	12.832	0.792
58	184-276	1: PIRSOHAWA - 9: WB@269.7 - 6@69.8	296.85	302.09	0	0	LOS_A									
59	184-276	1: PIRSOHAWA - 9: WB@269.7 - 15@4...	296.85	302.09	1	1	LOS_F	6	201.91	201.91	166.58	4.00	5.332	1.037	1.236	0.076
60	184-276	1: PIRSOHAWA - 12: NB2@11.7 - 3@3...	5.87	24.70	4	4	LOS_B	2	16.95	16.95	7.30	1.00	4.217	0.821	0.977	0.060
61	184-276	1: PIRSOHAWA - 12: NB2@11.7 - 6@6...	11.51	25.77	2	2	LOS_C	3	34.86	34.86	27.64	1.00	2.579	0.502	0.598	0.037
62	184-276	1: PIRSOHAWA - 12: NB2@11.7 - 8@2...	11.51	25.77	3	3	LOS_D	4	50.78	50.78	44.02	1.00	4.394	0.855	1.018	0.063
63	184-276	1: PIRSOHAWA - 12: NB2@11.7 - 15@...	0.00	0.00	0	0	LOS_A									
64	184-276	1: PIRSOHAWA - 14: NB1@53.6 - 3@3...	11.47	31.24	42	42	LOS_A	1	5.05	5.05	0.41	0.12	13.658	2.657	3.165	0.195
65	184-276	1: PIRSOHAWA - 14: NB1@53.6 - 6@6...	49.29	68.62	0	0	LOS_A									
66	184-276	1: PIRSOHAWA - 14: NB1@53.6 - 8@2...	49.29	68.62	5	5	LOS_F	6	97.35	97.35	81.22	2.00	13.673	2.660	3.169	0.196
67	184-276	1: PIRSOHAWA - 14: NB1@53.6 - 13@...	49.29	68.62	0	0	LOS_A									
68	184-276	1: PIRSOHAWA - 10005@8.1 - 3@30.1	296.85	302.09	0	0	LOS_A									
69	184-276	1: PIRSOHAWA - 10005@8.1 - 6@69.8	296.85	302.09	0	0	LOS_A									
70	184-276	1: PIRSOHAWA - 10005@8.1 - 15@43.2	296.85	302.09	0	0	LOS_A									
71	184-276	1: PIRSOHAWA - 10017@3.2 - 13@33.1	269.24	274.48	1	1	LOS_F	6	143.06	143.06	113.72	3.00	3.838	0.747	0.890	0.055
72	184-276	1: PIRSOHAWA	66.04	302.09	102	102	LOS_D	4	44.12	44.12	33.83	1.03	145.062	28.224	33.619	2.075
73	276-368	1: PIRSOHAWA - 2: EB@13.6 - 6@69.8	26.46	52.21	8	8	LOS_C	3	28.84	28.84	19.83	0.62	9.272	1.804	2.149	0.133
74	276-368	1: PIRSOHAWA - 2: EB@13.6 - 8@28.7	26.46	52.21	13	13	LOS_E	5	72.03	72.03	59.39	1.31	26.583	5.172	6.161	0.380
75	276-368	1: PIRSOHAWA - 2: EB@13.6 - 13@33.1	26.46	52.21	3	3	LOS_E	5	65.99	65.99	55.94	1.33	6.112	1.189	1.417	0.087
76	276-368	1: PIRSOHAWA - 2: EB@13.6 - 15@43.2	26.46	52.21	16	16	LOS_C	3	27.38	27.38	18.00	1.12	19.648	3.823	4.554	0.281
77	276-368	1: PIRSOHAWA - 7: SB@24.8 - 3@30.1	1.49	5.46	0	0	LOS_A									

Fig 4.11 Pir Sohawa Intersection – Unoptimized

Nu...	TimeInt	Movement	QLen	QLenMax	Vehs(All)	Pers(All)	LOS(All)	LOSVal(All)	VehDelay(All)	PersDelay(All)	StopDelay(All)	Stops(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	FuelConsumption
37	92-184	1: pirsohawa - 12: NB2@17.8 - 15@...	0.00	0.00	0	0	LOS_A									
38	92-184	1: pirsohawa - 14: NB1@59.1 - 3@5...	9.46	23.14	35	35	LOS_A	1	2.03	2.03	0.03	0.09	10.826	2.106	2.509	0.155
39	92-184	1: pirsohawa - 14: NB1@59.1 - 6@3...	40.43	55.38	0	0	LOS_A									
40	92-184	1: pirsohawa - 14: NB1@59.1 - 8@3...	40.43	55.38	4	4	LOS_D	4	35.52	35.52	27.77	0.75	4.984	0.970	1.155	0.071
41	92-184	1: pirsohawa - 14: NB1@59.1 - 13@...	40.43	55.38	0	0	LOS_A									
42	92-184	1: pirsohawa	48.58	300.82	116	116	LOS_C	3	26.79	26.79	19.01	0.62	119.773	23.304	27.759	1.713
43	184-276	1: pirsohawa - 1@411.6 - 6@36.7	28.10	56.99	3	3	LOS_A	1	7.90	7.90	4.59	0.33	2.098	0.408	0.486	0.030
44	184-276	1: pirsohawa - 1@411.6 - 8@37.2	28.10	56.99	16	16	LOS_D	4	44.81	44.81	34.64	1.12	26.074	5.073	6.043	0.373
45	184-276	1: pirsohawa - 1@411.6 - 13@26.8	28.10	56.99	1	1	LOS_F	6	114.14	114.14	100.45	2.00	3.033	0.590	0.703	0.043
46	184-276	1: pirsohawa - 1@411.6 - 15@37.5	28.10	56.99	10	10	LOS_D	4	42.43	42.43	33.67	1.00	14.286	2.779	3.311	0.204
47	184-276	1: pirsohawa - 7: SB@57.0 - 3@54.6	3.02	13.21	2	2	LOS_D	4	35.17	35.17	17.86	1.00	2.731	0.531	0.633	0.039
48	184-276	1: pirsohawa - 7: SB@57.0 - 8@37.2	0.00	0.00	1	1	LOS_A	1	0.03	0.03	0.00	0.00	0.206	0.040	0.048	0.003
49	184-276	1: pirsohawa - 7: SB@57.0 - 13@26.8	3.02	13.21	0	0	LOS_A									
50	184-276	1: pirsohawa - 7: SB@57.0 - 15@37.5	3.02	13.21	0	0	LOS_A									
51	184-276	1: pirsohawa - 9: WB@262.1 - 3@54.6	257.62	300.86	33	33	LOS_E	5	64.26	64.26	42.25	1.18	64.421	12.534	14.930	0.922
52	184-276	1: pirsohawa - 9: WB@262.1 - 6@36.7	257.62	300.86	1	1	LOS_D	4	49.53	49.53	40.18	1.00	1.497	0.291	0.347	0.021
53	184-276	1: pirsohawa - 9: WB@262.1 - 13@2...	223.35	266.57	1	1	LOS_D	4	53.20	53.20	42.13	2.00	2.072	0.403	0.480	0.030
54	184-276	1: pirsohawa - 9: WB@262.1 - 15@3...	257.62	300.86	2	2	LOS_E	5	61.45	61.45	42.78	1.50	4.027	0.784	0.933	0.058
55	184-276	1: pirsohawa - 12: NB2@17.8 - 3@5...	3.07	24.92	4	4	LOS_C	3	25.04	25.04	12.32	0.75	4.343	0.845	1.007	0.062
56	184-276	1: pirsohawa - 12: NB2@17.8 - 6@3...	10.79	25.51	3	3	LOS_D	4	47.51	47.51	40.72	1.00	4.242	0.825	0.983	0.061
57	184-276	1: pirsohawa - 12: NB2@17.8 - 8@3...	10.79	25.51	3	3	LOS_D	4	46.82	46.82	40.01	1.00	4.219	0.821	0.978	0.060
58	184-276	1: pirsohawa - 12: NB2@17.8 - 15@...	0.00	0.00	0	0	LOS_A									
59	184-276	1: pirsohawa - 14: NB1@59.1 - 3@5...	36.45	63.86	32	32	LOS_B	2	10.22	10.22	2.15	0.62	21.820	4.245	5.057	0.312
60	184-276	1: pirsohawa - 14: NB1@59.1 - 6@3...	68.80	96.09	0	0	LOS_A									
61	184-276	1: pirsohawa - 14: NB1@59.1 - 8@3...	68.80	96.09	3	3	LOS_F	6	118.40	118.40	102.05	1.67	8.383	1.631	1.943	0.120
62	184-276	1: pirsohawa - 14: NB1@59.1 - 13@...	68.80	96.09	0	0	LOS_A									
63	184-276	1: pirsohawa	63.12	300.86	115	115	LOS_D	4	41.40	41.40	28.43	0.97	163.610	31.833	37.918	2.341
64	276-368	1: pirsohawa - 1@411.6 - 6@36.7	38.73	62.89	7	7	LOS_C	3	33.01	33.01	21.12	1.00	9.741	1.895	2.258	0.139
65	276-368	1: pirsohawa - 1@411.6 - 8@37.2	38.73	62.89	15	15	LOS_E	5	62.02	62.02	48.72	1.20	28.785	5.600	6.671	0.412
66	276-368	1: pirsohawa - 1@411.6 - 13@26.8	38.73	62.89	3	3	LOS_F	6	113.62	113.62	90.41	3.33	11.127	2.165	2.579	0.159
67	276-368	1: pirsohawa - 1@411.6 - 15@37.5	38.73	62.89	11	11	LOS_D	4	41.88	41.88	32.42	0.82	14.666	2.853	3.399	0.210

Fig 4.12 Pir Sohawa Intersection - Optimized

Chapter 5

ANALYSIS AND RESULTS

General

This chapter presents a detailed analysis of the outcomes achieved through the optimization strategies implemented on Margalla Road, Islamabad. By evaluating key performance indicators such as queue length, delay time, emissions, and fuel consumption, we quantify the benefits of signal coordination and split phasing across the major intersections.

5.1. Introduction

The effectiveness of the optimization strategies was assessed using a comprehensive set of performance metrics derived from Vissim simulations. The improvements were measured in terms of reductions in queue length, delay time, emissions (CO, NOX, VOC), and fuel consumption. This chapter provides a thorough analysis of these results, demonstrating the impact of our project on traffic efficiency and environmental sustainability.

5.2. Queue Length Reduction

One of the primary goals of the optimization was to reduce the queue lengths at the intersections, thereby minimizing congestion and improving traffic flow. The implementation of signal coordination and split phasing led to a noticeable decrease in queue lengths.

QUEUE LENGTHS			
INTERSECTION	NODE		
	PRESENT	OPTIMIZED	DIFFERENCE
AIR UNIVERSITY	491.8	446.5	45.3
F-8 MARKAZ	505.0	435.5	69.5
FAISAL MOSQUE	209.8	181.0	28.8
AURANGZEB ROAD	157.5	136.9	20.6
STREET 5	39.33	30.6	8.7
SIACHEN RD	287.38	246.5	40.9
PIR SOHAWA RD	302	275.6	26.4
TOTAL	1992.8	1752.6	240.2
PERCENTAGE	12.1		

Figure 5-1: Queue Length Analysis

The Vissim simulation results indicate a 12.1% reduction in queue length across the seven major intersections. The graph below illustrates the comparison of queue lengths before and after optimization.

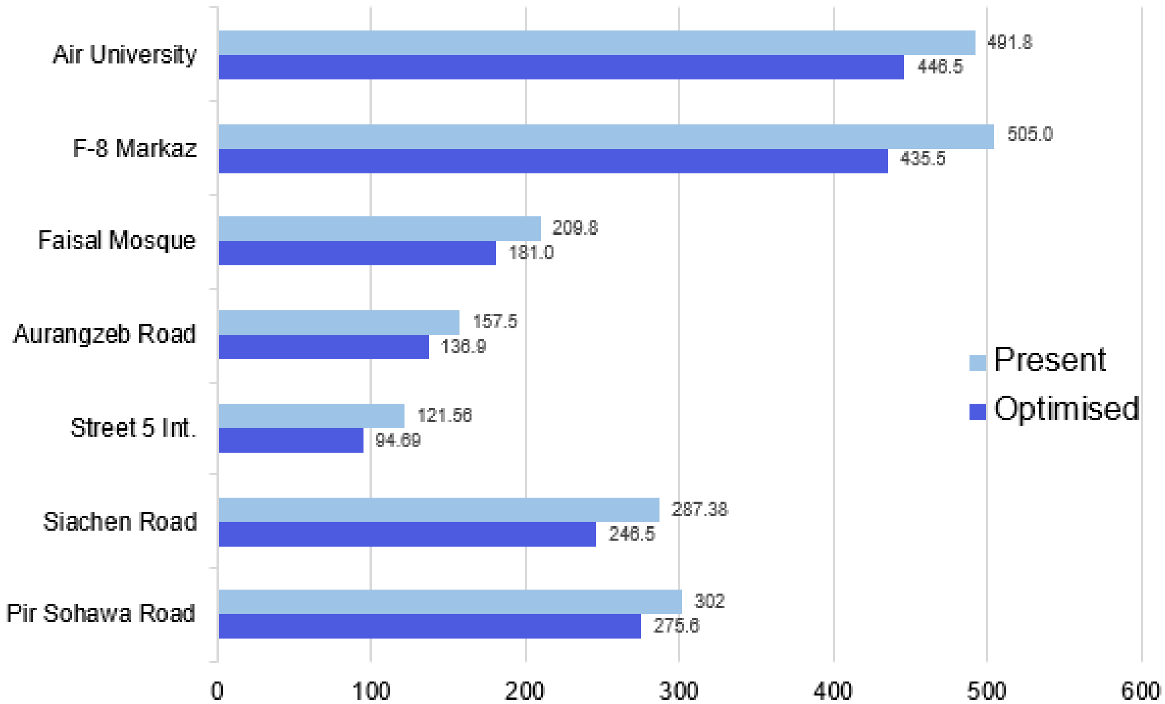


Figure 5-2: Queue Length Comparison

5.3. Delay Time Reduction

Reducing the delay time at intersections is crucial for enhancing the overall efficiency of the traffic system. By optimizing the signal timings and implementing split phasing, significant reductions in delay times were achieved.

DELAY TIME (NODES)			
INTERSECTION	NODE		
	PRESENT	OPTIMIZED	DIFFERENCE
AIR UNIVERSITY	121.0	90.8	30.2
F-8 MARKAZ	56.3	45.3	11.0
FAISAL MOSQUE	54.3	38.1	16.2
AURANGZEB ROAD	53.04	42.7	10.4
STREET 5	70.9	64.2	6.7
SIACHEN RD	60.94	46.67	14.3
PIR SOHAWA RD	44	40	4.0
TOTAL	460.4	367.7	92.7
PERCENTAGE	20.1		

Figure 5-3: Delay Time Analysis

The results show a 20.2% reduction in delay time, highlighting the effectiveness of the optimization strategies. The following graph presents the delay time data for both scenarios.

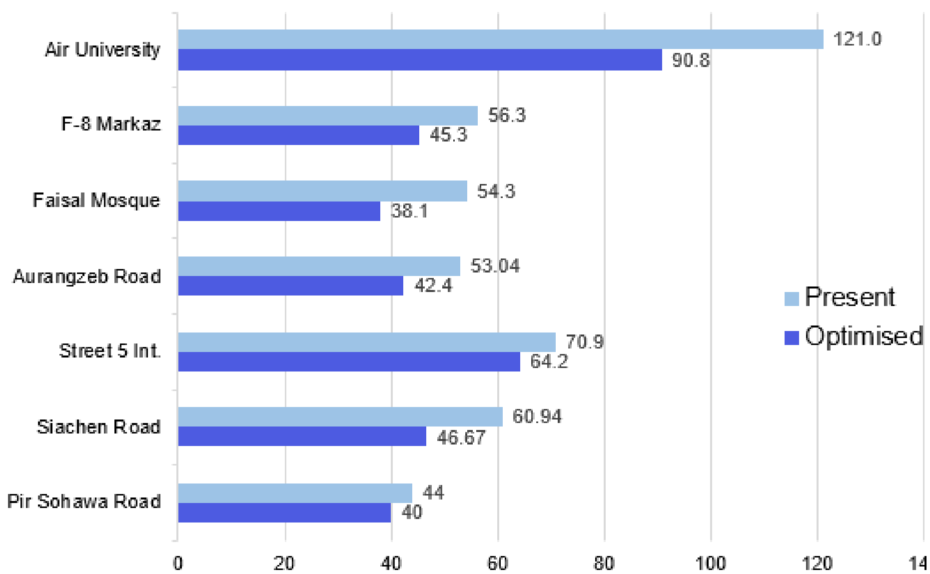


Figure 5-4: Delay Time Comparison

5.4. Reduction in Emissions

Improving traffic flow not only benefits drivers but also contributes to environmental sustainability as per UN SDG 11 by reducing vehicle emissions. The Vissim simulation allowed us to estimate the reductions in CO, NOX, and VOC emissions resulting from the optimization.

5.4.1. CO Emissions

The optimization led to a 13.1% reduction in CO emissions. The graph below displays the comparison of CO emissions before and after optimization.

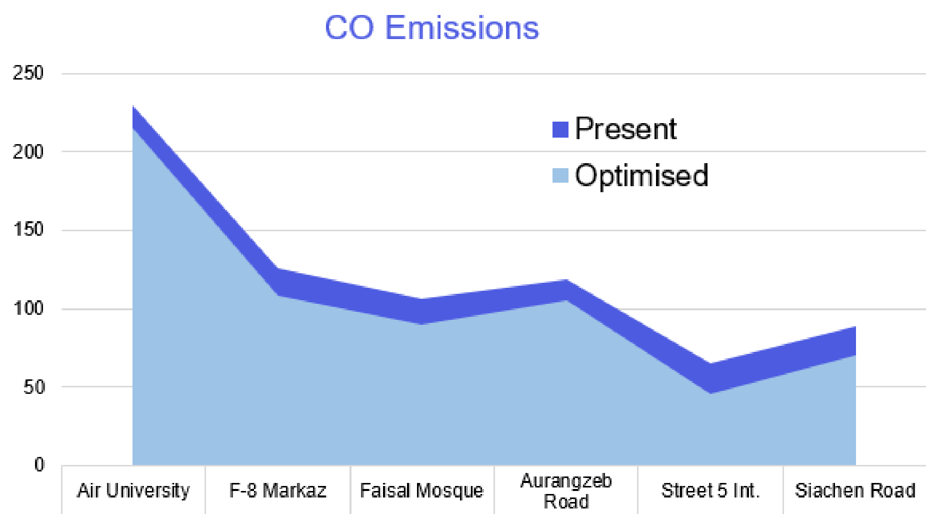


Figure 5-5: CO Emissions

5.4.2. NOX Emissions

The results indicate a 19.1% reduction in NOX emissions, further demonstrating the environmental benefits of the optimization.

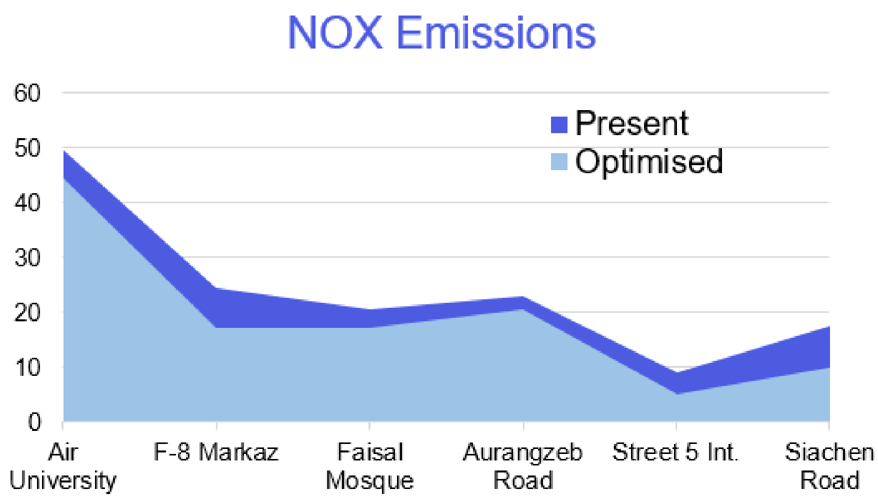


Figure 5-6: NOX Emissions

5.4.3. VOC Emissions

A reduction of 17.5% in VOC emissions was observed, contributing to improved air quality along the Margalla Road corridor.

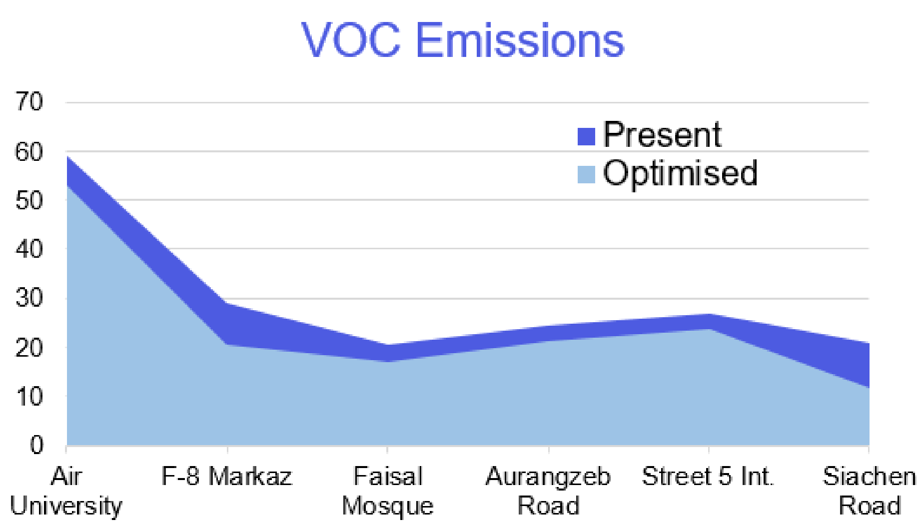


Figure 5-7: VOC Emissions

5.4.4. Fuel Consumption Reduction

Fuel consumption is a critical indicator of the economic and environmental impact of traffic systems. By reducing delays and improving traffic flow, the optimization strategies led to a significant decrease in fuel consumption.

FUEL CONSUMPTION			
INTERSECTION	NODE		
	PRESENT	OPTIMIZED	DIFFERENCE
AIR UNIVERSITY	3.64932	3.279459	0.36986
F-8 MARKAZ	1.799367	1.126283	0.67308
FAISAL MOSQUE	1.516	1.302	0.21400
AURANGZEB ROAD	1.704	1.203	0.50100
STREET 5	0.667763	0.365471	0.30229
SIACHEN RD	0.9056	0.724155	0.18145
PIR SOHAWA RD	2.340636	2.075274	0.26536
TOTAL	10.2	8.0	2.24168
PERCENTAGE	21.9		

Figure 5-8: Fuel Consumption Analysis

The Vissim simulation results indicate a 21.9% reduction in fuel consumption. The following graph provides a visual comparison of fuel consumption before and after optimization.

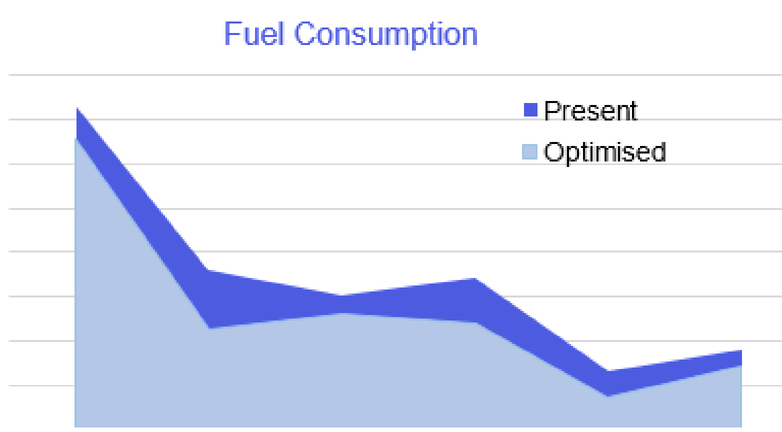


Figure 5-9: Fuel Consumption Comparison

5.5. Findings and Results

The table below summarizes the percentage reductions achieved in key performance indicators through the optimization of Margalla Road.

Metric	Reduction (%)
Queue Length	12.1%
Delay Time	20.2%
CO Emissions	13.1%
NOX Emissions	19.1%
VOC Emissions	17.5%
Fuel Consumption	21.9%

The analysis of Level of Service (LOS) data reveals significant shifts pre- and post-optimization. Prior to optimization, the most frequent LOS designations were E and F, occurring 10 and 9 times respectively, out of a total of 34 LOS calculations. Following optimization efforts, the most common LOS categories shifted to A and D, recorded 11 and 7 times respectively, within the same dataset of 34 LOS calculations.

A comparative examination of traffic flow patterns indicates a predominance of westbound traffic volume towards F-11, which serves as a crucial connector to the Srinagar Highway, over the eastbound traffic flow. Margalla Road, in particular, is intersected by four primary intersections that bear the highest traffic loads. These include the intersections at Air and Bahria University, which encompass Aurangzeb Road and connect with 9th Avenue; the Faisal Mosque intersection, which links Faisal Avenue and Islamabad Expressway; the intersection at 7th Avenue and Pir Sohawa, which connects sectors F-6, F-7, and F-8, areas dense with residential, commercial, and corporate activities; and the Service Road E intersection, which connects F-9 Park and F-10 Markaz, extending further towards Margalla Avenue and D-12.

The projection of traffic volumes on these roads indicates a continuing upward trend, driven by ongoing urbanization and development in adjacent regions. This increase is exacerbated by the absence of a dedicated bus service like the Metro Bus, which results in a heavy reliance on personal vehicles for daily commutes. Margalla Road is situated in an environmentally sensitive zone at the foothills of the Margalla Hills and includes significant green spaces such as F-9 Park. Consequently, urban planning and traffic management strategies for this area must prioritize the reduction of emissions to maintain its environmental integrity.

5.6 Summary and Recommendations

The findings of this study reveal a notable increase in Level of Service (LOS) subsequent to the implementation of optimization measures on Margalla Road, underscoring its potential for enhanced efficiency. The observed decrease in LOS could be attributed to the absence of designated bike lanes and pedestrian tracks extending along Margalla Road. The introduction of a dedicated bus service holds significant promise in reducing emissions, fuel consumption, and alleviating traffic congestion. Moreover, such a service could diminish reliance on private vehicles, which typically exhibit higher per capita fuel consumption compared to public transport alternatives

Integrating the gathered data into actuated signal systems offers the prospect of more refined signal optimization, particularly during peak office hours from 16:00 to 19:00 daily. Furthermore, augmenting the current infrastructure with a real-time traffic monitoring system has the potential to mitigate traffic congestion and minimize delays. This approach has been previously demonstrated in analogous projects, as referenced in earlier presentations. Leveraging PTV VISSIM to integrate real-time data would enable dynamic, on-the-go optimization solutions.

Given the environmental implications, prioritizing environmental protection measures along Main Margalla Road is imperative for relevant authorities. This research highlights the multifaceted benefits of optimizing urban road networks, emphasizing the integration of sustainable transport solutions and advanced traffic management systems to foster efficient, environmentally responsible urban mobility.

Chapter 6

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