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Author(s) Nazam Ali, Hashir Zia, Hamza Bin Sarwar, Muhammad Nadeem, Dr. Zafar Baig, Muhammad Abdullah

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Implementation of Different Traffic Management Strategies on Major Roads for the Improvement of Traffic Flow in Lahore City

Nazam Ali*, Hashir Zia, Hamza Bin Sarwar, Muhammad Nadeem,
Zafar Baig, Muhammad Abdullah

Department of Civil Engineering, School of Engineering,
University of Management and Technology, Lahore, Pakistan

[*nazam.ali@umt.edu.pk](mailto:nazam.ali@umt.edu.pk)

Abstract

Traffic congestion causes many socio-economic problems in developing nations. One of the main causes of traffic congestion can be attributed to poor design practices. In the last few years, Lahore city has expanded haphazardly where the allocation of resources was done based on political will instead of feasible design practices. This haphazard growth coupled with a poor design resulted in traffic congestion on the main roads of the city. In this study, simulations using different traffic management design strategies were carried out on major roads to check if traffic delays and Level of Service (LOS) can be improved. The most feasible designs based on the simulated results were proposed for the improvement of the existing infrastructure designs. These findings suggested that Akbar Chowk and Jinnah Hospital Intersection have greatly reduced the traffic delay time by 92.97% and 92.67%, respectively. Policymakers can utilize these simulated results for future design guidelines to accommodate the future growth of traffic on these arterial roads.

Keywords: Lahore city, traffic congestions, traffic management strategies, traffic simulation

Introduction

In developing countries, traffic congestion is an ever-increasing concern for the stakeholders. It is the main source of resource wastage, time wastage, and environmental emissions. The main reasons for traffic congestion in developing nations are poor planning, design and operational strategies pertinent to the transportation systems [1]. The already constrained resources are allocated for development projects based on political affiliations ignoring the technical feasibilities of these projects. It results in a biased and unequal allocation of resources which further depletes the situation and worsens the sustainability and

feasibility of the planned projects [2]. This unjustifiable allocation of resources coupled with poor designs and planning strategies results in the non-vertical expansion of growing cities. Cities expand at a greater rate as compared to the surrounding regions. People from areas around the cities migrate to these unprecedentedly growing cities for better health, education, and career opportunities [3]. This results in increased traffic demand as the number of daily commuters exceed the capacity of the road network causing major traffic bottlenecks. These bottlenecks contribute to an increase in fixed-distance travelling costs, maintenance costs, commute time and emissions [4].

The focus of the previous provincial governments was on spending more funds on Lahore city. Consequently, people from the city surroundings started moving in causing major traffic congestions on some of the main routes with commercial, educational, and industrial centers. Unfortunately, the stakeholders put more effort into attaining their political motives and gave little attention to the public transportation systems. The public transport has few routes, most of which don't have fixed schedules of which the commuters are unaware of [5]. Commuting is one of the necessities of the people as they must travel for education, work, health, shopping, or for recreational purposes daily. Therefore, the unavailability of public transport in the city has led travelers to commute by their private vehicles. The most common means of transport are rickshaws, motorcycles, and cars. As these means of transport occupy more space with less capacity, it resulted in an imbalance of demand and capacity measurement in the city for the smooth flow of traffic, which are the major causes of traffic congestion in the region.

The biased and limited allocation of resources for the development of public transportation systems coupled with an unprecedented rise in traffic demand and a huge number of personal motorized and non-motorized vehicles on the roads has worsened the traffic situation on major arterial roads of the city [5]. Plus, the poor management of traffic has been a continuous source of suffering for the inhabitants [6,7]. It demands that a well-established study on traffic management strategies for accommodating future traffic demands is imperative for feasible and sustainable solutions to the traffic bottlenecks. These sustainable traffic management strategies come in the category of Traffic Demand Modeling (TDM) [8]. TDM is a broader term, which includes the

strategies to improve the efficiency and performance of the infrastructure with a minimum allocation of resources and much-needed changes in the design. TDM is an important tool to lower the menace of travelling time, cost, safety and convenience of the travelers [9]. However, due to a lack of proper planning, the least involvement of the stakeholders, politically motivated decisions, poor infrastructure designs and lack of technological advancements [10], developing countries are finding it difficult to devise feasible infrastructure designs where fewer resources are allocated and no major design revision is considered at the later stages [11]. Improving the traffic signal timings and operation types can have a good impact on traffic delay and smoothen the traffic flow [12]. Ali et al. [13] investigated that providing a roundabout in signalized corridors can improve the traffic flow and reduce delay time, thus improving the LOS. Many of the researchers have investigated that adaptive traffic control strategies are necessary to improve the flow of traffic and reducing traffic delays [14, 15, 16]. Steven et al. [14] argued that adaptive traffic control (actuated-traffic control) can increase the traffic flow, though it cannot improve the traffic capacity. Schakel et al. [15] investigated that actuated traffic control system is important to improve the capacity, flow stability and safety of the road network. Ngoduy [17] showed through numerical simulations that actuated traffic control system performs better in dynamic capacity equilibrium conditions for fixed traffic control systems. Jennie Lioris et al. [18] argued that traffic throughputs can be doubled if we adopt actuated traffic control strategies for fixed traffic control systems.

As most of the traffic intersections operate on fixed traffic control systems, this research takes one of the major congested arterial roads of the Lahore city as a case study. As evident from Figure 1, this route serves as a main collector road between the traffic of Faisal Town, Model Town, Kot Lakhpat, and Ferozpur road. Simulation studies using four traffic management strategies namely actuated single control, semi-actuated signal control, fixed time signal control and the roundabout are evaluated, and the results are compared. HCS and Syncro Studio and Sim Traffic Software were used as analysis tools and the most feasible solutions for traffic congestion were proposed based on minimum delay time and improved LOS.

The remainder of the paper is divided into the following sections: section 2 highlights the selected route network and data collection process where some descriptions of the software are also given, section 3 describes the data analysis procedures and the main findings of the research study, and the last part, section 4, includes discussions and conclusions, while limitations and future research directions are also described at the end.

2. Methodology

2.1. Data Collection and Route Selection

The data was collected using manual traffic counts and video data from Punjab Safe City Authority (PSCA) at each of the intersections during the peak hours for fifteen minutes for one week in the morning and evening. The manual traffic counts were validated with the video recording traffic counts and an error of 5% was acceptable for validation. If there was more than a 5% difference between the traffic counts, only then the video recording was used as a reference input value. The traffic counts for different vehicles were converted as per ASHTOO green book guidelines that are discussed in the next section [19] (Table 1). The peak hours were selected from the report (JICA, 2012) published by Government of the Punjab in close collaboration with Japan International Corporation Agency as a part of Lahore Master Plan 2021. To avoid bias and distortion of the traffic counts, data was not collected during expected traffic disruptions due to political rallies and other protests staged by different organizations. It was collected between January to April of 2019. The peak days during weekdays included Monday to Friday at 8:30 – 9:30 am and then at 4:30 – 5:30 pm. While for weekends, Saturday and Sunday, the peak hours were between 9:00-10:00 am and 6:00-7:00 PM. The difference in peak periods between weekdays and weekends can be attributed to the change in commuting behavior of travelers during weekdays and weekends. During weekdays, most of the purposes of trips can be due to visits to educational centers for pick and drop of students and going to offices for jobs or businesses. However, for weekends, most trips can be categorized as visiting relatives, shopping or dining outside [20]. The data collection and analysis procedure is summarized in Figure 1.

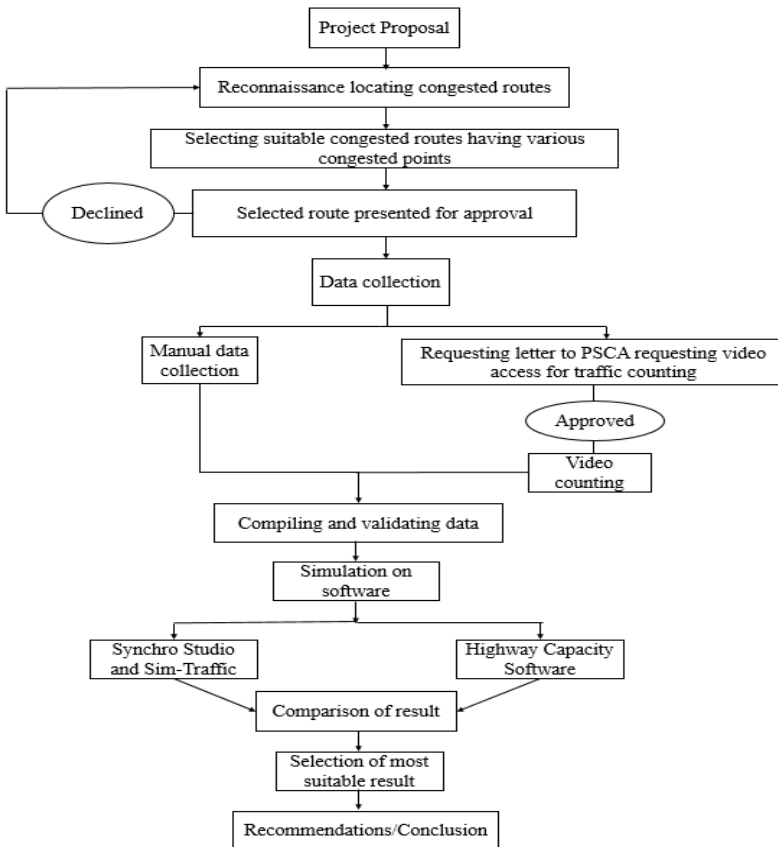


Figure 1. Data collection and analysis procedure

The data collection by manual traffic counts, and video recording by PSCA can be seen in Figure 2.

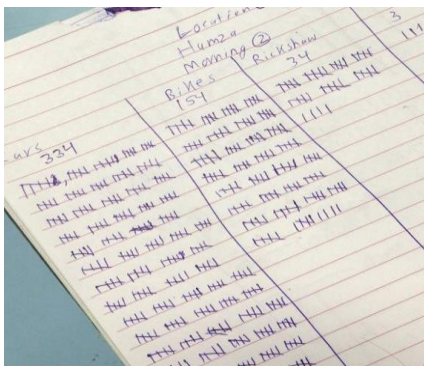


Figure 2. Traffic counts (Left: manual), (Right: video counts)

The selected route is a major arterial road connecting many commercial, educational, and healthcare centers. It was the primary criteria for selecting this route as it has huge traffic congestion during peak hours. Public transport is near non-existent on the selected route and the major means of transport are automobiles which include rickshaws, motorcycles, and cars. The non-compliance of motorized vehicle drivers with traffic rules and the low enforcement of rules by the traffic police along with poorly designed intersections are further reasons. Another reason for selecting this particular road network is that it has become a major business and residential hub in the city because of the expansion of various housing societies which are a major source of traffic generation. The map of the road network can be seen in Figure 3.

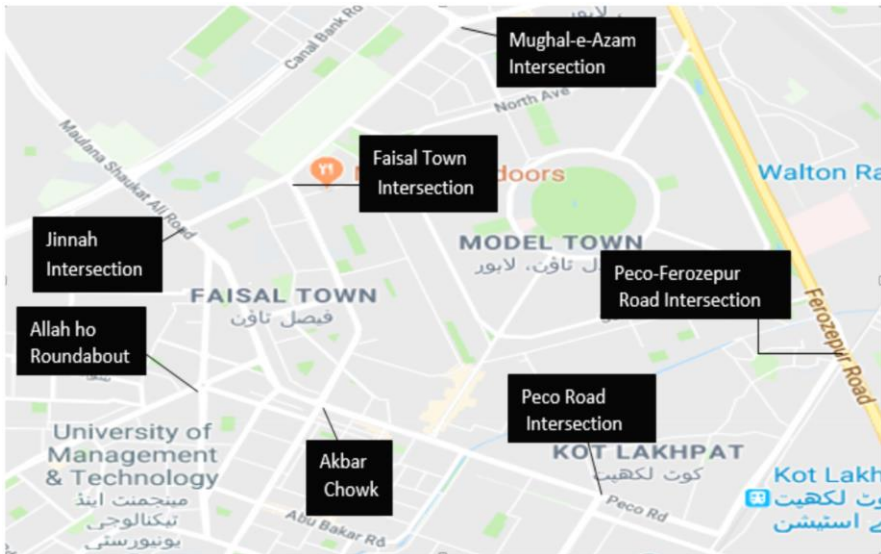


Figure 3. Map of the selected route (Source: Google Map)

2.2. Data Analysis

The analysis was carried out using HCS, Synchro Studio and Sim Traffic Software. The inputs in the software were the geometry of the intersections and traffic counts. The traffic counts were converted as per AASHTO standards, shown in Table 1.

Since the software is designed as per US standards, where the right turn is free-flow, the geometry of each intersection was customized according to Pakistani standards of driving where left-turn is considered

as free flow using the mirror-image concept. A schematic diagram of the Pindi Stop Intersection is shown in Figure 4.

Table 1. PCU by AASHTO for each Vehicle Type [19]

Vehicle Type	PCU Factor
Motorcycle	0.5
Car	1.0
Utility (Rickshaw, Qing qi),	1.0
Microbus <30 Seats	1.5
Minibus	3.0
Bus	3.0
Light Truck	1.5
Heavy Truck	3.0
Multi-Axle Truck	3.0
Others	1.0

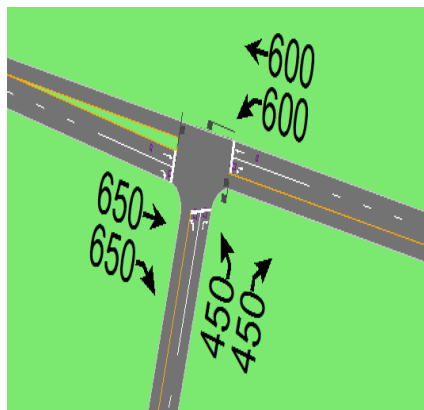
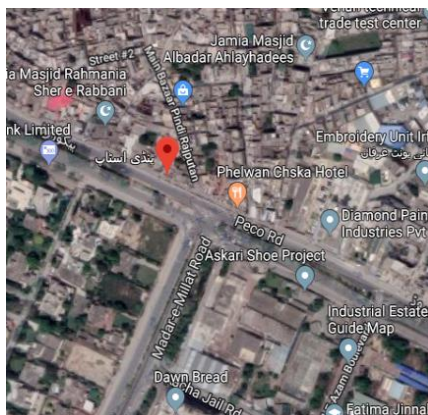


Figure 4. Schematic diagram of Pindi Stop intersection (Google map (left), Simulation diagram (right))

The most suitable, feasible and sustainable intersection design was selected among different traffic management techniques like actuated-signal control, semi-actuated-signal control, fixed timing signal control, and the provision of a roundabout. The selection criteria of the most feasible solution included the reduced delay timings and an improved LOS. However, the on-ground conditions of the right-of-way availability were also considered to incase there was sufficient space available to modify the road network design in the case of a roundabout if need be.

3. Results

The simulation results of all the selected intersections are shown in Table 2. As evident from the table, there are significant improvements in the results where LOS is improved and the maximum delay is decreased in each case.

Table 2. Comparison of Maximum Delay and LOS Before and After the Analysis

Intersection Name	Maximum Delay Time (sec)		Level of Service (LOS)		Traffic Management Strategy
	Before	After	Before	After	
Mughal-E-Azam Intersection	1414.4	416.6	F	E	Changing fixed-time signal control type to actuated-signal control type
Faisal Town Intersection	1587	416.6	F	E	Changing fixed-time signal control type to actuated-signal control type
Jinnah Hospital Intersection	1376	96.7	F	D	Changing fixed-time signal control type to actuated-signal control type
Akbar Chowk Intersection	859	20	F	C	Changing fixed-time signal control type to actuated-signal control type
Pindi Stop Intersection	1780.3	217	F	D	Changing fixed-time signal control type to actuated-signal control type

As can be seen from the above table, the most efficient and feasible traffic management strategy was to change the fixed-time signal control system into an actuated-signal control system. The main reason can be ascribed that on the major arteries the traffic is more as compared to the side connecting roads. While in fixed-time signal control, the green time allotted to the traffic from minor crossing roads is more which wastes

the green time to be allocated to the main traffic directions. The maximum improvement can be observed at the Jinnah Hospital intersection where the delay time reduced from 1376 seconds to 96.7 seconds. While the least improvement in the delay time reduction was observed at the Mughal-E-Azam intersection, where it reduced from 1414.4 seconds to 416.6 seconds (Figure 5).

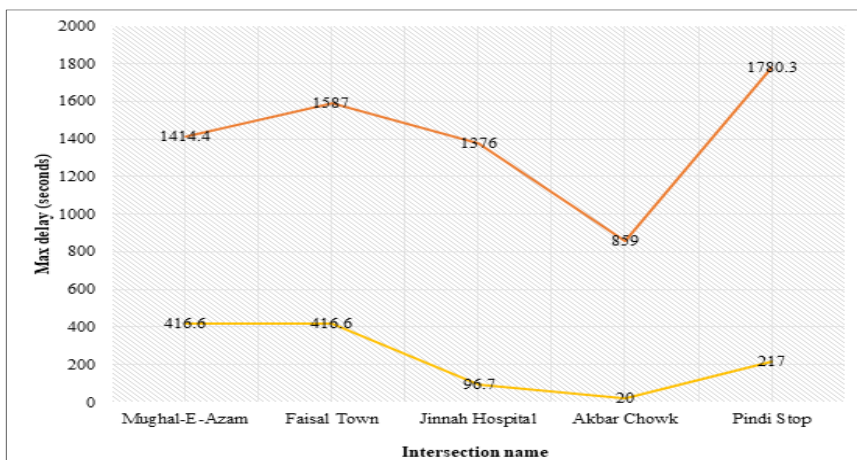


Figure 5. Comparison of the improvement of delay time before and after the analysis at each intersection

As mentioned earlier, in the results and the bar chart displayed below, the solutions suggested are very effective as they depict a major decrease in the maximum delay of each intersection. The chart shows the percentage difference of the maximum delays of intersections. There is a significant improvement showing that the intersections are suitable for service and there is a significant decrease in congestion on the existing number of vehicles currently using these intersections daily. It shows that the Jinnah Hospital intersection has maximum improvement (92.93%) (Figure 6) in the reduction of delay time. While, the least improvement can be observed at the Mughal-E-Azam intersection which is around 70.54%, which is still a significant improvement (Figure 6). The LOS improved from F to D and F to E for Jinnah Hospital and Mughal-E-Azam intersection, respectively.

It is evident from Table 2 and Figure 6 that the traffic management strategy of simply changing the fixed-time signal control system into an actuated-signal control system has an immense impact on the reduction of delay time and improving LOS. The actuated single control system

proved to be an effective strategy in this scenario which had a great impact on the delay time minimization. This study is in agreement with the previous simulation studies [16,18,21,22] which concluded that actuated signal control outperforms the signal control systems as compared to the fixed traffic control. Therefore, this research study reinforces the previous research findings.

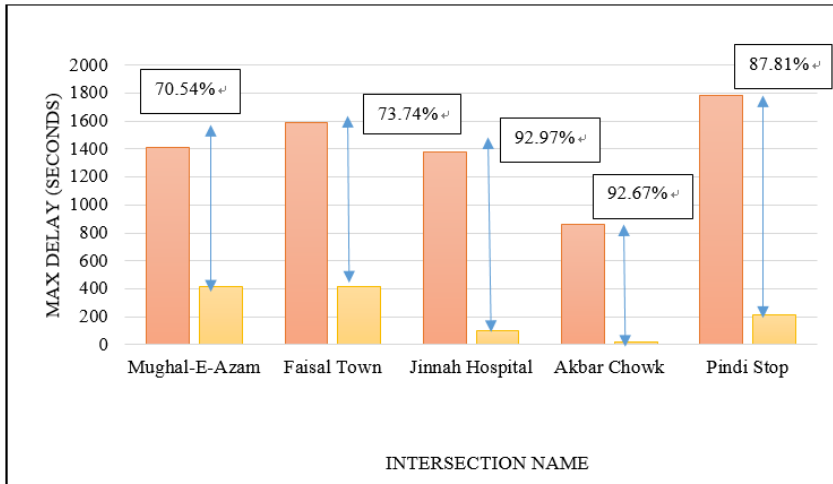


Figure 6. Percentage comparison of delay time improvement before and after the analysis at each intersection

4. Conclusion and Discussion

This study is a simulation-based which intended to evaluate the traffic congestion on one of the major arterial roads of Lahore city. The simulations were carried out based on the actual traffic counts on the selected routes. Data was collected using manual traffic count and video recording counts from PSCA. Different kinds of vehicle counts were input based on the PCU defined by AASHTO [19]. Special care was exercised in drawing the geometry of the selected intersections using the mirror image approach. Four different types of traffic management strategies were tried in simulation to evaluate the most feasible solution to mitigate the negative effects of traffic congestion. The criterion of the most suitable alternative was defined based on delay time in seconds and Level of Service. The simulations were carried out using two microscopic traffic simulation software: HCS and Synchro and Sim Traffic. The results manifested that there is a great improvement in the minimization of delay time and LOS.

All the selected intersections currently have fixed-time signal control systems. The actuated-signal control type proved to be an effective strategy in mitigating traffic congestion. In the actuated-signal control system, the sensors detected the longest traffic queue on the approaching leg based on infrared radiations and the signal facing the most traffic turned to green allowing the traffic to pass through. This simulation study can be used as an important tool to assess the performance of different intersections in given circumstances. However, actuated-signal control systems should be implemented without much delay as it is the last option to implement, and a special preemption should be given to the emergency vehicles for the safety improvement of the residents and commuters. This research study was carried out on a local scale and may not represent the actual reasons for traffic delay. Therefore, an extended research study is required to include a broader study area so that some valid conclusions could be made, and relevant suggestions are proposed.

However, the policymakers and traffic planners can get some insights from this research study: how the introduction of actuated-signal control can be used as an estimation for smooth flow and proper resource allocation. This study can help the authorities in mitigating traffic congestion problems for Lahore city and can give insights to policymakers in case of extension of the current route due to increased traffic demand in the future.

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