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Article

Microsimulation-Based Assessment of Traffic Performance and Sustainable Solutions: ACase Study of an Urban Intersection

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Abstract

Traffic jams are one of the most critical issues in fast-growing cities, and the twin city of Pakistan is no exception. Traffic Jams lead to significant operational problems, which is particularly growing in cities during rush hour, and as a result, it is creating additional delays, emissions, and safety concerns. This study evaluated the traffic performance of the intersection of the T-Chowk located at the southern end of the Islamabad Expressway with the help of microsimulation modeling. The analysis is based on traffic count data, and generated simulations are used to test the efficiency of the urban intersection and to test various sustainable solutions. The findings of the study showed that the adaptive signal control, expansion of the lanes, and the combination of the intelligent traffic systems (ITS) would significantly enhance the traffic flow, which would reduce the effects on the environment and delays.

Keywords: *Microsimulation, Traffic Congestion, Urban Intersection and Sustainable Solutions*

1. INTRODUCTION

The capital of Pakistan, Islamabad, has experienced tremendous growth in recent years because of the increase in population, where it has grown from a small town to a major urban center with a population of more than a million people[1]. This growth of population, combined with spreading urban growth has put the massive burden on the transport system infrastructure in the city especially at the vital intersections like the T-Chowk at the southern end of the Islamabad Expressway. It is a very strategic intersection, which is used by the traffic in the course of Islamabad to other urban and suburban regions including Rawalpindi, Rawat, and various other circles. Although it is an essential part of the structure of the transport in the city, T-Chowk is very congested during some time of the day, especially during the rush hours. These result in delays, wastage of signals at the crossroad, traffic congestion, delays, and environmental pollution due to vehicle emissions [2]. T-Chowk is an unsignalized three-leg intersection, which can barely carry the increased volume of traffic, particularly on the minor roads. This congestion results in the fuel wastage, motor vehicle emission, and carbon footprint, which contributes to the further aggravation of air quality problems of the city [3,4]. Inefficiencies in T-Chowk also have a negative impact on the local economy since any delay is translated to productivity, and in a sense that the emergency vehicles cannot operate efficiently in the locality, this is a threat to the local economy [5]. A complex, information-driven approach must form the basis of the solution to these issues. A positive example of the microsimulation that can be applied to the investigation of the dynamics of the traffic at a crossing as at T-Chowk is the PTV VISSIM tool. The PTV VISSIM is able to simulate various traffic facility scenarios such as signal alterations, lane extensions, and redesign of infrastructure to find out the efficiency in practice (by simulating the motions of the respective cars) before its actual implementation in the field.

This method, aside from lowering the costs of implementation, also makes sure that the proposed strategies are adapted to the unique conditions of T-Chowk traffic. The research will analyze the performance of T-Chowk through PTV VISSIM 2025 and suggest the sustainable solutions to the traffic congestion problems in order to reduce delays and minimize environmental effects. The research will focus on coming up with a comprehensive microsimulation model, which captures the real road traffic scenario and conditions, and therefore identify strategies that will maximize the performance of the traffic at T-Chowk, and also provide insights for similar intersections across Islamabad. Using the microsimulation, the current research also contributes to the general literature on sustainable urban transport solutions, i.e., effective and environmentally-friendly traffic management practices that enhance both mobility and environmental health[6].

2. LITERATURE REVIEW

The analysis tool of traffic simulation is incredibly crucial with respect to testing and optimization of the functioning of the traffic systems in the city. To formulate the models to analyze the flow of traffic, the interaction between vehicles, and the timing of signals at the intersections, microsimulation tools like PTV VISSIM are frequently applied. It models the automotive behavior in a lane-by-lane manner and aids in gaining insight into the impacts of traffic control techniques on traffic congestion, delays, and emissions by vehicles [7-9]. Rather, unlike macroscopic models such as VISUM and SYNCHRO, which work with aggregate information about traffic, the microscopic nature of VISSIM can provide the more individual dynamics of vehicle-based modeling, and therefore, is a perfect instrument to analyze an intersection such as T-Chowk [10]. It is also possible to understand driver behaviors, vehicle interactions, and congestion in more detail, which is especially relevant in intersections without signals, such as T-Chowk, due to the detailed analysis of the microsimulation models. Microsimulation is a model at the vehicle level of analysis, whereas macroscopic models are at the aggregate stage of traffic analysis, i.e. traffic flow and traffic density. Conversely, the macroscopic models embody accumulated traffic characteristics of vehicle density, average rate and traffic flow, which represents a more generalized measure of macroscopic, and not microscopic network analysis at an intersection level [11], [12]. As an example, Krauss et al. (2000) consider that the microsimulation models play a vital role in exploring complex intersections because the focus of the models is on the vehicle delays, dynamic actions, and stochastic occurrences [13]. The macroscopic models, like the Highway Capacity Manual (HCM), on the other hand, provide generalized measurements like Level of Service (LOS) and do not describe specific traffic behavior [14]. Measures of Effectiveness (MoEs) are used in the measurement of the performance of intersections in traffic analysis. The most widespread MoEs are: Average delay per vehicle: It is one of the most significant measures of the duration of time during which vehicles are held at an intersection (because of congestion) [15], Queue length: The number of vehicles at an intersection, which is one of the indicators of severity of congestion [16], [17], Level of Service (LOS): Qualitatively, it is a measure of the performance of an intersection between A (free-flow) and F (severe congestion) in terms of delay times and traffic flows [17]. In the case of unsignalized intersections, such as T- Chowk, the scoring of these MoEs will assist a traffic engineer in determining the point of congestion and optimizing the signal timing or proposing any changes required to improve the infrastructure [18]. Microsimulation has proven useful in making intersections more efficient, as demonstrated in case studies of several cities: Lahore, Pakistan. Ahmed and Raza (2020) conducted an experiment on the VISSIM to model a traffic intersection in Lahore, Pakistan. They maximized traffic signal timing, which decreased the delay by 30 percent and enhanced the traffic movement. The case study was a good example of the practical application of VISSIM in congested urban traffic conditions [19]. Cairo, Egypt: Shahin and Kamal (2017) have conducted a study in the city of Cairo wherein they analyzed the intricate relationships of vehicles, people, and buses at an uncontrolled intersection by use of VISSIM. The study suggested a 15 percent increase in the time taken by pedestrians to cross the roads and the buses to be prioritized during the busiest time, increasing the efficiency of the public transportation and lessening the waiting time of pedestrians [20]. New York, USA: NYCDOT applied VISSIM to optimize the traffic at various intersections within New York City. A 2016 case study showed that timing tuning of the signals and incorporation of exclusive turn lanes at an intersection with a high level of traffic minimized the delays of vehicles by 20 percent and the emissions of vehicles by a significant margin [21]. Mumbai, India: Vishwakarma et al. (2019) conducted a study in Mumbai to examine chaotic behavior of traffic at an uncontrolled intersection. The simulation showed significant parking points and suggested changes in the lane layouts and entry policies, which minimized congestion during the rush hours by 18% [22]. These case studies illustrate the versatility and the generalizability of microsimulation tools such as VISSIM in improving the performance of intersections in different geographical and traffic conditions. The capacity to simulate the real-life traffic conditions with the details will enable cities to experiment and apply effective solutions and before such a process is applied to the real-world infrastructure, which will in the end lead to lower costs and enhanced efficiency.

3. PROBLEM STATEMENT

Although a lot of literature has been conducted on traffic microsimulation and its uses, there is still a huge gap in ways of optimizing such an unsignalized intersection like T-Chowk. The majority of the studies were focused on signalized intersections or missed the implementation of main aspects of the pedestrian movement and the contribution of public transport to the traffic model. T-Chowk, a crucial intersection in the city of Islamabad, is a traffic intersection that is not marked and contains a wide array of traffic, such as personal vehicles, buses, and trucks. The current traffic management system is unable to deal with the dynamic nature of this mix, especially during rush hours. Also, when microsimulation models, such as PTV VISSIM, have been popularly implemented in signalized intersections, there is no detailed research about the calibration and usage of these models in unsignalized intersections in mixed traffic compositions. This is because it does not have any special models that can be used to manage unsignalized intersections; hence, it has poor traffic management measures that cannot be used to maximize flow, decrease waiting time, and minimize the environmental impact. Lack of precise and data-oriented solutions at T-Chowk has contributed to constant traffic jams, fuel wastage, and high emissions, and it is important to explore the intersection performance and present the sustainable strategies to manage traffic.

4. METHODOLOGY

4.1. Study Area

The research is centered on the T-Chowk intersection located on the Islamabad Expressway, as shown in Figure 1. This intersection is a major three-legged unsignalized junction that connects several critical urban and intercity routes. Due to its strategic importance and heavy daily traffic volumes, especially during peak hours, T-Chowk was selected as the case study site for traffic analysis and microsimulation.

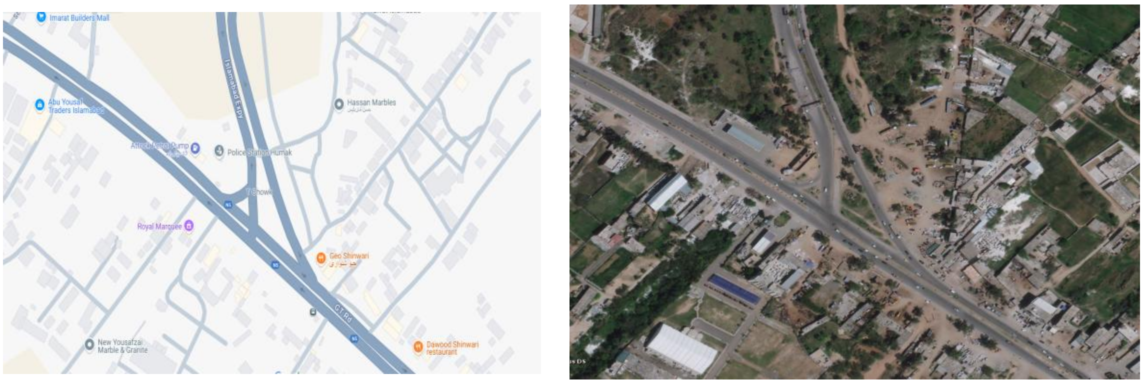

Figure 1: Study Area visualization using Google Map and VISSIM

4.2. Methodological Framework

The study follows a systematic methodology model of five phases to maintain a systematic implementation of the research. Each step is based on the earlier one to develop a detailed analysis of the T-Chowk intersection with the use of PTV VISSIM 2025. A detailed methodological framework is shown in Figure 2.

4.3 Problem Definition and Site Selection:

A major problem is the absence of clarity in the definition of the problem and its location, because this is not a literature review, but rather a personal approach to the problem. The initial step was to determine a location that is important in terms of traffic. The study site was determined to be T-Chowk, which is situated on the Islamabad Expressway, because of its importance as a large 3-legged unsignalized intersection of major arterial roads. Congestion is often experienced in this intersection during rush hours, which has an impact on both the commuting and commercial traffic. The initial field reconnaissance was able to confirm its high traffic volume and geometric complexity with the aid of high-resolution satellite images and it made it an excellent candidate of microsimulation modeling.

4.4 Data Collection:

The second stage involved the collection of detailed traffic data by use of primary and secondary sources. The field surveys were made directly to tally the number of vehicles, their type (cars, motorcycles, buses, LTVs, and HTVs) and the turning movement at the intersection. In order to capture the realistic traffic behavior, observations were done during peak as well as off-peak hours. On the basis of this observation, it was estimated that the traffic volumes were as follows: 1500 vehicles per hour (vph) northbound, 1200 vph southbound, and approximately 500 vph on each of the minor road approaches. The model development in PTV VISSIM involves the development of a model within the VISSIM functional offered in VSSIM (Machiavelli 2009, p. 24).

4.5 Model Development in PTV VISSIM:

This development of a model in VSSIM is done on the VSSIM functional provided in VSSIM (Machiavelli 2009, p. 24). The third stage was aimed at the development of a base model in PTV VISSIM 2025. The T-Chowk geometric pattern was reproduced in the software based on the satellite image of Google Maps and site measurements. Traffic volumes and turning movements information were also the inputs into the model.

4.6 Simulation and Scenario Testing:

After its development, simulations were run to determine the actual performance of the traffic. The baseline scenario i.e. the current conditions were first evaluated. Later, other configurations were subject to experimentation with geometrical alterations, to measure the enhancement in the flow of traffic and the curtailment of wait times. Such tests assisted in revealing situations that may provide best traffic performance.

4.7 Model Evaluation and Analysis

In the last phase, simulation outputs were analyzed with the help of most important traffic performance measures like the average vehicle delay, queue length, and Level of Service (LOS) in accordance with the Highway Capacity Manual (HCM). These outputs were compared with the field-observed data for validation. Differences observed were taken to re-tune the model, as it was highly accurate and reliable to use. The validated model clarified the areas of operational inefficiency and facilitated the recommendations for best signalization in the intersections..

4.8 Performance Indicators

There are various performance indicators used in this study of the traffic simulation to determine the efficiency and effectiveness of the traffic system at the T-Chowk intersection. These indicators are critical for comprehending movements in traffic, congestion, as well as the overall intersection performance. Average Delay is the average time that passes with a vehicle being delayed by the traffic congestion or the signal controls in the intersection. It is given in the units of seconds per car (s/veh). This metric is useful at determining the amount of time that drivers are wasting at the intersection. A larger average delay means more congestion or inefficiency in timing the signal. The Queue Length counts the number of vehicles that are waiting at the intersection, either at the stop line or in the approach lanes. It is measured in both average and maximum queue lengths. The average queue length is the average number of vehicles on the lines during the simulated period, while the maximum queue length is the longest line of vehicles during periods of highest congestion. These values give an insight into the amount of traffic build-up and the ability of the intersection to accommodate traffic at peak hours. Level of Service (LOS) is a qualitative measure of the performance of the intersection. It is measured on the scale of the Highway Capacity Manual (HCM) which constructs the levels of service from A to E where A stands for the uncongested conditions (excellent) and E indicates conditions of severe congestion (failure). LOS takes into account delay, length of queue, and flow of traffic and evaluates the performance of the intersection as a whole as given in Table 1.

Table 1: Summary of performance indicators:

Metric	Description
Average Delay (s/veh)	Time each vehicle is delayed
Queue Length (m)	Average and maximum queue lengths
Level of Service (LOS)	Assessed based on the Highway Capacity Manual (HCM)

These performance indicators provide valuable insights into the traffic behavior at the intersection, helping to identify areas for improvement in signal timing, infrastructure capacity, or traffic management strategies.

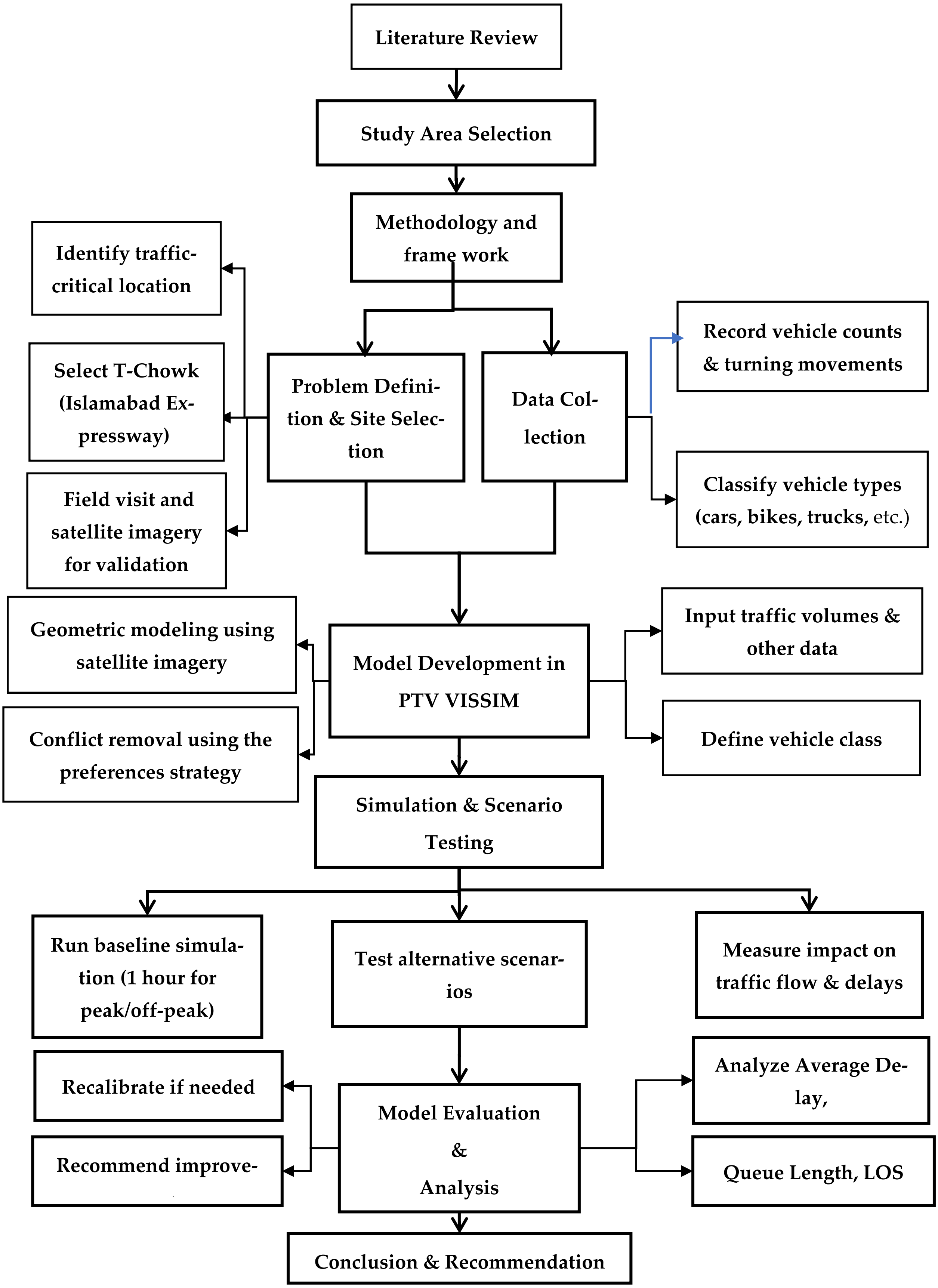

Figure 2: Methodological framework for microsimulation-based traffic performance analysis and scenario evaluation at T-Chowk intersection

5. MICROSIMULATION MODELING USING VISSIM

The Microsimulation PTV VISSIM tool was applied to simulate the traffic flow at the T-Chowk intersection, the present and the suggested improvements of the intersection [23]. It consists of a number of steps:

Loading the Study Area: VISSIM was loaded with geographical coordinates of T-Chowk (33.511579, 73.178772), and it was used to get a graphical representation of the intersection. This makes the simulation consist of an accurate layout in the real world.

Development of Links (Roads): There were four major road links modeled (East-West (EW), West-East (WE), South-North (SN) and North-South (NS)) and they were planned with the required number of lanes (e.g., 4 lanes in NS/SN, 3 lanes in EW/WE).

Production of Connectors: Connectors became links between the links to indicate the vehicle movements, as left turning, straight, or right turning. This makes sure that there is proper road flow between major and minor roads.

Defining Turning Movements (Vehicle Routes): Turning ratios were indicated in each direction (e.g. 70% straight, 20% left, 10% right) that enabled VISSIM to model traffic behavior and measure the performance of every intersection.

Composition and Types of Vehicles: Vehicles were divided into cars, light goods vehicles (LGVs), heavy goods vehicles (HGVs), and motorcycles, each of which had a designated target speed (e.g., 50 km/h in the case of cars, 40 km/h for trucks).

Traffic Volume input: This was 1500 vehicles per hour of traffic volume on each of the major links (EW, WE, NS), indicating the average traffic requirement at T-Chowk.

Setting Conflict Areas: The conflict areas were characterized as Conflict zones where vehicles of varying directions come into contact. Priority rules were developed that emulated real-world traffic mode at the intersection, which was not signaled.

Running the Simulation: Once the model was set up, the simulation was executed in order to check the traffic movement, delays, queue length, and traffic throughput. The findings allow determining the places of congestion and experimenting with solutions as shown in Figure 3.

The various strategies of managing traffic can be tested during this process and thereby enhance traffic flow, delays, and intersection performance.

Figure 3: Simulation Run in the PTV VISSIM

6. ANALYSIS AND RESULTS

The simulation results analysis of the unsignalized T-Chowk intersection involved such key performance indicators (KPIs) as Level of Service (LOS), average vehicle delay, queue length, and vehicle throughput. Both peak and off-peak hours were used to run the baseline model to determine the performance of the traffic. The simulation showed that there was LOS F on the minor roads during peak times, which means there were massive traffic jams in the roads accompanied by long queues, and the traffic was very inefficient. The expressway (Islamabad Expressway) had slightly better LOS C, which was moderate congestion. The mean delay on the minor roads was found to be 45 seconds per vehicle, which is very high and exceeds the tolerable limits. The level of delays decreased on the main road, and vehicles experienced delays of 10-15 seconds during the peak hours. The congestion was very high, as the queue on the minor roads was more than 200 meters, and it was at times up to 300 meters, especially with the vehicles that were on the minor roads. This congestion highly lowered the vehicle throughput because traffic could not flow effectively, and this augmented delays further throughout the intersection. Some changes were also bootstrapped on the outcomes of the simulation to enhance traffic flow in T-Chowk. To begin with, the increase of lanes on minor roads and turning lanes resulted in the decrease of the queue length by 15-20% and the decrease of the delays by 20%, proving that the improvement of the lanes configuration is able to increase the traffic volumes. The Link Evaluation in Figure 4 shows that the speed, density, and vehicle volume in the evaluation segments have a strong correlation with the main issue of congestion at the intersection. Moreover, the simulation was used to test the use of priority rules on major roads, which enhanced the flow by 10-15% on minor roads. This finding can be observed in Figure 5, which depicts the traffic parameters, including the queue length, vehicle delay, and fuel consumption, and proves that the focus on the high-capacity vehicles, including buses, was effective. Also, a roundabout was experimented with in the simulation, and it was found to improve the throughput by 10-15 percent and delays were minimized. This observation can be justified by the findings of the Node Evaluation in Figure 6, which indicates the relationship between queue delay, fuel consumption, and average acceleration at peak hours. The roundabout structure was such that traffic flow was continuous and therefore, there was less stopping and starting and they might be a viable idea to enhance the overall performance of the traffic. Also, the refining of conflict zones, in which there is a merging of vehicles moving in different directions, demonstrated a 15-20% increase in the speed of the vehicles and decreased delays. The Delay Measurement is shown in Figure 7, and it is clear that there is a distinction between the stop delay, vehicle delay, and the number of stops in a time interval, and it has been seen that there are areas where the delays can be reduced. Another effect of the congestion at T-Chowk that was revealed in the simulation was its environmental implications. The lengthy waiting time and congestion levels were very high, resulting in vehicle emissions that are much more than what would have been expected. The outcomes of the simulation revealed that the fuel consumption and emissions could be halved or decreased by 5-10 per cent. by enhancing the traffic flow. This is also reiterated in Figure 8 which shows the queue length and stops made by the queue at the intersection. This would be achieved by maximizing the efficiency of the traffic and reducing the emissions through better lane structures, including a roundabout and Intelligent Transportation Systems (ITS) to provide real-time traffic monitoring. Finally, the results of the simulation showed that T-Chowk was not efficient, particularly when it comes to vehicles in the minor roads. The improvements identified and listed (lane expansion, priority rules, roundabout design, and conflict zone management) would potentially make a significant contribution to the traffic flow, as well as congestion reduction. The refinements of the model should be concerned with testing these strategies and the possibility of combining ITS in order to guarantee the optimization of traffic management in real-time. These measures will provide workable solutions to the congestion problems experienced at T-Chowk and can be used to address the problem in other intersections within cities.

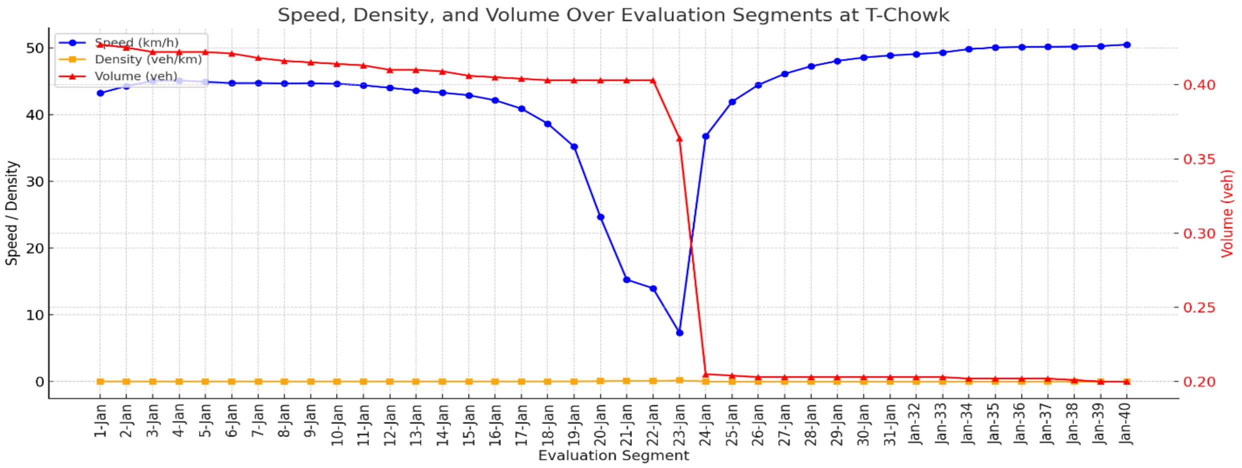

Figure 4: Link Evaluation

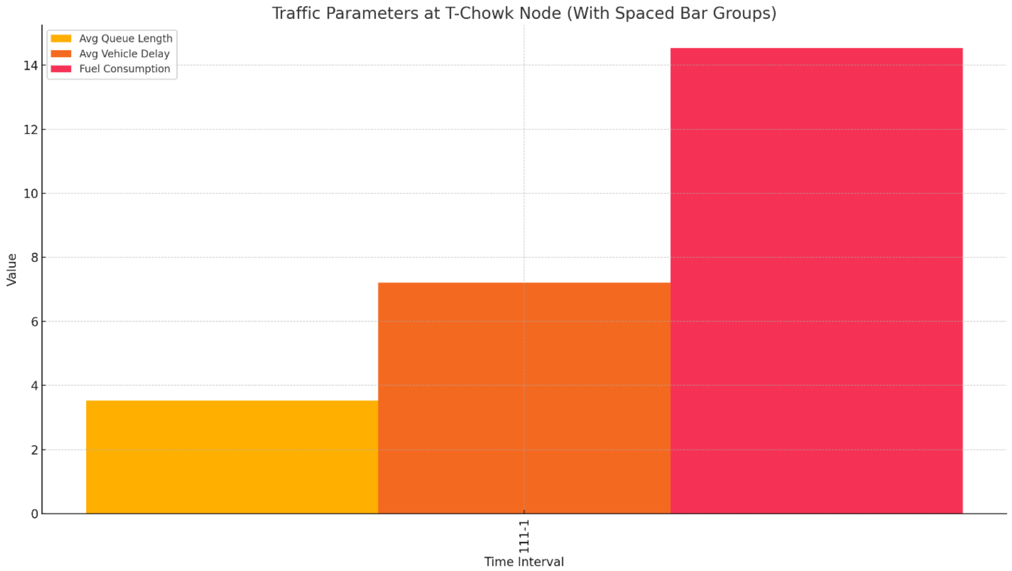

Figure 5: Node Evaluation

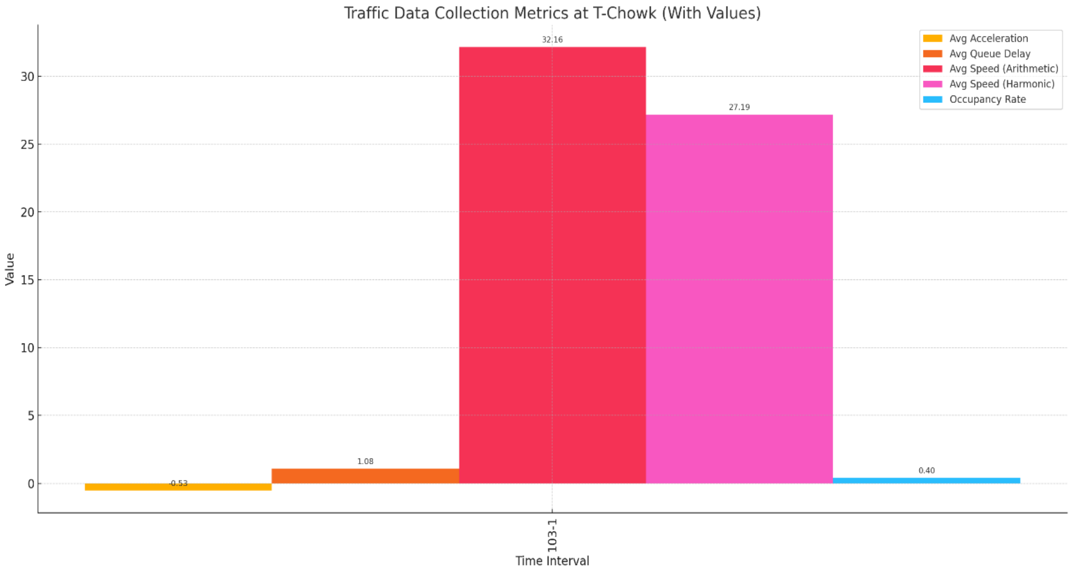

Figure 6: Traffic Data Collection Metrics

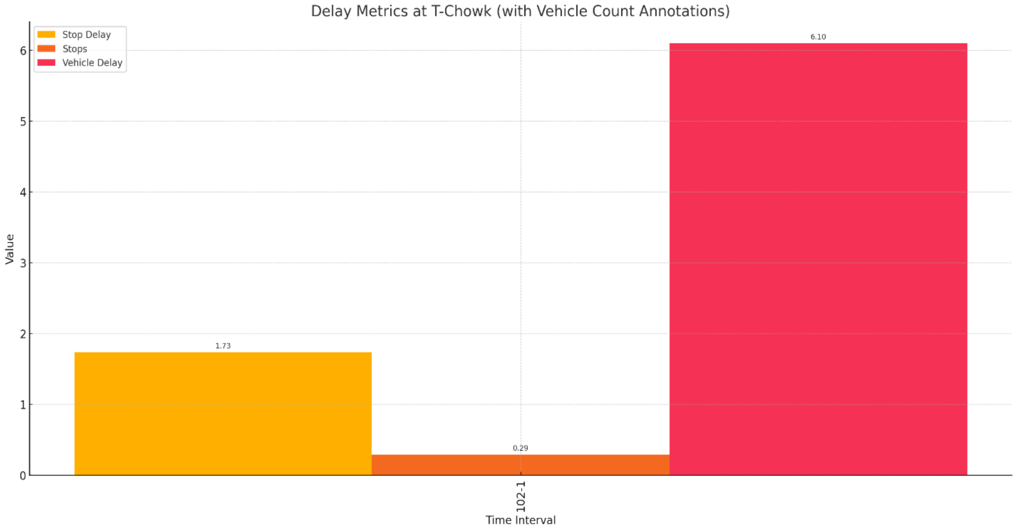

Figure 7: Delay Measurement

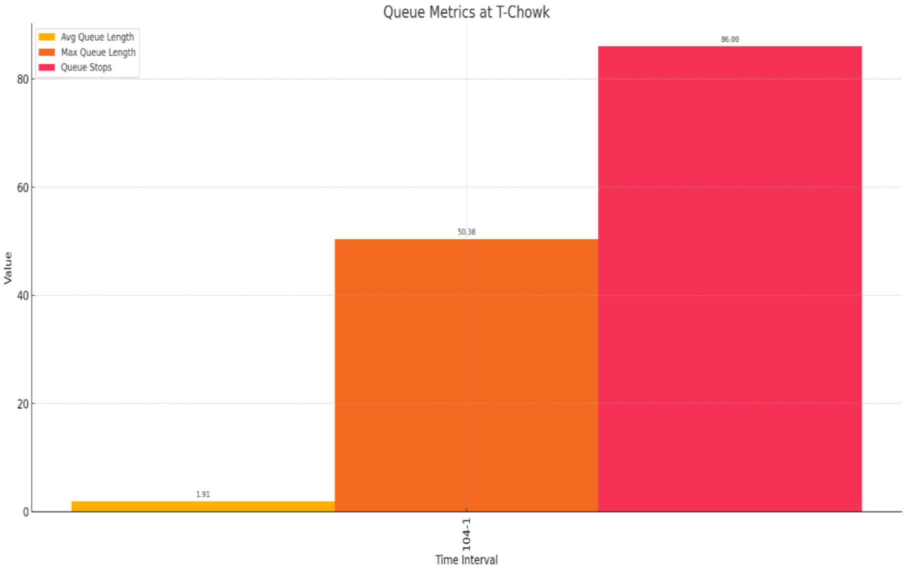

Figure 8: Queue Length Measurement

7. POLICY RECOMMENDATIONS AND DISCUSSION.

The purpose of this study was to assess traffic performance in the intersection of T-Chowk, which is highly congested, particularly during peak hours. Microsimulation was used to identify areas of concern and potential solutions to the problems. The findings indicated that LOS F was attained during peak hours on minor roads and the delay was as high as 45 seconds per vehicle and queue length of over 300 meters. These are the inefficiencies that cause increment of fuel use and emissions. The geometric improvements that were necessary were the expansion of the lanes and the creation of turning lanes by 20 percent of the delays and 15-20 percent of the queue length. The unsignalized crossroad of T-Chowk further leads to traffic congestion, especially because vehicles are not given priority on the major roads. Traffic congestion on minor roads was improved by 10-15 percent by introducing priority rules on major road vehicles. Furthermore, a roundabout would be a further improvement to the traffic throughput and decrease the delays by 10-15, which provides the benefits of continuous flow and safety. Another effect of congestion on the environment was also noticeable, and the simulation revealed that through better traffic flow, emissions would be reduced by 5-10 percent. Traffic management by installing Intelligent Traffic Systems (ITS) may streamline the traffic and ease congestion particularly by the population and emergency vehicles.

Policy Recommendations:

1) **Lane Expansion and Redesign**: Increase lanes and new turning lanes on minor roads as shown in Figure 9.

Figure 9: Proposed geometric redesign and traffic improvement scenario for T-Chowk intersection

2) **Priority Systems**: Implement priority systems on the big roads, in particular buses.
3) **Roundabout Design:** This aims at substituting the uncontrolled intersection with a roundabout to allow continuous traffic movement.
4) **Environmental Solutions:** Traffic management measures to control emissions.
5) **ITS Integration**: Research ITS technologies to be used in real-time traffic monitoring and optimization.

These suggestions will aid in relieving the congestion, limiting the environmental effects, and enhancing traffic at T-Chowk and other similar junctions.

8. CONCLUSION

The results of this research can highlight the significance of the detailed traffic management approaches towards such unsignalized intersections as T-Chowk. Using the knowledge of microsimulation modeling, we have been able to locate some highly critical solutions, such as lane expansions, redone roundabouts, and priority systems, which can be used to reduce congestion, minimize delays, and decrease environmental effects. The next round of research and practical experimentation should be directed on the validation of these strategies and the combination of Intelligent Traffic Systems aimed at the optimization of traffic flow in T-Chowk.

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References

[1]. Liu, Y., & Jiang, Y. (2021). Urban growth sustainability of Islamabad, Pakistan, over the last 3 decades: a perspective based on object-based backdating change detection. *GeoJournal*, *86*, 2035-2055.

[2]. Farooq, D., Tufail, R. F., Ali, M., Iqbal, H., & Tariq, A. R. (2024). Investigation of Traffic Issues at Unsignalized Taxila Intersection and their Countermeasures. *Periodica Polytechnica Transportation Engineering*, *52*(3), 310-316.

[3]. Dogar, A. U. R., Khattak, M. Z., Gazder, U., Jamal, A., & Gohar, M. M. (2020, September). Comparing smart traffic management solutions with infrastructure expansion projects: a case study for Rawalpindi, Pakistan. In *3rd Smart Cities Symposium (SCS 2020)* (Vol. 2020, pp. 331-336). IET.

[4]. Hassan, L., Chaudhry, A., & Jalil, H. H. (2021). *A Traverse of Illegalities in the Private Housing Societies in Islamabad* (No. 2021: 5). Pakistan Institute of Development Economics.

[5]. Muneera, C. P., & Karuppanagounder, K. (2018). Economic impact of traffic congestion-estimation and challenges. *European Transport-Trasporti Europei*, (68).

[6]. Samal, S. R., Kumar, P. G., Santhosh, J. C., & Santhakumar, M. (2020, December). Analysis of traffic congestion impacts of urban road network under Indian condition. In *IOP conference series: materials science and engineering* (Vol. 1006, No. 1, p. 012002). IOP Publishing.

[7]. Baldi, S., Michailidis, I., Ntampasi, V., Kosmatopoulos, E., Papamichail, I., & Papageorgiou, M. (2019). A simulation-based traffic signal control for congested urban traffic networks. *Transportation Science*, *53*(1), 6-20.

[8]. Sadoun, B. (2003). An efficient simulation methodology for the design of traffic lights at intersections in urban areas. *Simulation*, *79*(4), 243-251.

[9]. PTV Group, PTV VISSIM 2025: Simulation Software Manual, PTV Group, 2025.

[10]. M. Shahin, "Urban traffic analysis using VISSIM: A comparative study," Transportation Research Part C, vol. 38, pp. 108-115, 2017.

[11]. K. Dixon, B. Thompson, and M. O'Connor, "Comparing the benefits of macroscopic and microscopic modeling for urban intersection design," Journal of Transportation Planning, vol. 33, no. 3, pp. 189-203, 2017.

[12]. D. Krauss, P. Wagner, and W. Schindler, "The microscopic traffic simulation tool VISSIM," Proceedings of the European Simulation Multiconference, vol. 4, pp. 6-10, 2000.

[13]. L. Liu, H. Zhang, and S. Chien, "A simulation study on traffic flow improvement with adaptive signal control: A VISSIM application," Journal of Transportation Engineering, vol. 145, no. 2, pp. 55-66, 2019.

[14]. Highway Capacity Manual, Transportation Research Board, National Research Council, 2010.

[15]. Federal Highway Administration (FHWA), Highway Capacity Manual: Methods and Measures of Effectiveness, Washington, D.C., 2021.

[16]. M. Mousavi, P. Bansal, and Y. Bie, "Measuring the effectiveness of different traffic signal control strategies at signalized intersections," Transportation Science, vol. 52, no. 4, pp. 825-839, 2018.

[17]. Z. Zhang, F. Wang, and Q. Yu, "Traffic flow optimization in urban intersections: A VISSIM approach," Urban Traffic Studies, vol. 15, no. 2, pp. 120-132, 2021.

[18]. S. Chien, Y. Ding, C. Wei, and C. Wei, "Environmental impact analysis for traffic congestion: A case study in Taipei using VISSIM," Transportation Research Part D: Transport and Environment, vol. 15, no. 5, pp. 232-240, 2010.

[19]. M. Ahmed and M. Raza, "Traffic optimization using VISSIM: A case study of Lahore's major intersections," Journal of Traffic Engineering, vol. 24, no. 5, pp. 243-255, 2020.

[20]. M. Shahin and A. Kamal, "Microsimulation for traffic management at unsignalized intersections in Cairo," Transportation Science, vol. 32, no. 1, pp. 102-110, 2017.

[21]. New York City Department of Transportation, "Optimizing traffic flow in New York City using microsimulation," NYCDOT Research Report, 2016.

[22]. P. Vishwakarma, M. Jain, and S. Sharma, "Optimizing unsignalized intersection performance in Mumbai using VISSIM," Indian Journal of Transport Engineering, vol. 16, no. 3, pp. 45-59, 2019.

[23]. [S. Chien and Y. Ding, "Analysis of unsignalized intersection operations: A case study using microsimulation," Transportation Research Part C: Emerging Technologies, vol. 16, no. 6, pp. 759-772, 2008.

[24]. J. Lin, K. Chang, and Y. Hsieh, "Traffic flow simulation for mixed-traffic intersections," Transportation Research Part A: Policy and Practice, vol. 120, pp. 102-115, 2018.