OPTIMAL REDESIGN AND ANALYSIS OF CONGESTED INTERSECTIONS; A COMPARATIVE STUDY OF ALTERNATIVE SOLUTIONS

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By

Muhammad Hamza Abid-342039 (GL)
Shamiyan Khan-344553
Annas Noroz Khan-347508
Muhammad Ehsaan Sadiq-356655

NUST Institute of Civil Engineering
School of Civil and Environmental Engineering
National University of Sciences and Technology, Islamabad, Pakistan
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This is to certify that the

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submitted by

Muhammad Hamza Abid-342039 (GL)
Shamiyan Khan-344553
Annas Noroz Khan-347508
Muhammad Ehsaan Sadiq-356655

has been accepted towards the requirements for the undergraduate degree
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Dr Kamran Ahmed
Assistant Professor
National Institute of Transportation
School of Civil and Environmental Engineering
National University of Sciences and Technology,
Islamabad, Pakistan

ABSTRACT

Focusing on the optimal redesign and analysis of congested intersections, specifically examining the Kernal Sher Khan Shaheed Road (KSKSR) in Islamabad. Due to its strategic importance and increasing traffic volumes, the KSKSR has experienced significant congestion, leading to delays, increased vehicle operating costs, and negative environmental impacts. The project employs traffic simulation modeling using PTV VISSIM software to evaluate the current operational conditions and propose alternative solutions for improving traffic flow and reducing congestion. The study encompasses key intersections along the KSKSR, analyzing both pre- and post-rehabilitation scenarios to assess the effectiveness of recent improvements implemented by the Capital Development Authority (CDA) and the National Logistics Cell (NLC). By comparing these scenarios, the project aims to provide evidence-based recommendations for further enhancements, including potential changes in U-turn locations, safety measures, traffic efficient measures like Actuated Signals, Protected Phasing etc. The findings indicate significant improvements in traffic flow, reduction in congestion, travel time at the studied intersections, demonstrating the value of simulation-based analysis in urban traffic management. This research contributes to optimizing urban transportation systems, ultimately enhancing mobility and quality of life for residents and commuters of Islamabad/Rawalpindi.

DEDICATION

This work is dedicated to our parents and teachers, who were a source of motivation and have been our great strength. They have taught us every step of life and made us stand at the position we are today. This work is also dedicated to every other person who has been part of our development in any way.

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CHAPTER 1

INTRODUCTION

1.1 Background

The inter junction principal formerly known as IJP Road and newly renamed as Kernal Sher Khan Shaheed Road henceforth named as KSKSR measuring 9.8 kilometers from Pirwadhai Morr to Faizabad Interchange was constructed in 2004 under CDA. This road provides an efficient corridor to bypass the twin cities thereby maintaining inner city calmness. Transportation is termed as the backbone of all socio-economic conditions of any country. In the past railway was a popular mode of transport because of cheaper freight carrying capability. Advancement in transportation technology enabled vehicular transport and today, everybody prefers to travel by road, whether to transport people, materials, or perishable goods to meet the needs of an increasing population. Our concern is the study of the KSKSR connecting Rawalpindi to Islamabad. Post the 2008 Marriott hotel attacks. All the trucks using Islamabad Highway were diverted to the KSKSR, leading to an increased demand on the road. Each day considerable traffic volume passes along the road, increasing its importance and requirement of smooth traffic operations. Public Safety is also a concern due to highly populated areas around it. This principal road incorporated many bus stands, vegetable markets, and main markets and on its way attracts a heterogeneous mix of traffic ranging from multi-axle trucks to Single Unit Trucks, bikes, cars and buses. Congestion management of traffic was required to maintain the functionality of the road. After a decade of research, it is an established fact that the key to traffic problems lies in a simple combination of engineering, education and traffic law enforcement. A combination of all three are key to solving and mitigating problems one might run into, while driving down the KSKSR

1.2 General

The assessment of operational conditions on city street networks holds paramount significance within the realm of transportation-making plans and management. As towns continue to extend and populations grow, the call for green and dependable transportation structures is of the utmost need. Among the diverse additives of city mobility, street networks play an essential position in facilitating the motion of human beings and goods. Within this context, the overall performance of roads, especially in phrases of visitor flow, congestion levels, and journey times, turns into an important metric for assessing the general effectiveness of transportation infrastructure.

The increase in number of vehicles in Pakistan cannot be ignored while considering other factors for traffic congestion. As per CEIC data, Number of Registered Vehicles was reported at 7,020,803 Unit in Dec 2022. This records an increase from the previous number of 6,692,474 Unit for Dec 2021 in Pakistan. [1]

This increase in the number of vehicles is one of the factors, responsible for traffic congestion in Pakistan. Apart from that, major causes of traffic congestion include uncoordinated traffic control, offensive driving, the mixing of through traffic with city traffic, and the inadequacy of transportation facilities such as traffic lights, traffic signals, pedestrian crossings, etc. Similarly, poor road quality, narrow roads, an increased number of cars demanding roads, on street parking, the non-functional traffic signal system, and other factors such as encroachments and on-street parking are responsible for traffic congestion.

All these traffic congestion problems are main bottlenecks in the free movements of the vehicles on the roads as well as the intersections. Road intersections are a major part of the road section which plays an important role in channelizing traffic movements. The various traffic congestion problems associated with the road intersection networks are traffic delays, environmental problems, higher cost due to more fuel consumption, traffic safety problems and many more. Thus, traffic congestion is the result of the gap between traffic supply and traffic demand.

To cope with those challenges, transportation planners and engineers regularly switch to simulation studies, which provide a cost-effective and green manner of comparing specific operational situations and proposed interventions. By developing digital fashions of real-international scenarios, the simulation software program permits researchers to investigate the capacity effects of operational modifications without the want for substantial area experiments. Traffic modeling and simulation is one of the frequently used tools used in road infrastructure design. Software tools such as PTV VISSIM, Synchro etc. designed for traffic simulations are an important supportive tool in decision-making and in choosing the optimal solution. In these softwares, traffic on the selected road or usually intersection is modeled and simulated first for the current state, then for other proposed alternative models with modifications that are to increase the throughput of the intersection [2].

This thesis makes a specialty of accomplishing a simulation based earlier-than-after evaluation to assess the overall performance of operational situations at the IJP Road. Utilizing superior simulation strategies and incorporating real-international data, this observes objectives to evaluate the results of decided-on operational enhancements on key overall performance metrics, inclusive of site visitors' waft and congestion levels. By evaluating consequences earlier than and after the implementation of those modifications, the studies seek to offer evidence-primarily based totally suggestions for boosting the operational performance of the IJP Road and enhancing city mobility in Islamabad.

In the upcoming sections, this thesis will delve into the technique used for the simulation observation, the delineation of the observed location on the IJP Road, the evaluation of simulation results, and the dialogue of findings. Ultimately, the insights derived from this study enterprise are anticipated to tell decision-makers and practitioners of their efforts to optimize city avenue networks and beautify transportation offerings for the citizens of Islamabad.

1.3 Problem Statement

The main problem on IJP Road was that the traffic volume increased the road capacity. There were more vehicles than the two-lane road capacity and this resulted in congestion causing long queues and traffic jams. These, combined with the adverse road conditions and greater travel time delay negatively impacted the efficiency of daily activities of daily commuters. This resulted in congestion and delays that increased vehicle operating costs, fuel expenses and increased vehicular emissions, affecting the environment negatively.

1.4 Purpose of Research

To address these problems CDA launched a project, which was a massive step towards making Islamabad transportation system efficient. We seek to identify if the problem is solved or not. Going forward, a continuous appraisal of success of projects is needed to quantify and evaluate the extent of the mitigation of problems for a more holistic approach to the project. If solved, what is the extent of improvements and to identify if there are still possible measures that can make this project a success and this road as efficient as possible.

1.5 Study Objectives

1. Analyze the “Before Rehab” and “After Rehab” conditions.
2. Evaluate if the problem is actually solved or not.
3. Provide possible optimization measures to increase efficiency.
4. Address and incorporate possible safety concerns.
5. Use Simulation Softwares such as PTV VISSIM for said purpose.

1.6 Scope of the Study

This study will include an in-depth evaluation of the operational traffic conditions at the IJP Road and the usage of simulation-primarily based on earlier-than-after evaluation. The scope of the study encompasses the eight intersections on the IJP road starting from I-8 Intersection to the last Range Road Intersection of the road. The in-between six intersections that will also be the concentration points of the whole study are Double Road Intersection, Saidpur, New Katarian, Khayaban e Sir Syed, Faqeer Aipee intersection.

The study will be done on the before-project scenario of the road from the traffic volume data (AADT and Peak Hour Flow) obtained from CDA. The road will be simulated for the previous scenario, when it was a two-lane roadway, and some required results will be saved. Moving forward, traffic will be simulated for an after-project scenario including all the improvements made in the project by CDA and NLC. After that, conclusions will be drawn in the best format possible to understand exactly the extent of betterment of IJP road. We will also devise possible recommendations and measures that can add in to the safety of the roadway which may include but not limited to possible change of U-turn locations throughout the bridge, measures to make them efficient, possible environment-friendly measures including air quality, noise levels, and nearby ecology.

Overall, the scope of the project targets to offer a complete assessment of operational conditions at the IJP road traffic simulations, with the remaining aim of informing decision-makers and practitioners of their efforts to optimize city transportation structures and decorating the nice of mobility for citizens and commuters in Islamabad.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter gives a brief review of the literature and theory related to transportation systems in Pakistan, the types of intersections, and the various reasons for congestion and their respective effects on both the efficiency of traffic, and the end users of a road network. Only after delineating the theoretical aspects of the problems that we are encountering on the KSKSR, will we be able to provide a complete and efficient foolproof solution.

2.2 Transportation Systems

A transportation system represents a comprehensive, interconnected network that includes various modes of transportation and facilitates the movement of large populations and goods across destinations. This framework includes highways, railways, air transport, waterways, mass transit systems and pipelines, forming an extensive and interdependent system that interacts with the environmental and economic sectors. This network emphasizes its central role in the national economy and social structure.

Within this diverse network, our primary focus is on road transport, the main land transport system in the world today. The system covers a wide range of road types, including highways, motorways, urban and rural arterial roads, and regional links and connectors, strengthening the country's economy and promoting economic cohesion.

Efficient transportation systems are central to economic vitality and are characterized by fluid and agile traffic flows. Its efficiency is determined by the absence of traffic obstacles, traffic jams, and bottlenecks that impede mobility and affect the efficiency of the system. Increasing mobility demands due to population growth, demographic change, urbanization, and economic factors are increasing the need for robust transportation systems. This requires the development of more efficient and sustainable transport systems that meet the needs of a growing population.

2.3 Transportation System in Pakistan

Pakistan's transport system is primarily dependent on roads, which make up 90 percent of national passenger traffic and 96 percent of freight movement. Over the past years, road traffic both passenger and freight has grown much faster than the country's economic growth.

Road density calculated as (Total length of road/ Total area) is a common indicator for the development of a country's road system and is concurrently used as an index for prosperity, economic activity, and development. It is low in Pakistan, especially when compared to other countries of equivalent development and geography. Pakistan, with a population of 242 million people, has a reasonably developed transport system, and The Economic Survey of Pakistan 2022-23 [3] quotes the following Table 1:

TABLE 13.1 A

TRANSPORT (Roads)

(in kilometers)

Years	Expressway	Highway	Local Road	Metro Road	Motorway	National Highway	Primary Road	Secondary Road	Total
2019-20	460	20,089	373,423	86	3,210	12,122	4,387	87,647	501,424
2020-21	428	32,097	373,525	76	2,471	-	4,388	87,765	500,749
2021-22	428	32,097	373,525	146	2,816	-	4,388	87,765	501,165
2022-23 (Jul-Mar)	428	32,097	373,525	146	2,816	-	4,388	87,765	501,165

Source: National Transport Research Center

Table 1: Statistics of Road Transportation Systems in Pakistan [3]

2.4 Intersection

An intersection is a location where two or more roadways come together to facilitate the gathering, turning, and evacuation of cars and pedestrians. Infrastructure for traffic control, such as traffic signals and additional facilities for managing traffic are frequently placed at junctions to guarantee traffic flow and safety. Properly planning road junctions and arranging and managing things logically in Intersection traffic is essential for enhancing traffic flow and making sure everyone is safe.

2.4.1 Why do we need Road Intersections?

Intersection is one of the most important components of urban roads, and traffic flow is the node that realizes route change. When the vehicle passes through the intersection due to the need for traffic flow route conversion, the driver can slow down, change lanes, park, steer. A series of tasks such as acceleration, etc., must be completed, and this process must be completed at the intersection and its neighboring area. Therefore, several traffic conflict points are formed at the intersection and its adjacent area, and the intersection between traffic flows in different directions, Traffic conflicts such as merger and direction change occur. Traffic characteristics of intersections are more complex than road sections, and road traffic bottlenecks and traffic accidents are frequent. Good design of intersections ensures safe and efficient operation of the entire road network.[4]

Well-designed intersections, featuring optimized traffic light phasing, geometric layouts, and intuitive signage, can go a long way in reducing congestion, minimizing travel time, and improving overall traffic efficiency. Conversely, poorly planned intersections can create bottlenecks, leading to traffic congestion, increased travel delays, increased risk of accidents, and a resulting reduction in economic efficiency. [4]

2.4.2 Classification of Intersections

Depending on how two roads intersect, intersections are classified as plane or grade intersections. Intersections can be classified based on their traffic control and based on their shape.

There are two basic types of intersections based on shape:

a) Plan Intersections
b) Grade Intersections

2.4.2.1 Plan Intersections

Intersections that are plan in shape with no grade involved are plan intersections. They can further be classified into different types as follows:

Crossing Intersection:

The type of intersection which is very common to see in daily life. The application scope of scope intersection is broad, the form is easy to use, the traffic organization is practical, and the street corner building is manageable. However, there are many conflict points in making this intersection.

T-Intersection:

Such types of intersections are preferred at intersecting roads where the traffic is small. These offer good visibility and ensure safe driving. In theory, it has a degree of 3, of which two segments have a flat angle (i.e. 180 degrees); and the third segment has a right angle (i.e. 90 degrees) with the other two; however, in a practical road network, such a flat angle or a right angle may exist as a deflection (angle). Thus, an intersection has a degree of 3, of which two segments are nearly flat and the third segment has a nearly right angle with the other two, viewed as a T-shaped intersection.

Roundabout Intersection:

The most common type of intersection that is preferred is at a place where the area available is large and the traffic requirement is very high. It saves time, reduces the number of traffic accidents, improves safety in driving, and adds to the aesthetics of the intersection. The vehicle speed is low, and the construction cost of roundabout intersections is higher as compared to all the above discussed types of intersections.

2.4.2.2 Grade Intersections

Grade Intersections use space to separate the flow of traffic, although it can avoid the formation of conflict points at the intersection. It reduces the traffic flow, reduces delays, ensures traffic safety, improves traffic capacity and transportation efficiency, and solves the problems caused by level crossing but it cannot completely replace the plan intersections.

These can also be classified based on their shape as follows:

Underpass Interchange

As the name suggests, these are formed by providing a passageway under the ground. It uses less land and has less impact on urban space and the surrounding environment. However, the underpass interchange requires large excavation and high attention and efficiency in designing the drainage system.

Overpass Interchange:

The intersection at the upper grade which helps in the efficient flow of traffic is an overpass interchange. The construction is more convenient than the underpass interchange, the excavation work is small, the interference with the underground pipelines is small and the drainage is also easy to deal with. The demerits of using this type of intersection are the large use of land, the line bridge affecting the sight and surrounding landscape, the approach road being long or the longitudinal slope being large, which is non-conducive to non-motor vehicle traffic.

2.4.3 Types based on Traffic Control

Uncontrolled Intersection

An unregulated or uncontrolled intersection is one that has no signs or traffic lights. At such intersections, vehicles on the main road have priority at three-way intersections, and vehicles on the right side have priority at four-way intersections. However, priorities vary from country to country. Uncontrolled intersections reduce delays but increase the likelihood of collisions, especially when there is heavy traffic at the intersection.

Controlled Intersection

The intersections which are controlled by traffic signals are the controlled intersections. Traffic lights are installed at intersections with relatively heavy traffic, which give drivers the right of way, improving traffic mobility at busy intersections. At low-traffic intersections, the installation of traffic signs and roundabouts generally ensures perfect usability. Traffic lights are often seen at four-way intersections.

2.5 Reasons for Traffic Congestion

Reasons for traffic congestion in Pakistan are listed as following

2.5.1 Rapid urbanization and population growth

Pakistan has long been a country defined by its geography. This is the country where most of the population lives and where the largest industries are concentrated. Pakistan is urbanizing at an annual rate of 3%, the fastest rate in South Asia.[5] Urban expansion is a form of urbanization and occurs in different ways, for example in the form of increasing population density, redeveloping built-up areas, creating new urban land that was previously not urban, etc. [6]

In 1981, there were about 24 million people residing in urban areas of Pakistan, accounting for, 28% of the country's total population. According to the 1998 census, the urban population of 4,444 stood at 43. 5 million people, accounting for 32. 5% of the country's total population (143 million). In 2010, the total population of the country increased to 4,444 million people and the urban population was 4,444 people reaching 63.1 million people, accounting for 36.3% of the total population. It is estimated that the urban population could exceed 121 million by 2030. The 45. 6% level of urbanization would then be the highest among Southeast Asian countries.2 For these reasons, the need to study the relationship between urbanization processes and the traffic (transport) structure and volume is currently extremely relevant.

2.5.2 Lack of integrated transportation planning

Lack of comprehensive and integrated transportation planning exacerbates congestion problems. An ideal transport system is a safe, fully integrated transport network that supports economic and social regeneration, while ensuring good accessibility for all. It is operated to the highest standards to protect the environment and ensure quality of life. The long-term strategy should be to manage the growth of transport demand to ensure the efficient movement of people and goods. Road transport, rail transport and even airlines must establish Plan and operate integrated projects.[7]

The Paris transport system is a good example of how you can travel with a single ticket on the metro, buses and trains. The current level of technological development and the advanced level of transport planning make it possible to have several possible solutions to each problem. However, an important requirement is to accurately diagnose problems. This requires an understanding of important transportation issues by all those involved in planning and operating the transportation system. [7] Integrated transportation modes can mitigate road congestion by offering alternative travel options, dispersing the demand for road space. By facilitating seamless connections between transportation modes and promoting multi-modal journeys, integrated systems efficiently distribute traffic, alleviating pressure on roads.

2.5.3 Urban Sprawl and Land Use Patterns

Unplanned urban sprawl and haphazard land use patterns are major causes of traffic congestion. Poorly designed urban planning and inappropriate zoning regulations lead to longer travel distances and traffic bottlenecks, increasing congestion in urban centers. Urban sprawl is a multifaceted concept, encompassing the expansion of cities and suburbs towards the periphery in the direction of self-contained, low-density development on rural land, clear separation of uses, and various design features that encourage car dependence. It has been argued that urban sprawl is the cause of many environmental problems. Urban sprawl also has negative impacts on the infrastructure and sustainability of cities. Urban sprawl has a direct impact on traffic congestion, high oil consumption, and many other transportation problems.[8]

Because land use and zoning regulations in Pakistan are not enforced because of various political pressure and inadequacy of funds, facilities and housing are spread far and few in between, leading to an increase of road dependance.

2.5.4 Inadequate public transport infrastructure

Limited and inefficient public transport systems increase reliance on private cars and worsen congestion. Pakistani cities entered the 20th century with urban trams and commuter rail systems. One hundred years later, these systems have stopped working or almost stopped working. [9]

Although a large number of non-motorized trips still exist in Lahore and Karachi, the expansion of Pakistan's cities has increased the travel time of most urban residents, caused walking and cycling become less feasible than before, encouraging constant change from non-motorized mode to motorized mode. In this situation, public transport can provide high-quality services to urban residents at much lower costs than systems for private motorized transport and road expansion. Virtually no attention has been paid to the ways and means by which the need for motorized transport can be met by improving the quality of public transport. Therefore, faced with a low level of public transport services, middle- and high-income people living in big cities prefer personal vehicles rather than motorbikes or cars to get around. When public transit systems fail to provide efficient, accessible, and reliable services, people are compelled to rely on cars for their daily travel needs, leading to higher traffic volumes and congestion. [9]

2.5.5 Traffic Management and Enforcement Issues

Inappropriate traffic management strategies and lax enforcement of traffic regulations contribute to chaotic traffic conditions. Violation of traffic rules, illegal parking, and improper synchronization of traffic lights cause traffic congestion problems on highways. According to a traffic study done in a central area of Lahore city in which a sample of 365 respondents was included through the administration of the questionnaire survey to record the explanatory variables. In-depth interviews were conducted with 7 individuals from Traffic Engineering and Planning Agency (TEPA) and Department of

Transportation Engineering and Management (DTEM), about their perceptions of traffic management in Lahore city. The results show that illegal parking on roadside, bad attitude of motorists and shop keepers, encroachments and running business on streets are the primary reasons for traffic congestion. These traffic congestions are hindering the efficient movements of the flow entities and causing mental stresses in the residents. The findings of this study endorse that strict enforcement of traffic laws, provision of adequate parking spaces, provision of overhead pedestrian bridges, and education of traffic rules among masses could help to manage the traffic congestion in the central area of Lahore city.[10]

2.5.6 Rapid motorization and car ownership

An efficient transportation system is essential to sustain economic growth in modern economies because it connects different parts of the country with the rest of the world. A well-developed transportation system is not only essential for national growth but also acts as a catalyst for a country's economic development. Therefore, urban mobility is a core problem that all city dwellers face.[11]

As a result, cities around the world have undergone intense motorization over the past century, especially since 1988, when the global car population exceeded 400 million. This phenomenon occurs because few activities are poorer than urban transport, in both developed and developing countries. Because public transportation cannot meet the needs of tourists, the demand for private cars increases. Due to high levels of motorization, combined with inadequate traffic management strategies, aging and poorly maintained vehicle fleets, inadequate land-use and transport planning, especially in developing economies, modern cities have suffered from disproportionate traffic flows congestion. [11]

2.6 Effects of Traffic Congestion

The effects of traffic congestion significantly reduce the efficiency of the transportation system and cause serious economic setbacks for the country. These effects include:

2.6.1 Travel Time Delays

Congestion causes traffic jams and long queues, causing significant delays in vehicle movement. These delays significantly reduce productivity and negatively impact businesses that rely on on-time delivery. Extended delivery times for time-sensitive products increase storage and logistics costs, leading to economic losses. Since traffic congestion causes heavy delays, it is very costly for intensive road users such as logistic service providers and distribution firms. The Dutch Organization for Transport and Logistics (TLN) estimated that over 10% of the truck drivers' working hours are lost due to delays because of traffic congestion. This causes large costs for hiring truck drivers and the use of extra vehicles, and if they are not accounted for in the vehicle route plans they may cause late arrivals at customers or even violations of driving hours' regulations. Therefore, accounting for and avoiding traffic congestion has a large potential for cost savings.[12]

2.6.2 Fuel Consumption Cost

In congested conditions, the vehicle's fuel consumption increases due to changes in vehicle speed that affect rolling resistance and additional inertial fuel consumption during acceleration and deceleration. Particularly heavy vehicles, such as trucks and trailers, experience high fuel losses due to speed changes, reducing the productivity of the entire transportation system. In this backdrop, a study in Nepal empirically examines the growth of traffic congestion and its impact on urban households and livelihood based on 160 vehicle owners and users' survey at six major traffic routes of two urban cities by applying mixed analytical methods (qualitative cum quantitative), descriptive statistics and multiple regression model. The descriptive statistics result of the study reveals nearly 94 percent acceptance level of vehicle owners and users about the growth of traffic congestion. Despite short distances of the road i.e. 2-4 kilometers and vehicle efficiency, the growth of traffic congestion increases 14036-liters fuel additional consumption. Per month, additional cost of fuel is estimated at 18,808 US dollars for a sum of distance i.e. 72,992 km between residence location and workplace each month. In the case of commuters, the estimated result of the study is 1188 hours of additional time loss with 6706 US dollars' worth per month, overall proving the increase of fuel consumption with traffic congestion.[13]

2.6.3 Environmental impact

Normal speed ensures maximum fuel efficiency and minimum environmental impact. However, traffic congestion, characterized by frequent speed changes, stops, and starts, puts a strain on engines, reduces fuel efficiency, and increases environmental impact.

In recent years, a major concern in sustainable transport has been the environmental impact of emissions generated by traffic congestion. Traffic congestion is caused by the increased or excessive use of a road network that restricts the movement of vehicles in each direction at a given time and is characterized by longer queues, longer travel times, poor vehicle conditions, slower and stopping and starting times, and increased passenger discomfort, environmental degradation and economic losses. In modern urban societies, traffic congestion is a major source of greenhouse gas (GHG) emissions and air pollution. According to one global estimate, nature accounts for more than 90% of the carbon monoxide (CO) in the air (NRC 1970). Of the 10% of 4,444 CO emissions that are of human origin, about 70% are due to road transport (NRC, 1970). Traffic-related pollution accounts for an average of 60% of all pollutants in the atmosphere. Of this total, passenger cars contribute 90 to 95% of air pollution.[14]

2.6.4 Psychological Impact

Trying to arrive on time is of utmost importance for every commuter. Traffic jams, traffic delays, and long lines of vehicles have a huge impact on the psychological state of travelers. Being stuck in traffic increases stress levels, anger, and psychological distress, putting passengers' health at risk. As per an experimental study to assess the effects of routine exposure to traffic congestion on the mood, physiology, and task performance of automobile commuters. Traffic congestion was conceptualized as an environmental stressor that impedes one's movement between 2 or more points. 61 male and 39 female industrial employees were assigned to low-, medium-, or high-impedance groups based on the distance and duration of their commute and were classified as either Type A or Type B on the Jenkins Activity Survey, a measure of coronary-prone behavior. As expected, subjective reports of traffic congestion and annoyance were greater among high- and medium-impedance commuters than among low-impedance individuals. Also, commuting distance, commuting time, travel speed, and number of months enroute were significantly correlated with systolic and diastolic blood pressure.[15]

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter outlines the comprehensive methodology used to analyze and optimize the traffic conditions at major intersections along the IJP Road in Islamabad-Rawalpindi. The methodology encompasses data collection, simulation modeling, problem identification, proposal of alternative solutions, and evaluation of these alternatives. Each step as shown in Figure 1 is designed to ensure a thorough and accurate analysis of traffic conditions and the effectiveness of proposed interventions.

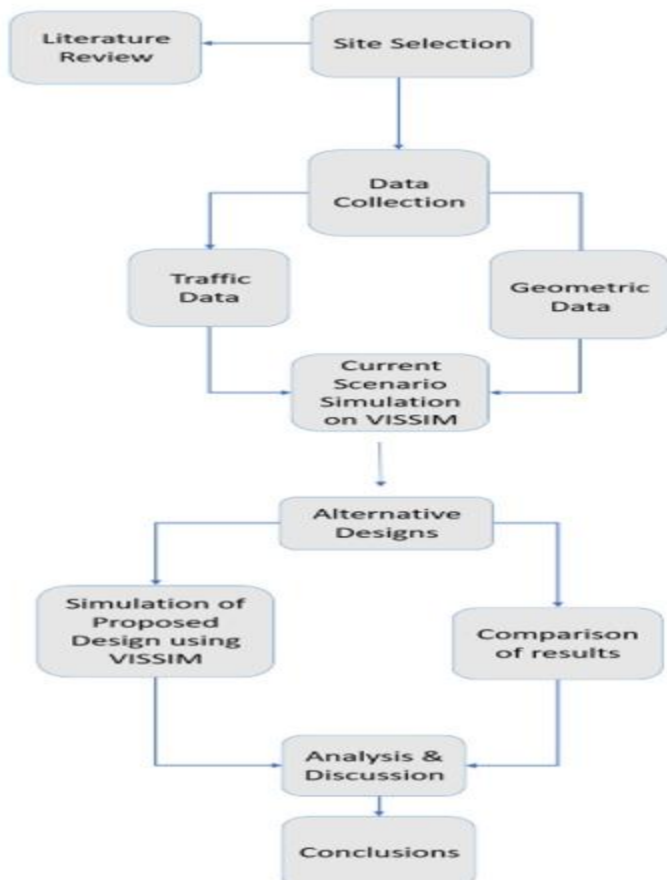


Figure 1: Study Framework of Our Design Project

3.2 Data Collection

The foundation of any traffic optimization study lies in the accuracy and comprehensiveness of the data collected. For this study, a multi-faceted approach was employed to gather traffic data, geometric and signal timing information, and other relevant data to accurately model the traffic conditions along IJP Road. The data collection phase as shown in Figure 2 was meticulously planned and executed to ensure that the simulation model would be as close to reality as possible.

Figure 2: Site Data Collection Visits

3.2.1 Traffic Volume Data

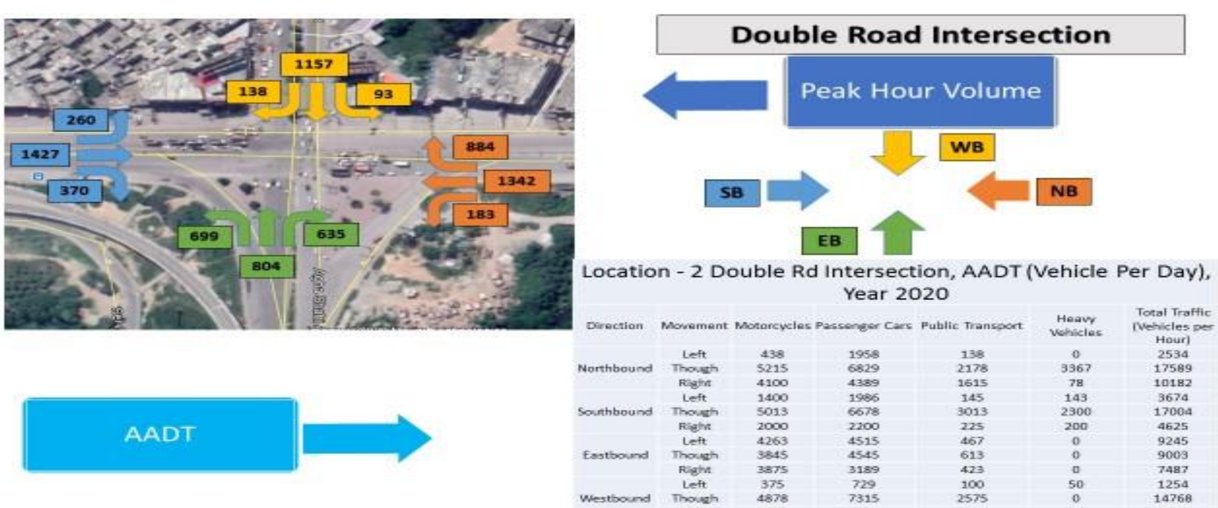
Traffic volume data is critical in understanding the flow and density of vehicles at different times of the day. To capture a comprehensive picture of the traffic conditions, data was collected during the peak hours, typically between 7:00 AM to 9:00 AM and 5:00 PM to 7:00 PM, when congestion is at its highest. This data collection was conducted over multiple weekdays to ensure that the data reflected typical traffic patterns and was not skewed by anomalies such as holidays or local events.

The primary method for collecting traffic volume data was manual counting, where field surveyors were stationed at each major intersection to count the number of vehicles passing through each approach. This method, while labor-intensive, provided high accuracy and allowed for real-time adjustments and clarifications. Additionally, Automatic Traffic Counters (ATCs) were deployed at strategic points along the arterial to continuously record traffic volumes over extended periods. These counters provided a wealth of data that complemented the manual counts and helped in identifying daily and weekly traffic patterns. Historical traffic data was also obtained from local traffic management authorities, which provided a long-term perspective on traffic trends and helped validate the current data against historical patterns.

3.2.2 Geometric and Signal Timing Data

The geometric properties of each intersection and the existing signal time are carefully recorded as shown in Figure 3. This includes detailed field surveys to capture the physical design of the intersections, including the number of roads, road widths, turns, pedestrian crossings, any aerial obstacles or barriers and high-resolution satellite imagery also served to supplement field data and ensure that no important features were overlooked

Signal timing data, including current phase sequences, cycle length, and allocation of green time for each traffic flow, were obtained from the local traffic signal management system and this data is critical for baseline condition to be established in the simulation model. Extensive observational and timing studies were conducted to verify the accuracy of the signal timing data and to understand the performance characteristics of traffic signals under different traffic conditions.



Location - 2 Double Rd Intersection, AADT (Vehicle Per Day), Year 2020

Direction	Movement	Motorcycles	Passenger Cars	Public Transport	Heavy Vehicles	Total Traffic (Vehicles per Hour)
Northbound	Left	438	1958	138	0	2534
	Though	5215	6829	2178	3367	17589
	Right	4100	4389	1615	78	10182
Southbound	Left	1400	1986	145	143	3674
	Though	5013	6678	3013	2300	17004
	Right	2000	2200	225	200	4625
Eastbound	Left	4263	4515	467	0	9245
	Though	3845	4545	613	0	9003
	Right	3875	3189	423	0	7487
Westbound	Left	375	729	100	50	1254
	Though	4878	7315	2575	0	14768
	Right	343	1167	113	0	1623

Figure 3: Data Compilation

3.2.3 Other Relevant Data

In addition to vehicle density and geometric data, other relevant information was collected to provide a comprehensive view of driving conditions. This also included a composition of traffic, which showed the percentage of vehicles such as cars, trucks, buses, motorcycles, etc. Understanding the mix of vehicles is important because vehicles have speed, acceleration, and turning characteristics affecting all types of vehicles. The flow is affected

Speed data were also collected, as pedestrian crossings can have a significant impact on intersection performance. The number of pedestrians at each intersection and crossing time were calculated manually. Additionally, data on traffic violations such as running red lights and illegal construction were collected through field surveys and reviewing footage from traffic cameras This information helped to hear under driver behavior and its impact on traffic and safety.

3.3 Traffic Simulation Modeling

With complete data in hand, the next step was to develop detailed traffic models using PTV VISSIM as shown in Figure 4. This framework will serve as a basis for analyzing current conditions and testing proposed improvements. The simulation modeling process was methodical and iterative, ensuring that the model accurately represented real-world conditions.

Figure 4: Traffic Simulation Model in PTV VISSIM

3.3.1 Networks

The first step in the simulation modeling process is to produce a detailed digital representation of the IJP road network as shown in Figure 5, including six major intersections: Double Road, Saidpur, Katarian, Khayaban, Pir Wadhai and Faqeer Aipee. This includes road widening, road design, road modeling and more accurate pedestrian crossing models. Particular attention was given to ensuring that the model captured the complexities of each intersection, such as the precise location of traffic signals, stop lines and crosswalks

Figure 5: Road Network Development in PTV VISSIM

The traffic control devices were also modeled on the network. This involved placing traffic signs, stop signs and yield signs in their precise locations and setting their operating parameters according to the data collected. The software's graphical interface was used extensively to visually verify that the modeled network matched real-world conditions.

3.3.2 Investment in traffic infrastructure

Once the network was created, the next step was to input traffic data. This includes defining the flow of traffic at each intersection, identifying traffic volumes and the direction of distribution. Traffic density was loaded based on data collected during peak hours, adjusted for different times of the day to simulate traffic conditions

Traffic demand input also includes using the network to determine vehicles. Previously collected vehicle design data were used to identify vehicle types, such as cars, trucks, buses, motorcycles Summary This step was necessary to ensure that the model accurately represents real-world transportation conditions, since different cars have different driving habits, and impact on traffic flow.

3.3.3 Signal Timings

The existing signal timings were programmed into the simulation model to simulate current conditions accurately. This involved defining the phase sequences, cycle lengths, and green times for each intersection based on the collected signal timing data. Each traffic signal's operational parameters were input into the software.

3.4 Identification of Problematic Intersections

Preliminary assessments of the current traffic situation at the IJP highlighted several critical factors that significantly impact both traffic and network infrastructure Basic metrics used to characterize this problematic intersection included queue length, average delay, and rate of operation (LOS). Queue length was measured during peak periods to determine traffic density at each intersection. The delay time was calculated to determine the time lost due to traffic congestion, and the LOS was analyzed to determine the efficiency of the traffic at each intersection.

Based on these metrics, Double Road, Faqeer Aipee intersections and the U-turns between Katarian and Khayaban emerged as the most problematic. The Double Road intersection featured unusually long queues and significant delays at peak times, resulting in a LOS of F, indicating severe road congestion and poor efficiency Similarly, the Fakir AP intersection exhibited extensive traffic queues and significant delays, which in turn resulted in poor LOS These findings highlighted the need for targeted interventions to improve traffic conditions at these intersections.

Based on the findings, several strategies were proposed for improving traffic flow along problematic corridors. These roads were designed to solve specific congestion problems and increase overall traffic flow efficiency.

3.5 Proposal of Alternative Solutions

Double Road and Faqeer Aipee intersections were identified as major challenges, several alternative solutions were proposed to reduce congestion and increase traffic These measures were designed to address specific issues at each intersection when evaluating the overall performance of the network.

3.5.1 Two-way networks

The Double Road junction caused severe traffic congestion due to heavy traffic and timing malfunctions. Two main strategies were proposed to address these issues.

3.5.1.1 Traffic signal optimization

The first approach focused on optimizing the timing of traffic signals to reduce traffic delays and improve traffic flow. This includes a detailed analysis of the current signal phase, cycle length and timing of the green distribution. By modifying these assumptions, the aim was to create a balanced signaling system that could meet varying traffic demands throughout the day. Improvements included the introduction of better traffic signal software and techniques such as synchro software for more efficient time management The expected outcome of this new approach was a reduction in delays reduced delays, reduced queue lengths, and improved LOS for encounters.

3.5.1.2 Protected Phasing System

The second option involves the implementation of a protected phasing system at the Double Road intersection. This policy aims to increase safety and reduce conflicts by dedicating time to specific vehicle types, such as left turns and crosswalks to separate conflicting lanes and introduce paved roads to provide safer and more efficient traffic flow. The anticipated benefits of this alternative included improved safety, reduced delays at critical speeds, and possible improvements in LOS to A or B levels, meaning convergence performance is much better.

3.5.2 Faqeer Aipee Network

Faqeer Aipee intersection witnessed heavy accidents due to heavy traffic and poor signage. Two approaches were proposed to address these issues.

3.5.2.1 Actuated Signal Control

The first approach proposed to implement active signal control on the Faqeer Aipee Intersection. The actuated signage dynamically changes signal time based on real-time traffic conditions, detected by sensors at the intersection. These sensors monitor the traffic volume and adjust the signaling phase accordingly to reduce latency and improve traffic flow. The purpose of the installation of the actuated signal controllers was to provide an efficient traffic signaling system that could adapt to changing traffic demands. Expected outcomes included decreased average delay time, reduced queue length, and improved LOS.

3.5.2.2 Elevated U-turn

The second option is to build an elevated U-turn between Kataria and Khayaban. The elevated U-turns were designed to separate the U-turns from the main traffic, thereby reducing conflicts and improving traffic on the main artery It was intended that dedicated U-turns will be used to streamline traffic operations and reduce congestion on highways. The expected benefits included reduced congestion, better traffic flow and improvements to the overall network.

3.6 Assessment of alternatives

To evaluate the effectiveness of the proposed alternatives, each solution was implemented in the PTV VISSIM simulation model, and their impact on traffic and collision performance was evaluated. The evaluation criteria included the usage rate (LOS), average duration, and travel time.

3.6.1 Level of Service (LOS)

LOS is a qualitative measure ranging from A (free flow) to F (severe congestion), which reflects the performance status of assemblies where LOS was used to compare assembly performance before using an alternative each is using and after. Improvements in LOS showed improved traffic flow and a decrease in accidents.

3.6.2 Average delay time

Each vehicle delay was calculated for each intersection to measure the time lost due to congestion. By increasing the average delay, the proposed alternatives effectively reduced congestion and improved traffic efficiency.

3.6.3 Travel time

The travel time through the IJP channel was measured to assess the overall impact of the proposed solution on network performance. The reduced journey times meant increased traffic and improved network efficiency.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Combined Results of PTV VISSIM Analysis and Evaluation of the Current Scenario

A detailed analysis of the current traffic situation on IJP road was done using PTV VISSIM (Figure 6), a powerful micro-traffic simulation software The study focused on six major intersections: Double Road, Saidpur, Katarian, Khayaban, Pir Wadhai and Faqeer Aipee. This section presents an overview of the simulation results and a detailed discussion of the findings, highlighting key issues and areas for improvement.

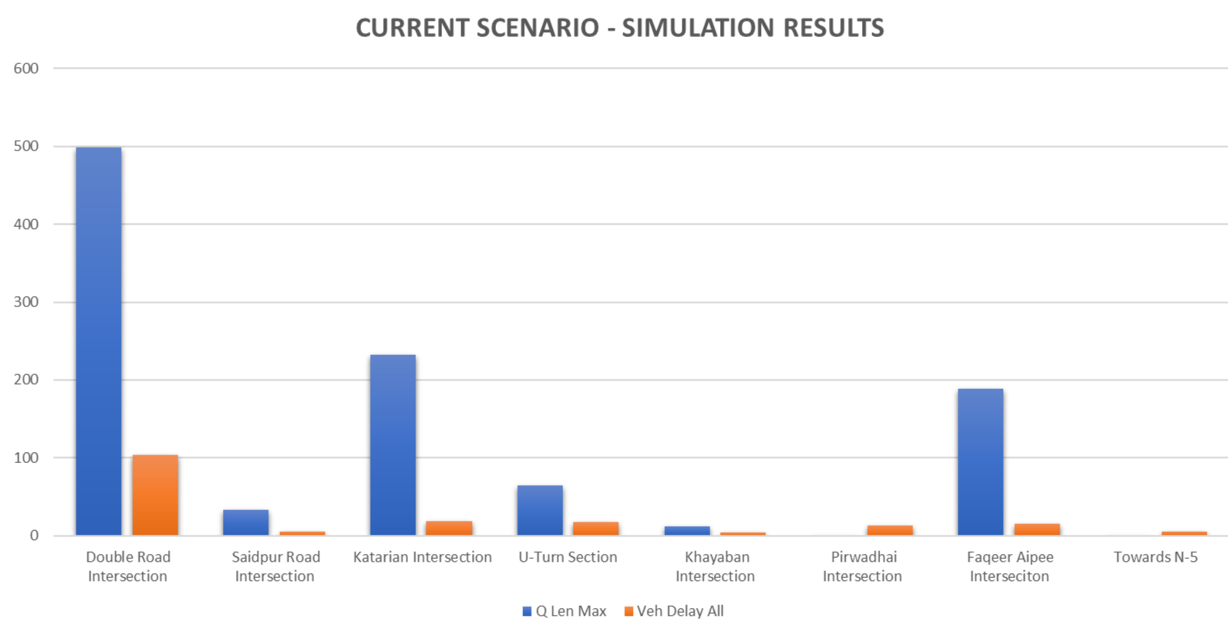


Figure 6: Results after Current Scenario simulation

4.2 Problematic Intersections Modifications Results:

A few intersections that were problematic were given attention and alternatives were given on each of them separately.

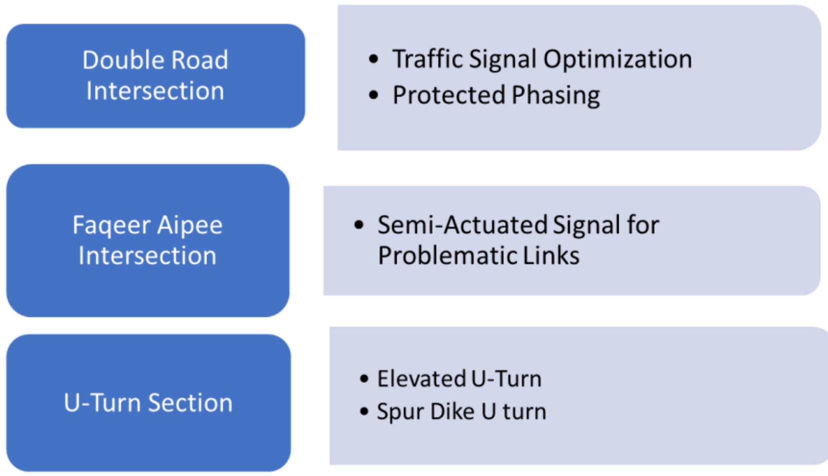


Figure 7: Problematic (Shortlisted) Intersections with their Modifications

4.2.1 Double Road Intersection

As discussed earlier, two alternatives were given a test on the said intersection including current traffic signal optimization and the protected phasing system.

4.2.1.1 Signal Optimization and its results

Signal optimization refers to the slight change in current green timings of the phases with respect to the traffic demand over there. In our case, the signal optimization proved better than the current scenario as the vehicle delays were reduced slightly. A comparison of the current and optimized signal timings and the result of them is shared below in Table 2 & Table 3:

	Signal Timings - Current		Signal Timings - Optimized	
	Green	Amber	Green	Amber
NorthBound	27	3	39	3
SouthBound	27	3	11	3
Eastbound	67	3	68	3
Westbound	37	3	40	3
Cycle Length	170		170	

Table 2: Signal Timings Data of Double Road Intersection

Double Road Intersection-Comparison (Current and Optimized)						
	Current Signal Timings			Optimized Signal Timings		
Links Direction	Delay	Q Len Max	LOS	Delay	QLenMax	LOS2
SW-NE	30.725614	45.083964	LOS_C	30.723503	45.083964	LOS_C
SE-NE	118.123673	323.00644	LOS_F	119.602393	323.068952	LOS_F
SE-NW	117.271663	384.557244	LOS_F	129.265178	384.619757	LOS_F
SE-SW	87.527844	323.00644	LOS_F	90.461291	323.068952	LOS_F
NW-SE	160.573115	451.147213	LOS_F	131.598328	451.108383	LOS_F
NW-NE	39.740008	309.678034	LOS_D	27.578606	309.639204	LOS_C
NW-SW	164.145796	451.147213	LOS_F	133.968331	451.108383	LOS_F
NE-SW	19.532809	0	LOS_B	19.539243	0	LOS_B
SW-SE	510.325607	471.426755	LOS_F	303.109652	471.231269	LOS_F
SW-NE		56.156716	LOS_A		55.163443	LOS_A
SW-NW	430.692709	56.156716	LOS_F	241.754555	55.163443	LOS_F
NE-SE	7.074002	0	LOS_A	99.408826	0	LOS_F
NE-NW	69.462591	107.405575	LOS_E	242.16199	273.97412	LOS_F
NE-SW		0	LOS_A		0	LOS_A
Total	**91.921112**	**471.426755**	**LOS_F**	**89.346481**	**471.231269**	**LOS_F**

Table 3: Results after optimization

4.2.1.2 Protected Phasing System:

Protected phasing system refers to the change in phasing which is currently split phasing. There are usually three types of phasing system. Split phasing, Protected phasing and Permitted phasing. Protected phasing as shown in Figure 8 is protected for the problematic right turns in which the right turns of the traffic signal are turned green separately for the opposite movements. This works best if the through volume for the opposite movements or the right movements for both opposite movements are high. In the case of Double Road Intersection, the volume for both opposing volumes is high and thus it reduces the delay for the intersection slightly but did not prove to be the best alternative.

The results for the protected phasing system is showed below in Table 4 in which different trials were done after setting up the signal controller. The evaluation was done after running the simulation and the results showed a massive decrease in delays with every next trial. The best result was achieved in the last trial where the delay reduced from 91s to 18s and LOS improved from F to B, which was a massive breakthrough for improving the flow conditions over the intersection without any expensive procedure. The things required included guiding the drivers about the correct use of the protected phasing system. Although, this phasing system is not operating so much in Pakistan, but it should be implemented for the ground-breaking results it can generate. The results are shown in the following Table 4:

Cycle Time (s)	Trial 01-140	Trial 02-140	Trial 03-100	Trial 04-85
Links	Veh Delay	Veh Delay	Veh Delay	Veh Delay
NE-SW	3.976191	3.976191	3.976191	3.976191
SW-NE	5.457331	5.571019	5.679003	5.529345
SE-NW	72.283026	113.459593	28.760278	30.801965
NW-SW	80.032733	36.964739	99.372958	93.929779
SW-SE	80.54336	87.403686	64.27998	50.819984
SW-NE				
NE-NW	40.868647	43.279525	31.793523	23.686335
SE-NE	41.432604	29.525378	35.704649	30.811968
NW-SE	46.660632	92.772003	18.197841	17.095712
NE-SW	6.215868	6.625837	8.166001	5.403757
E-SW	42.087006	62.911183	18.40595	16.582847
SW-N	31.409619	34.767886	22.407884	18.606185
NE-SW				
Total	**27.900272**	**30.797182**	**21.82443**	**19.789475**
LOS	C	C	C	B

Table 4: Results after Protected (Three) Phasing

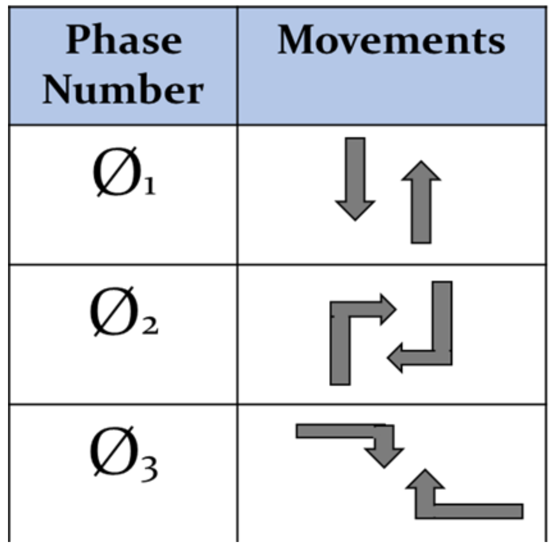


Figure 8: Three Phasing Used for Modification

4.2.2 Faqeer Aipee Intersection

The second shortlisted problematic intersection was Faqeer Aipee Intersection. The main problem over there was the conflicting movements below the flyover which is already constructed and operational, only for cars and bikes. The current scenario results for the intersection proved the problem in numbers as two conflicting movements were rated F by the software while the overall LOS of the intersection was C. The below Figure 9 shows the results for the current scenario.

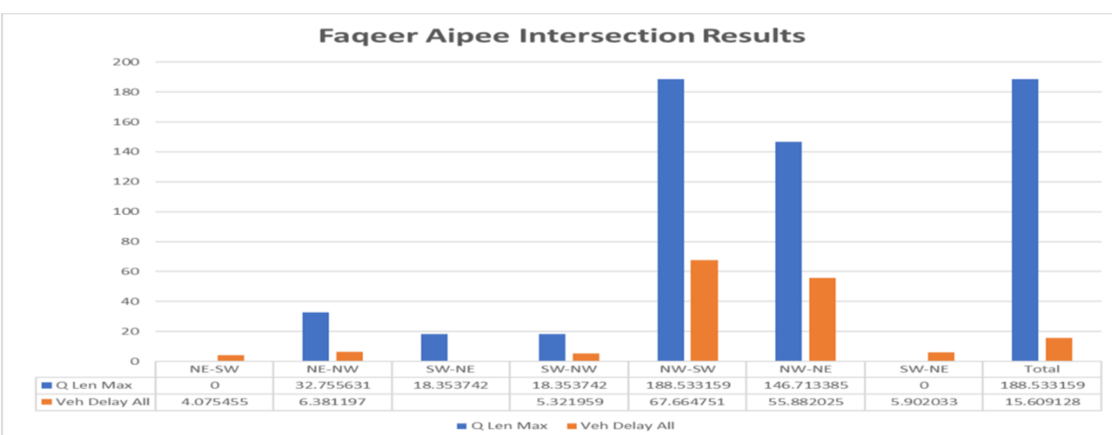


Figure 9: Graphical Representation of Before Modification Results

4.2.2.1 Actuated Signal Control:

To counter the identified issue for this intersection, the best methodology found from different literatures was the provision of actuated signal control which in this case will be called as Semi-Actuated Signal Control because only the two of the approaches were to encounter the traffic signal. Actuated signal control, as discussed previously, is the type of signal control in which the signal timings usually change automatically depending upon the traffic demand over the approaches. To determine the demand required by any of the approach, the detectors are installed at a specific location that could sense any vehicle coming, and based on that the signal controller adapts its timings. Also, it is worth-knowing that the actuated signal works best for those areas where the traffic demand of different approaches is variable, ideally some require high demand and some requiring low green time demand, which was exact the scenario in this case and that also justifies the alternative.

4.2.2.2 Semi-Actuated Signal Results:

So, to start with, the signal controller was set up on the software (VISVAP) that required modifying a flow chart as shown in Figure 10 and determining the exact scenario for the controller to operate successfully. After that, the controllers were placed at the desired locations and the simulation was done. After one complete simulation of 3600s, the evaluation was recorded, and the results obtained were a step forward in making this part of the IJP efficient. The results obtained are shown in Table 5:

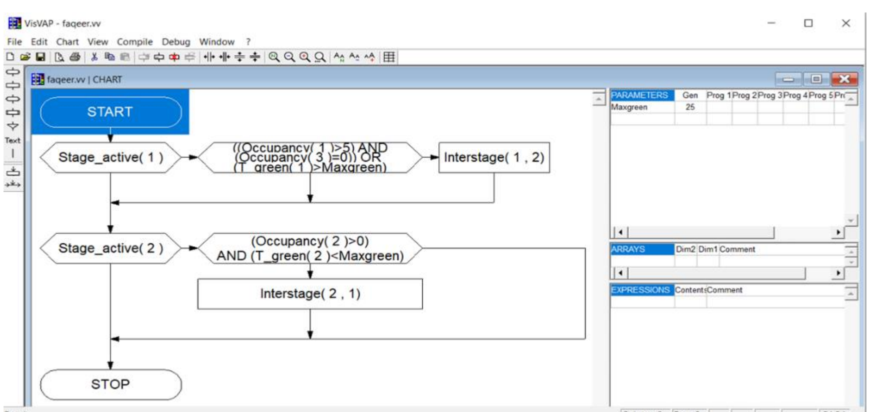


Figure 10: Design of Semi Actuated Signal on VISVAP

Faqeer Aipee Intersection						
Movement	Before	Semi Actuated	Results	After	Semi Actuated	Resutls
	Delay	Q Len Max	LOS	Delay	QLenMax	LOS
NE-SW	3.99	0.00	LOS_A	5.82	0.00	LOS_A
NE-NW	6.14	40.17	LOS_A	21.67	61.36	LOS_C
SW-NE		0.00	LOS_A		0.00	LOS_A
SW-NW		11.65	LOS_A		19.46	LOS_A
NW-SW	79.24	177.02	LOS_F	21.25	164.47	LOS_C
NW-NE	42.37	107.45	LOS_E	13.06	106.61	LOS_B
TOTAL	**19.50**	**177.02**	**LOS_C**	**10.21**	**164.47**	**LOS_B**

Table 5: Semi Actuated Results

From the results, the delays for the targeted two approaches were reduced massively from 79s to 21s and from 42s to 13s respectively. Also, the level of service was improved from C to B, which was not the direct requirement but due to the reduction in delay, it must improve.

4.2.3 U-Turn Section:

The last of the identified problematic areas found in the first analysis was the area of U-turns in between Katarian and Khayaban Intersection. There are two U-Turns operating there currently, the problem of those two intersections is nothing but the U-turns failure. Because IJP is mostly used by trucks and cars. The turning radius on the provided U-turns is not reasonable. The trucks while turning must stop which causes queue formation and ultimately disrupts the efficiency of the road network. The current scenario results of the area are shown below in Table 6:

Katarian & U-Turn Section - Before Results			
Direction	**Q Len Max**	**Veh Delay**	**LOS**
NE-S	232.311239	17.239608	LOS_C
NE-SW	232.311239		LOS_A
S-SW	28.135943	6.985953	LOS_A
NE-S	232.311239	32.26238	LOS_D
NE-SW	232.311239	34.802415	LOS_D
SE-NE	0	17.434426	LOS_C
SE-NE	0	16.120496	LOS_C
Total	**232.311239**	**19.151628**	**LOS_C**
SW-NE	64.879856	33.045096	LOS_D
NE-SW	0	7.140879	LOS_A
NE-NE	0	16.005032	LOS_C
W-SW	64.624875	36.385501	LOS_E
Total	**64.879856**	**17.372743**	**LOS_C**

Table 6: Results before Elevated U-turn Modification

4.2.3.1 Alternative for U-Turn Section:

Several alternatives were deduced from the literature to minimize the problem but the most efficient and safe among them was the provision of Elevated U-Turns. These are the safe U-turns provided from the left most lane of the running approach, elevates over the road and then enters the left most lane of the opposite flowing approach. It is safer for the trucks providing them the efficiency and free-flow condition as intended for IJP.

To analyze and implement the alternative on the IJP, the elevated U-turns were first drawn on the software as shown in Figure 11 and then traffic inputs and routes were allotted followed by the analysis and evaluation of different parameters in the PTV VISSIM. The results of the provided elevated U-turn is shown Table 7 below:

Figure 11: Elevated U-turn Modeling in VISSIM

Elevated U-Turn Resutls			
Direction	**Q Len Max**	**Veh Delay**	**LOS**
NE-S	42.421075	3.855227	LOS_A
NE-SW	42.421075		LOS_A
S-SW	38.323594	7.187295	LOS_A
SW-NE	0	10.001333	LOS_B
Total	**42.421075**	**21.055422**	**LOS_A**
SW-NE	0	61.121142	LOS_A
SW-SW	0	15.01637	LOS_A
NE-SW	0	51.142863	LOS_A
Total	**0**	**127.278603**	**LOS_A**

Table 7: Results after Elevated U-turn

CHAPTER 5

CONCLUSIONS & RECOMMENDATIONS

The comprehensive study of IJP Road, focusing on its six major intersections, has led to valuable insights and actionable solutions for improving traffic flow and reducing congestion. By leveraging PTV VISSIM for simulation and analysis, we identified critical bottlenecks and evaluated various alternatives to enhance the overall efficiency of this major urban arterial. The key takeaways from our study are summarized below.

5.1 Summary of Findings

Our analysis revealed significant congestion issues at the Double Road and Faqeer Aipee intersections, which were operating at suboptimal levels of service (LOS) and experiencing excessive delays and long queue lengths. These intersections were the primary focus for our proposed interventions.

5.2 Proposed Solutions and Their Impact

We proposed several smart traffic management solutions aimed at improving the traffic conditions along IJP Road, particularly at the problematic intersections. The strategies included traffic signal optimization, the introduction of a protected phasing system, the provision of actuated signals, and the implementation of elevated U-turns.

5.2.1 Traffic Signal Optimization at Double Road Intersection

By optimizing the traffic signals, we aimed to reduce the average delay per vehicle and improve the LOS. The simulation results indicated a notable reduction in delays and an improvement in LOS from E to C during peak hours.

5.2.2 Protected Phasing System at Double Road Intersection

The introduction of a protected phasing system was designed to enhance traffic flow by prioritizing movements based on demand. This system significantly reduced vehicle delays and enhanced the overall safety of the intersection.

5.2.3 Actuated Signal Implementation at Faqeer Aipee Intersection:

The provision of an actuated signal system at Faqeer Aipee intersection was aimed at dynamically adjusting signal timings based on real-time traffic conditions. This approach effectively reduced delays and improved LOS from F to D during peak periods.

5.2.4 Elevated U-Turns Between Katarian and Khayaban Intersections:

The implementation of elevated U-turns was proposed to alleviate congestion by providing an alternative route for turning movements. This strategy helped in reducing the queue lengths and improving the overall traffic flow along the arterial.

5.3 Improvement in Traffic Flow and Reduction in Congestion

The combined effect of these smart traffic management solutions resulted in a marked improvement in traffic flow and a significant reduction in congestion along IJP Road. The LOS at the major intersections improved, and the average delays were reduced, leading to a more efficient and safer traffic environment.

5.4 Importance of Proper Implementation and Maintenance

While the proposed solutions demonstrated positive results in simulations, their real-world effectiveness hinges on proper implementation and ongoing maintenance. It is crucial to ensure that the traffic management systems are regularly monitored, updated, and maintained to sustain their efficiency over time.

5.5 Investment in Infrastructure and Technology Upgrades

For long-term success in managing traffic congestion and enhancing road safety, investing in infrastructure and technology upgrades is essential. This includes not only the initial installation of advanced traffic management systems but also the continuous enhancement of these technologies to adapt to evolving traffic patterns and demands.

5.6 Conclusions

In conclusion, the study underscores the importance of smart traffic management solutions in addressing congestion and improving traffic flow on major urban arterials like IJP Road. By implementing targeted interventions and leveraging advanced technologies, it is possible to achieve significant improvements in traffic efficiency and road safety. However, the success of these measures depends on a commitment to proper implementation, regular maintenance, and continuous investment in infrastructure and technological advancements. Through these efforts, we can ensure sustainable and effective traffic management that meets the growing demands of urban transportation networks.

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