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Enhancing Mobility at Multi-Modal At-Grade Intersections: A Case Study of Patang Chowk Peshawar Intersection Using VISSIM Micro-Simulation

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Abstract
The primary goals in managing traffic at non-signalized intersections are improving travel efficiency and ensuring road safety. The Patang Chowk Peshawar intersection, a multi-modal at-grade crossing, faces challenges such as congestion and safety risks, primarily due to the merging of service road traffic into the main highway traffic before U-turns. This study hypothesized that merging service road traffic earlier could enhance traffic mobility on the main highway. Data collection included traffic volume surveys, geometric condition surveys, and travel time assessments using manual counting methods. VISSIM micro-simulation software was utilized to model and calibrate existing traffic conditions, followed by evaluating the proposed solution.

The results demonstrated a significant reduction in travel times, averaging a 25% improvement on the main highway, with notable reductions in Directions D2 (25%) and D4 (30.6%). However, travel time for service road traffic (Direction D5) increased, attributed to prioritizing smoother main highway flow. These findings validate the proposed model's effectiveness in alleviating congestion and improving mobility at the intersection. The study underscores the significance of optimizing intersection design and calls for further research incorporating heterogeneous traffic conditions specific to Pakistan.

Keywords
VISSIM, non-signalized intersection, mobility, travel time survey, traffic volume survey.

1. Introduction

The transportation system of a city plays a crucial role in shaping the economic and social activities of its residents [1]. Urban mobility significantly affects access to work, education, healthcare, and social interaction. Efficient transportation systems drive urban development, but poor traffic management and insufficient urban planning often lead to adverse consequences [2]. Peshawar, one of the oldest cities in Pakistan and the capital of Khyber Pakhtunkhwa, exemplifies this dilemma. Despite its status as an important administrative, commercial, and economic hub, Peshawar's transportation infrastructure is plagued by congestion, overcrowding, and frequent traffic accidents. Urbanization, while enhancing living standards and economic opportunities, has also exacerbated issues such as traffic congestion, environmental degradation, and safety risks [3].

Existing traffic management in Peshawar suffers from several inadequacies. Poor urban planning has led to uncoordinated growth, with roads and intersections ill-equipped to handle increasing traffic volumes. Congestion in urban areas has serious economic and environmental consequences, including productivity losses, increased fuel consumption, and elevated levels of air pollution [4]. The societal cost of traffic-related delays and accidents further underscores the urgency of addressing these issues. Studies such as those have highlighted the critical need for improved urban traffic management systems in Pakistan, particularly in cities like Peshawar, where population growth and vehicular density have outpaced infrastructure development [5, 6].

One of the most problematic areas in Peshawar is the Patang Chowk intersection, a multi-modal at-grade crossing on Ring Road. This intersection experiences severe traffic congestion, especially during peak hours, primarily due to unregulated merging of service road traffic into the main highway traffic before U-turns. The resulting interference disrupts the smooth flow of vehicles, creating delays and increasing the risk of accidents. Addressing these challenges requires a detailed understanding of the intersection's unique dynamics and the interaction of various road users, including vehicles, pedestrians, and cyclists [7].

Numerous studies have explored traffic simulation and management techniques using tools like VISSIM, a microscopic traffic simulation software. Koh demonstrated VISSIM's utility in modeling urban traffic flows, highlighting its effectiveness in evaluating different intersection designs [8]. Similarly, utilized VISSIM to assess highway capacity, showing how simulations could improve understanding of vehicular interactions under heterogeneous conditions [9]. In Dhaka, calibrated VISSIM models to reflect local traffic behaviors, demonstrating the importance of adapting simulation parameters to specific urban contexts [10] emphasized the need to modify default behavioral parameters in VISSIM to account for heterogeneous driving conditions, underlining the software's flexibility for localized applications [11] extended this approach to evaluate feedback-based tolling systems, showing VISSIM's adaptability in diverse traffic management scenarios [12].

Despite these advancements, significant gaps remain in the literature. Most studies focus on general traffic congestion or specific urban contexts, with limited attention to the unique challenges of multi-modal at-grade intersections in developing countries like Pakistan [13]. The interference of service road traffic with main highway mobility—a critical issue at intersections like Patang Chowk—has been largely overlooked. Moreover, existing studies often fail to incorporate the diverse vehicular composition and driving behaviors prevalent in Pakistan, limiting the applicability of their findings [14]. These gaps highlight the need for research tailored to the specific conditions of Peshawar's urban traffic.

To address these shortcomings, this study investigates the Patang Chowk intersection using VISSIM micro-simulation. By calibrating the simulation model with localized traffic data, including travel times, vehicle dimensions, and geometric conditions, this research aims to propose practical, context-specific solutions. The proposed redesign involves merging service road traffic into the main highway before U-turns, thereby minimizing interference and enhancing overall mobility. This approach contrasts with the existing conditions, where service road vehicles act as barriers to main highway traffic, exacerbating congestion and delays.

The objectives of this study are threefold. First, it aims to analyze the current traffic conditions at the Patang Chowk intersection, identifying key factors contributing to congestion and inefficiency. Second, it seeks to evaluate the impact of the proposed redesign on traffic flow and travel times using VISSIM simulations. Third, it intends to provide actionable recommendations for implementing the proposed solutions, with an emphasis on scalability and adaptability to other intersections in Peshawar and similar urban contexts.

This research is significant for several reasons. By addressing a critical gap in the literature, it contributes to the growing body of knowledge on urban traffic management in developing countries. The findings have practical implications for policymakers, urban planners, and traffic management authorities, offering evidence-based strategies

to alleviate congestion and improve mobility. Moreover, the study underscores the importance of incorporating local traffic dynamics into simulation models, paving the way for more accurate and effective solutions. Ultimately, this research aims to enhance the quality of life for Peshawar's residents by fostering safer, more efficient transportation systems, thereby supporting the city's economic and social development.

Figure# 01 represents the image of study area "Patang Chowk intersection" Ring Road Peshawar, taken from Google map.

Fig. 1. *Patang Chowk intersection Ring Road Peshawar*

2. Methodology

Simulation method and its practice is the most preferable technique for detailed study of traffic flow and its physical characteristics. For using this technique, several data collection surveys were conducted including Travel time survey, Traffic volume survey, Vehicle dimensions survey and Geometric condition survey. From the study site, the data required for this study was collected through a combination of field surveys and manual observations at the Patang Chowk intersection on Ring Road, Peshawar. Traffic volume data was collected by using tally sheets i.e. manual count method. Travel time survey was performed in "Patang Chowk Intersection". While Geometric condition survey was performed at different points at study area by measuring width of road and then scaled for further verification. For creating a simulation model all the data was carefully evaluated and analyzed in VISSIM and for imitating the field condition, the model was calibrated and validated.

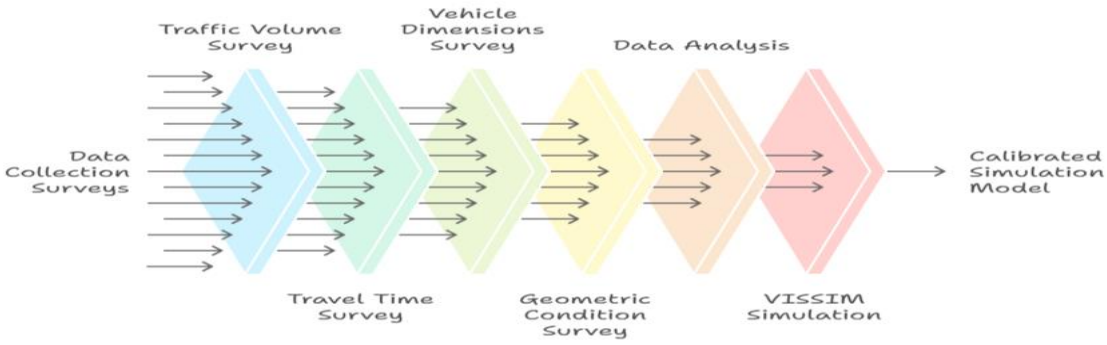

Fig. 2. *Traffic data to simulation Model*

2.1 Model Calibration and Data Collection

For this study, the model focuses on evaluating the effect of merging service road traffic into the main highway before the U-turn. This aspect is crucial because the current field conditions at Patang Chowk show that service road vehicles interfere with the flow of main highway traffic when trying to access the U-turn, creating congestion and delays. The proposed model aims to alleviate this issue by merging service road traffic earlier, thus preventing it from acting as a

barrier to main highway traffic. Travel time was considered as the parameter for calibration. Table 1 shows the average travel time of existing field condition in each direction.

Table 1: Average Travel Time Calculated in Field

Distance (m)	Direction	Avg Travel Time calculated in field (Sec)
500	D1	48.75
500	D2	57.75
565	D3	64.25
389	D4	57.75
312	D5	94.5

2.2 Simulation of Traffic on the Existing Road Network

Figure 3 illustrates the existing road network. Here the arrows refer to the vehicle flow in each direction. The main highway traffic is affected due to the direct interference of service road (D5). Traffic jam usually occurs at intersection as vehicles from main highway want to pass smoothly without hindrance while the service road vehicles try to utilize the U-turn and acting as a barrier to the main highway traffic (perpendicular direction of movement to the main highway traffic). This direct interference of service road traffic affects the mobility of main highway traffic. This condition mainly occurs in peak hours when people are going to their workplace.

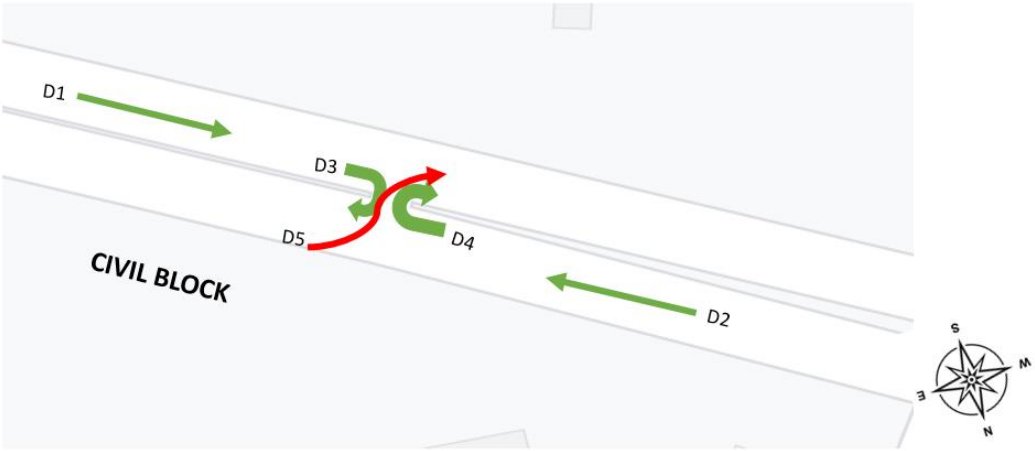

Fig. 3. *Ring Road Peshawar Patang chowk Intersection*

Table#2 presents the current traffic data (direction, hourly volume and relative flow). Traffic on peak hours on weekdays was carefully observed while performing traffic volume survey.

Table 2: Traffic Volume Data during Peak Hours

Directions	**Hourly Volume**	**Relative flow %**
Volume of D1 to D1	1930	0.69524496
Volume of D1 to D3	846	0.30475504
Sum	2776	1
Directions	**Hourly Volume**	**Relative flow %**
Volume of D2 to D2	1691	0.70106341
Volume of D2 to D4	759	0.29893659
Sum	2450	1
Directions	**Hourly Volume**	**Relative flow %**
volume of D5 to D1	250	1

For the intersection at ring road, the vehicle categories and traffic composition in percentage during peak hour is presented in Table#03 in each direction.

Table 3: Traffic Composition in Percentage during Peak Hour

Direction	**Vehicle types**				**Total**
Relative% of vehicle	Car	Rickshaw	Bike	Bus	Total Vehicles %
Direction#01	35	27	35	3	100
Direction#02	37	31	30	2	100
Direction#03	36	38.5	25	0.5	100
Direction#04	32	35.4	30	2.6	100
Direction#05	29	39	31.7	0.3	100

By using VISSIM micro-simulation software we created a model and calibrated based on the data according to the real field conditions.

2.3 Simulation of Traffic on the Proposed Road Network

The proposed network model at Patang chowk intersection area is illustrated in Fig.4 where the direct interference of service road traffic into the main highway is restricted and a new path is provided to the service road traffic and the vehicles are directed to enter the main highway from new proposed path. The new road network i.e. merging the service road traffic into the main highway traffic before making the U-turn, as opposed to the existing field conditions will improve the mobility of main highway traffic.

Though, in order to prove that proposed model will show better outcomes than the existing condition, a simulation using VISSIM software is implemented in the proposed model. The data required for simulation of proposed solution is relatively similar with the data of existing network.

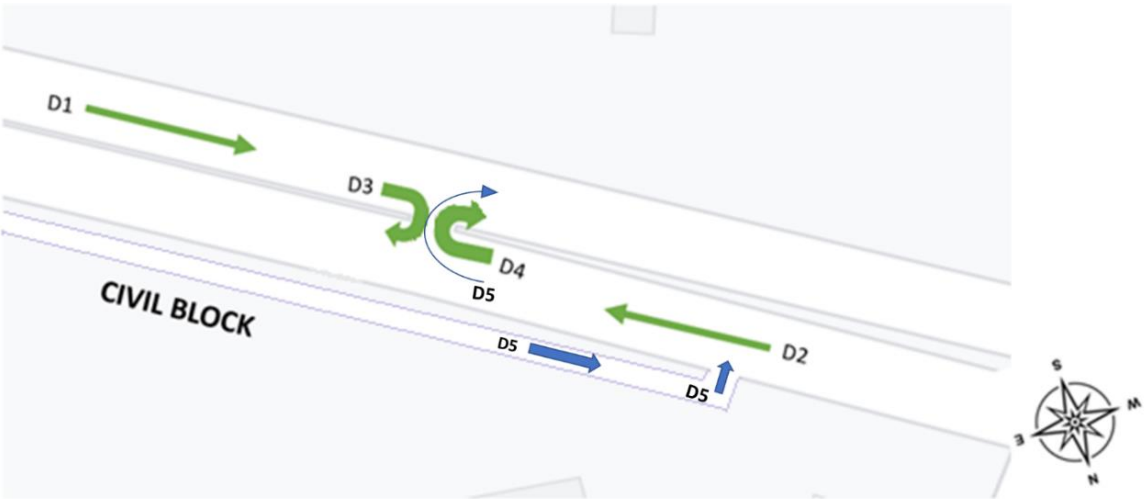

Fig. 4. *Proposed Road Network of Patang chowk Intersection*

3. RESULTS

The simulation results show the differences in travel times for the two models. By comparing travel times for each direction, we can assess the effectiveness of the proposed road network.

Existing Network: Vehicles experience delays, especially during peak hours, as service road traffic tries to merge into the main highway at the U-turn, causing congestion and longer travel times.

Proposed Network: With the early merging of service road traffic into the main highway, the vehicles experience smoother traffic flow, leading to a reduction in travel times.

The following results were observed based on the travel time measurements from both models:

Direction D1:

Existing Travel Time: 48.75 seconds

Proposed Travel Time: 48.59 seconds (an improvement of 0.5%)

Direction D2:

Existing Travel Time: 57.75 seconds

Proposed Travel Time: 44.94 seconds (a 25% improvement)

Direction D3:

Existing Travel Time: 64.25 seconds

Proposed Travel Time: 60.21 seconds (a 1.75% improvement)

Direction D4:

Existing Travel Time: 57.75 seconds

Proposed Travel Time: 40.28 seconds (a 30.6% improvement)

Direction D5 (Service Road):

Existing Travel Time: 94.5 seconds

Proposed Travel Time: 122.87 seconds (an increase, but due to better flow on the main highway)

Overall, the proposed model showed an average improvement of 25% in travel time compared to the existing conditions. The most notable improvements were in Direction D4 (30.6%) and Direction D2 (25%), which are the directions most impacted by the service road traffic interference.

Figure 5 shows the existing traffic conditions, where vehicles from the service road create delays by trying to merge into the main highway at the U-turn. This direct interference leads to congestion and longer travel times.

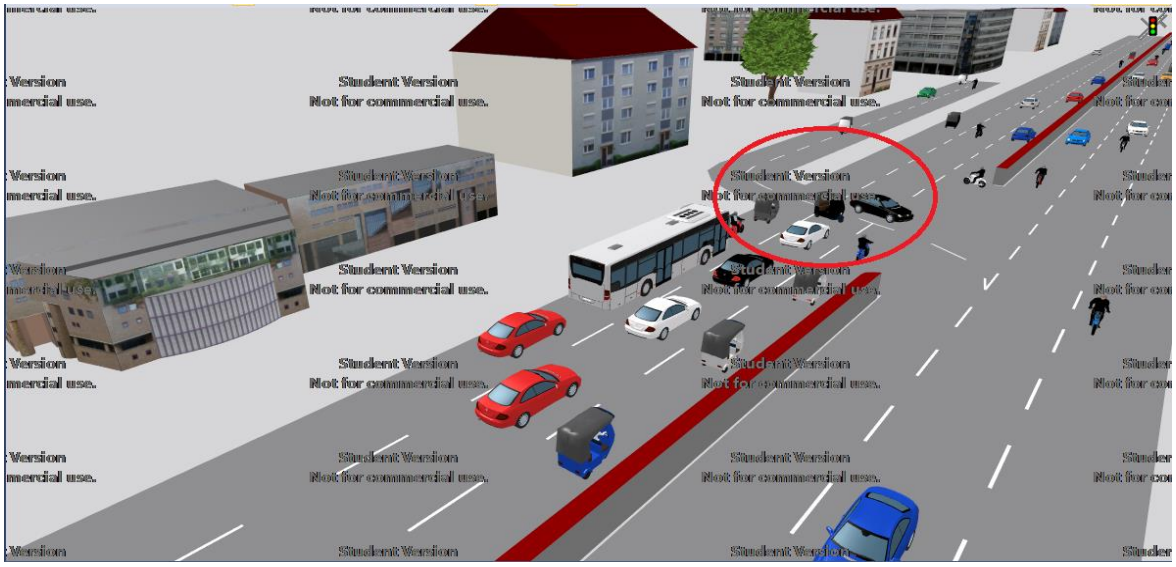

Fig. 5. Existing Condition- Patang Chowk Intersection in VISSIM

Figure 6: Illustrates the proposed solution where service road traffic is merged earlier, avoiding interference with main highway traffic. The smoother flow reduces travel time and congestion, particularly on the main highway. Generated through VISSIM, the redesigned intersection, where service road traffic merges into the main highway before reaching the U-turn. This configuration eliminates the direct interference observed in the existing layout.

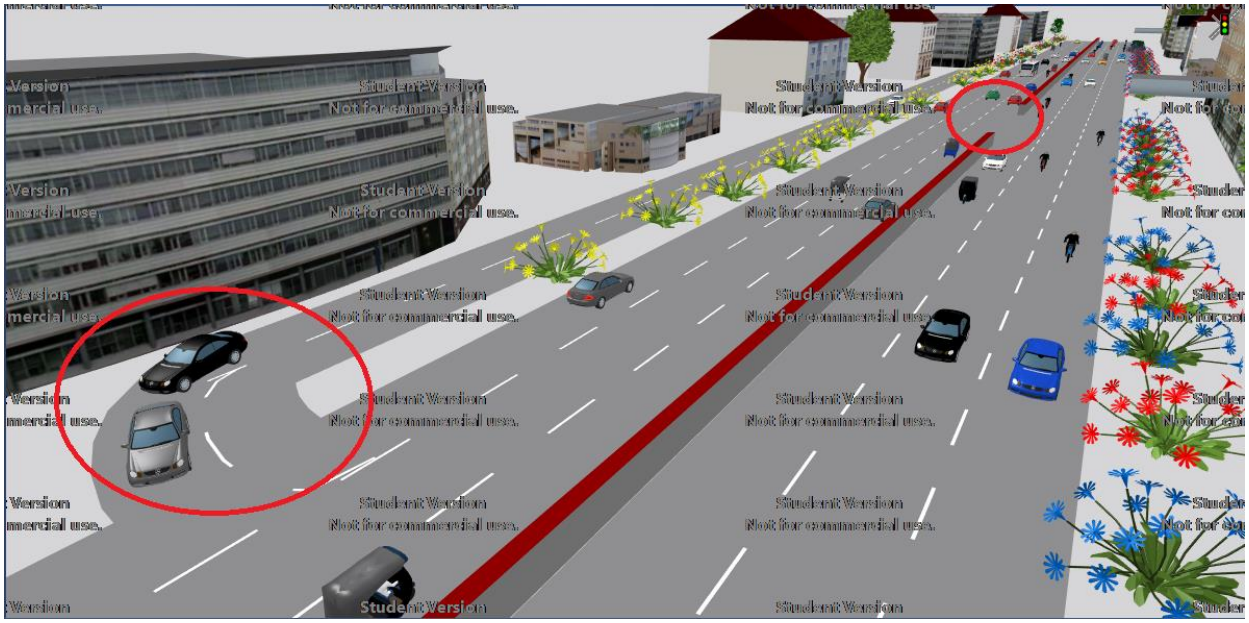

Fig. 6. Proposed Condition- Patang-Chowk Intersection in VISSIM

Travel time, a well-known indicator that includes waiting time, can be used for measuring the performance of traffic network. This data can be attained from VISSIM in travel time segment. Table 4 presents the average travel time simulation results for both the existing network and the proposed road network at the Patang Chowk intersection. The table also includes the calculated travel time in the field, the simulation travel time for both conditions (existing and proposed), and the percentage improvement in travel time based on the proposed solution.

Table 4: Statistic Average Travel Time

Distance (m)	Direction	Avg. Travel Time calculated in field (Sec)	Avg. Simulation Travel Time (Sec)	Avg. Simulation travel time of proposed model (Sec)	Distance (m)	Avg.travel time percentage improvement
500	D1	48.75	48.591018	48.469420	500	0.5%
500	D2	57.75	57.966661	44.93576	500	25%
565	D3	64.25	61.269957	60.20517	565	1.75%
389	D4	57.75	54.86668	40.28434	389	30.6%
312	D5	94.5	98.72188	122.8722	480	
					Avg. percentage	14.46%

4. Conclusion and Recommendations

This study aimed to evaluate the impact of a proposed road network redesign at Patang Chowk intersection in Peshawar, with a focus on improving traffic flow and reducing travel times. The study utilized VISSIM micro-simulation to model both the existing road network and the proposed solution, which involved merging service road traffic into the main highway before the U-turn.

4.1 Conclusions

The proposed model resulted in an average improvement of 14.46% in travel time across all directions. The most notable improvements were observed in Direction D2 (25%) and Direction D4 (30.6%), suggesting that the proposed changes significantly reduced congestion, particularly where service road traffic interfered with main highway traffic. The main highway (Directions D1-D4) experienced reduced travel times due to smoother traffic flow, as the interference caused by merging service road traffic at the U-turn was minimized. While the travel time for service road traffic (Direction D5) increased in the proposed model, this increase was offset by the significant improvement in travel times on the main highway. The overall traffic efficiency at the intersection improved due to the smoother flow of vehicles on the primary lanes. The proposed model proved effective in optimizing traffic flow, reducing congestion, and improving mobility at the Patang Chowk intersection. The results support the hypothesis that early merging of service road traffic enhances traffic conditions by reducing interference with main highway traffic.

4.2 Recommendations

Based on the simulation results, it is recommended to implement the proposed traffic management solution, particularly the earlier merging of service road traffic into the main highway before the U-turn. This would alleviate congestion, improve traffic efficiency, and reduce travel times on the main highway. While the proposed solution showed significant improvement for the main highway traffic, the increase in travel time for service road vehicles (D5) should be monitored. Future studies could explore alternatives for managing service road traffic to balance flow and minimize the travel time impact on service road vehicles. The simulation model could be further refined by incorporating heterogeneous traffic conditions specific to Pakistan, such as varied vehicle types (e.g., motorcycles, rickshaws) and driver behaviours. This would enhance the accuracy of the simulation and ensure that the model reflects local traffic dynamics more precisely. As the study suggests, driver behaviour (e.g., wrong-way driving) can negatively impact traffic flow and increase risks at intersections. Public awareness campaigns and driver education programs should be implemented to promote safe driving practices and ensure that drivers adhere to traffic rules, particularly in high-traffic areas like Patang Chowk.

Future research should focus on refining traffic management strategies to balance improvements across all traffic directions, particularly addressing the increased travel time for service road vehicles. Developing localized driver behaviour models, incorporating heterogeneous traffic conditions, and integrating non-motorized road users into simulations will enhance the realism of future studies. Long-term traffic projections, economic feasibility analyses, and the application of intelligent traffic management systems can provide scalable and cost-effective solutions.

Comparative studies at other intersections and cities will validate the generalizability of the findings, while public awareness campaigns and policy recommendations can support the practical implementation of these solutions.
This study has several limitations that should be addressed in future research. The simulation relied on default VISSIM parameters, which may not fully capture the diverse and unpredictable driving behaviors common in Pakistan, such as lane indiscipline and informal road usage. Non-motorized road users, including pedestrians and cyclists, were excluded, limiting the model's comprehensiveness. The focus on a single intersection restricts the generalizability of the findings, while the short-term analysis does not account for future urban growth and traffic changes. Additionally, the increased delays for service road traffic highlight the need for more balanced solutions. Manual data collection methods may introduce inaccuracies, and the absence of economic feasibility, environmental, and social impact assessments further constrains the study's applicability to real-world contexts.

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