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AN INTEGRATED APPROACH TO GEOMETRIC DESIGN OPTIMIZATION AND SAFETY PLANNING FOR REDUCING TRAFFIC COLLISIONS ON ALLAMA SHABBIR AHMED USMANI ROAD

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Abstract
The study Focuses on assessing the existing geometric design and safety conditions of Allama Shabbir Ahmed Usmani, Road along the traffic corridor between Maskan and Disco Intersection in Karachi City. Recent traffic conditions are evaluated in response to persistent congestion and frequent traffic accidents through comprehensive traffic surveys and vehicular traffic counts. Advanced micro simulation tools which includes PTV Vissim and AutoCad Civil 3D for geometric design visualization.These software are used to accurately replicate existing traffic flow conditions within the corridor. The results of traffic volume analysis from the basis for proposing alternative geometric design solutions such as signalized intersection and roundabouts, aimed at reducing congestion and improving road user safety. The proposed interventions seek to improve traffic capacity, reducing vehicular conflicts and optimize overall operational performance by integrating traffic flow theory with geometric design principles. The results of this research provide data driven recommendations for urban planners, traffic engineers, and local authorities to improve safety and efficiency of Allama Shabbir Ahmed Usmani Road, Karachi.Ultimately, This research supports the broader goals of sustainable urban mobility, intelligent transportation system and livable city development through innovative geometric design solutions

1. INTRODUCTION

Karachi's Rapid urbanization has significantly increased traffic demands on its road infrastructure, particularly on major urban arterial corridors which connects residential, commercial and institutional zones. Allama Shabbir Ahmed Usmani road represents a critical traffic corridor that suffers from consistent traffic congestion, extended travel delays and high rate of traffic collisions. These problems stem from multiple factors which includes substandard geometric design, heterogeneous traffic condition, inadequate signalized intersection and poorly managed pedestrian movements.

The corridor connects two major and highly complex intersection Maskan and Disco which are characterized by complex vehicular interactions and heavy pedestrian activity. The absence of properly designated lanes, poorly defined medians and limited pedestrian infrastructure further aggravate traffic conflicts and safety risks. In light of these challenges, this research aims to conduct comprehensive analysis of the corridor and develop strategic geometric and traffic management interventions that prioritize traffic safety , traffic efficiency and sustainable urban mobility

Research Objectives:

To achieve the research aim, the following objectives have been outlined:

1. To assess the geometric design features and identify design deficiencies contributing to traffic collisions.
2. To propose optimized geometric design solutions based on identified issues.
3. To evaluate the effectiveness of the proposed interventions using simulation tools or comparative safety analysis.

2. LITERATURE REVIEW

The problems of growing traffic levels, as has always been, are many including urbanization and vehicle ownership. This road gets stuck during the peak hours due to heavy traffic with most of the delays occurring at the junctions. Such conditions not only annoy the users of the roads and delay their activities but also increase the risk of accidents since as more vehicles crowd a road, the more chances for the occurrence of an accident. The present day infrastructure cannot also cope with the various types of transport and number of vehicles, thus the need to look at lane realignment, intersection design, and access in a more critical way. Furthermore, ongoing and planned urban developments in nearby areas could worsen current traffic problems. It's important to understand how traffic works now, so that future plans and investments in roads and other infrastructure are smart.

Geometric road design encompasses the alignments, dimensions and overall configuration of roadways including parameters such as shoulder width, lane width, horizontal and vertical curvature, gradient, sight distance and intersection layout. These design elements are critical detriments of road safety as they directly influence driver perception, operating speed, visibility and traffic performance. In densely populated urban corridors such as Allama Shabbir Ahmed Usmani Road in Karachi, inadequate geometric design can greatly increase the risk of accidents especially at intersections, pedestrian crossings and access points.

Roadway lacking appropriate lane delineation, turning radii, median treatments and pedestrian facilities are more susceptible to higher crash frequencies and traffic conflicts. International research and practical implementations consistently demonstrate that optimized geometric design improves road safety outcomes. Zaheer et al. (2008) reported that by enhancing horizontal curvature on urban roads in the United states

results in crash reduction of up-to 20%. Likewise, a world bank funded intervention in Dhaka introduced channelized turning lanes and improved pedestrian crossings, achieving a 32% reduction in vehicle pedestrian crashes within one year (World Bank, 2015). Similarly, safety improvements were observed in Pune, India, following the implementations of traffic separators, roundabouts and pedestrian refuge islands (Pundir & Patel, 2016)

In Karachi, arterial like Allama Shabbir Ahmed Usmani Road typically suffer from geometric deficiencies such as abrupt lane terminations, improper bus bay design, narrow pedestrian paths, and obstructed sight-lines due to roadside encroachments. These issues contribute to traffic chaos and frequent collisions. A survey conducted by NED University (2018) identified several arterial roads in Karachi where retrofitting geometric features like raised pedestrian crossings, signalized intersections, and turning lanes could improve traffic efficiency and significantly reduce accident rates. The same study suggested that implementing AASHTO standards (American Association of State Highway and Transportation Officials) for intersection design and pedestrian facilities could reduce crashes by up to 40% in high-risk areas. Applying these insights to Allama Shabbir Ahmed Usmani Road, the thesis proposes using modern tools like PTV VISSIM to simulate current geometric conditions and test optimized alternatives, including improved median designs, standard lane widths, controlled intersections, and pedestrian refuge zones. These design refinements not only enhance traffic operations but also serve to protect vulnerable road users, such as pedestrians, school children, and motorcyclists, who are disproportionately affected by poor geometric planning in Karachi's urban environment. In Karachi, a study utilizing high-resolution satellite imagery identified that approximately 34% of road crashes were attributable to geometric design flaws, particularly at U-turns constructed on fast lanes without adequate safety measures (Zubair & Ghazal, 2016). Such findings underscore the necessity for meticulous geometric planning to enhance road safety.

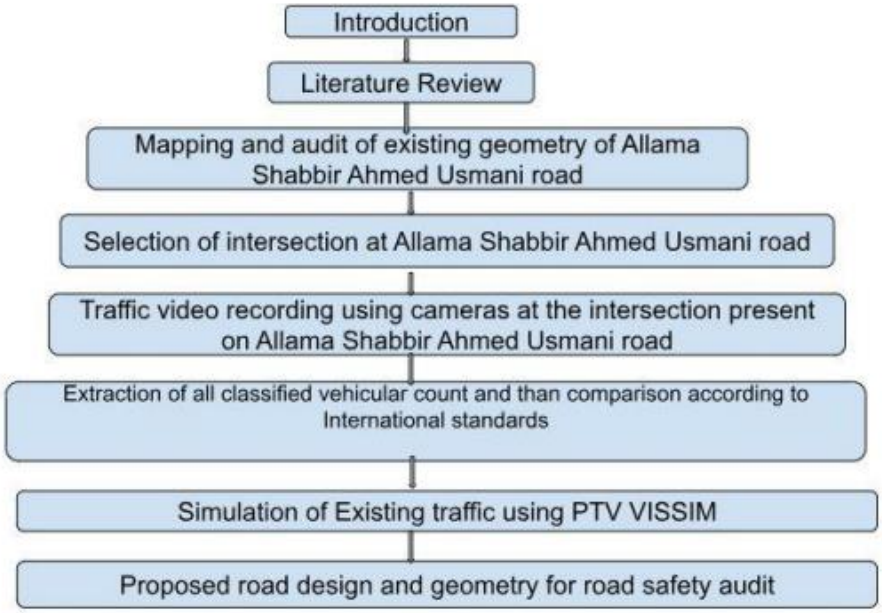
Urban arterial are high-capacity roads designed to facilitate the efficient movement of traffic across urban regions. These roads form the backbone of a city's transportation network by connecting local streets to highways and expressways, managing both intra-city and intercity traffic. They typically feature multiple lanes, limited access points, signalized intersections, and are often prioritized for public transportation, emergency 10` services, and commercial traffic. The primary function of urban arterial is mobility enabling faster travel across longer distances within urban boundaries while maintaining reasonable access to local land uses. In the context of Karachi, Pakistan's largest and most densely populated city, urban arterial are vital for sustaining the daily movement of millions of people and goods. Major arterial such as Shahrah-e-Faisal, University Road, Rashid Minhas Road, Abul Hassan Isphani Road, and Allama Shabbir Ahmed Usmani Road play a crucial role in linking residential, commercial, and industrial zones. However, despite their importance, many of these roads are facing severe operational stress due to rapid urban expansion, lack of integrated land use planning, outdated geometric design, and excessive traffic demand.

Urban arterial in Karachi often experience high congestion levels, illegal parking, encroachments, and insufficient pedestrian infrastructure, which undermine their functionality. A study by JICA (Japan International Cooperation Agency, 2012) noted that most arterial in Karachi operate beyond

their designed capacity, leading to reduced speeds, increased travel time, and heightened accident risk. The Karachi Strategic Development Plan 2020 also emphasized the critical need to upgrade the city's arterial roads by implementing modern geometric standards, introducing mass transit systems, and regulating roadside land use. Furthermore, issues like poor signal coordination, lack of pedestrian crossings, improper bus stop placement, and damaged pavements are frequently reported on arterial like Allama Shabbir Ahmed Usmani Road, causing operational inefficiencies and safety hazards. To enhance the performance of urban arterial in Karachi, a multi-faceted approach is necessary one that includes strategic infrastructure investments, geometric redesign, intelligent traffic management systems (ITS), and enforcement of urban development controls. Integrating these roads into broader urban planning strategies is essential for promoting sustainable mobility, reducing congestion, and improving road safety for all users.

The literature emphasizes the multifaceted nature of road safety, highlighting the interplay between geometric design, urban planning, traffic calming measures, and technological interventions. For Allama Shabbir Ahmed Usmani Road, adopting a comprehensive approach that incorporates these elements is essential for mitigating traffic collisions and enhancing overall safety. The Allama Shabbir Ahmed Usmani Road in Karachi is a major urban road that illustrates the benefits and challenges of elevated roads in congested cities. The connectivity of these roads is an important part of urban mobility as it can reduce travel times and increase access to essential services such as healthcare, education and commerce. This Road is the hub of Karachi's transport network, serving both private and public transport, and serves as a major thoroughfare for the city's daily operations. However, managing traffic flows on urban roads such as Allama Shabbir Ahmed Usmani Road is challenging due to many factors such as road design, signal management, and congestion. Inadequate spatial design and poor road management can lead to increased traffic congestion, especially during rush hours. In addition, traffic distribution on urban roads is influenced by land use, with more traffic near commercial centers, universities, and residential areas. For example, the traffic distribution on Allama Shabbir Ahmed Usmani Road varies throughout the day, peaking during rush hour when passengers are traveling to work or school. These changes require better traffic management strategies to reduce congestion, such as separate lanes for different types of vehicles. Land use patterns also have a significant impact on traffic dynamics. Mixed-use areas that combine residential, commercial, and administrative spaces create a variety of pedestrian and vehicle interactions that contribute to congestion but also foster a vibrant.

3. METHODOLOGY



3.1 Mapping and Audit of Existing Road Geometry of Allama Shabbir Ahmed Usmani Road

A Detailed geometric mapping and audit of Allama Shabbir Ahmed Usmani Roads were undertaken as part of research methodology to asses the existing roadway alignment and structural condition. This process integrated field surveys with digital mapping tools, including Google Earth and Auto-cad, to develop a precise base map of the study corridor extending from Maskan intersection to Disco Intersection. Field measurements were conducted to capture actual lane widths, shoulder conditions, median treatments, intersection configuration, turning radii, pedestrian crossings locations, curb heights and road side encroachments. Additionally, the audit documented pavement conditions, traffic signage, road markings, and drainage infrastructure. Emphasis are placed on identifying geometric deficiencies such as irregular merging sections, insufficient sight distance, absence of channelization and abrupt variation in carriageway width that may contribute to increase traffic conflicts and unsafe operating conditions

3.2 Traffic Video Recording Using Cameras at the Intersections on Allama Shabbir Ahmed Usmani Road

Video based traffic data collection was adopted as a primary method at key intersections along the corridor. High resolution surveillance cameras were installed at the specific locations which includes DISCO four leg intersection and Maskan 3-leg intersection, where traffic volume and operational capacity was particularly high. The cam,eras were placed at an elevated position to capture wide angle views of traffic movements, facilitating detailed observations of vehicle classifications, turning movements, lane utilization and pedestrian crossing behaviour. Data recording was carried out during both peak and off peak hours on weekdays to ensure representative traffic conditions.

Traffic volume data were collected at all exits and entry points of both intersections by using classified volume counts for motorcycles, cars, rickshaws, buses and heavy vehicles. The primary

analysis focused on the evening period between 6.00pm to 8.00 pm to determine peak hour vehicular demand.

3.3 Simulation Of Existing Traffic By Using PTV VISSIM

Traffic data obtained from manual counts and video based surveys were used as inputs for the VISSIM micro simulation model. The primary simulations parameters included vehicle composition, traffic volumes, turning movements proportions, which were defined based on observed traffic behaviour. The existing road network of Allama Shabbir Ahmed Usmani road was precisely replicated on VISSIM, incorporating lane configuration, geometric design elements and traffic control devices. This accurate representation enabled realistic simulation of prevailing traffic conditions. The model was used to evaluate traffic flow characteristics, congestion levels and travel time delays. The simulation results supported the development of traffic management and geometric design interventions which includes the implementation of signalized intersections or roundabouts in order to enhance traffic efficiency and to reduced congestion of the study corridor

3.4 Suggested Road Design And Strategies To Mitigate Traffic Collisions

On the basis of analysis and simulation results, a number of design amendments were recommended to improve safety in terms of efficiency on Allama Shabbir Ahmed Usmani Road. Introduction of a signalized roundabout at the high conflict intersection like Maskan 3 leg intersection has been recommended. This roundabout would help to streamline the flow of traffic coming from different directions while minimizing conflict points and increasing overall safety. In addition, realignment was recommended for some road sections to eliminate geometric inconsistencies in traffic transitions and overcome bottlenecks. Adjustments to parking were also incorporated into the potential improvements. On-street parking along busy sections was reappraised with the view to relocation or optimization so that their impacts were not too greatly felt on the flow of traffic. Off-street parking lots were also redesigned to maximize vehicle turnover and enhance pedestrian access without increasing safety risks from pedestrians crossing high traffic zones. Among those proposals includes adding pedestrian crossings, speed limit sign boards, and dedicated cycling lanes. All these measures towards creating a safer transportation corridor that meets international standards for road safety shall be attained collectively.

4. STUDY AREA CHARACTERISTICS

The corridor extends between Maskan and DISCO Chowrangi, with high commercial activity, mixed traffic (cars, motorcycles, rickshaws, buses), and heavy pedestrian presence. Encroachments and improper parking further reduce effective roadway width.

Google earth image shows area of study

Table 1: ***Summary of Geometric Features of Allama Shabbir Ahmed Usmani Road***

Feature	Existing Condition	Standard Requirement	Issue Identified
Lane Width	2.70–2.90 m	3.0–3.6 m	Substandard lanes
Carriageway Width	Varies	Uniform width required	Inconsistent width
Median Width	Narrow; unprotected	Raised median	Unsafe mid-block crossings
Shoulders	Absent	1.0–1.5 m	No breakdown space
Turning Radius	Very sharp at intersections	Standard turning radius	Causes vehicle conflicts
Pedestrian Facilities	Nonexistent	Dedicated crossings	High pedestrian risk

5. TRAFFIC VOLUME ANALYSIS

Below is a summarized form of Maskan and Disco volumes based on your thesis descriptions:

Table 2: ***Peak-Hour Traffic Volume Summary (Maskan Intersection)***

Movement	Volume (veh/hr)
Through	High
Left Turn	Moderate
Right Turn	High
U-Turn	Significant conflicts

Traffic at Maskan is highly unbalanced with heavy through and right-turn movements. U-turns create additional delays and conflicts.

Table 3: *Peak-Hour Traffic Volume Summary (Disco Intersection)*

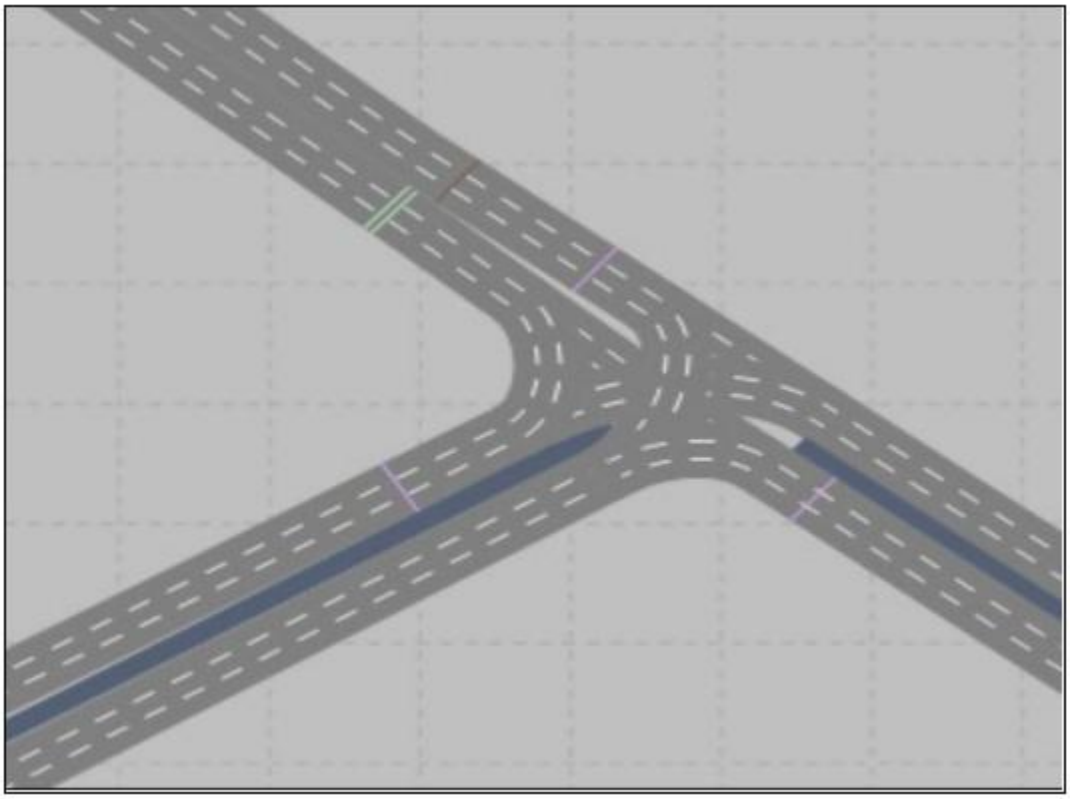
Movement	Volume (veh/hr)
Through	Very High
Right Turn	High
Left Turn	Moderate
Pedestrian Crossings	Extremely High

The Disco intersection experiences the highest degree of pedestrian interaction, resulting in unsafe conflicts.

7. SIMULATION RESULTS (VISSIM)

7.1 Traffic simulation Results of Maskan Intersection

The first simulation modeled the current traffic conditions of Maskan 3 leg intersection without any interventions, revealing significant delays, bottlenecks, and frequent lane changing conflicts, especially during peak hours.



Network diagram developed on VISSIM

Table 5-3: *Comparison between Existing road and proposed road simulation*

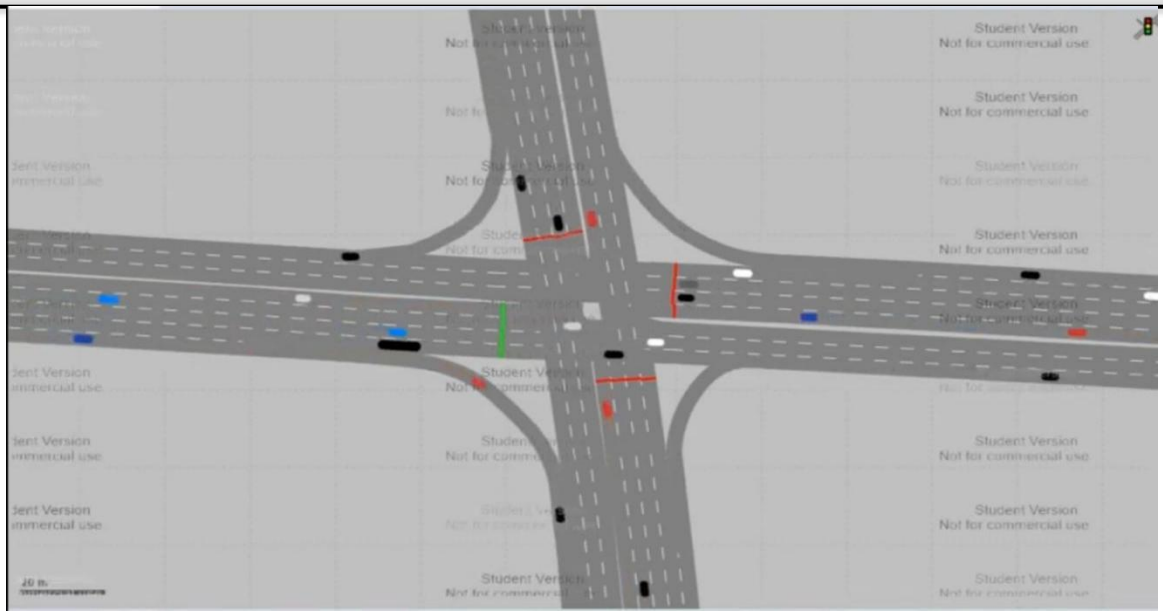
Performance Metric	Existing Design	Proposed Design	Change	Remarks
Average Travel Time (s)	30.71	42.34	↑ 11.63 seconds	Slight increase due to extended network routing
Total Distance Travelled	658.27	925.25	↑ 266.98	Indicates more movement

(m)			meters	coverage
Vehicle Input (Link 3 + 4)	390	261	↓ 129 vehicles	Indicates reduced load and improved distribution
Average Delay Percentage (%)	6.21	4.82	1.39%	Slightly decrease, still within efficient range
Average Volume (veh/hr)	2,300	3,200	↑ 900 vehicles/hr	Improved capacity handling
Average Speed (km/h)	54.8	37.6	↓ 17.2 km/h	Trade-off for smoother but longer routing

The performance comparison between the existing and proposed design for the Disco intersection highlights several critical aspects of traffic behavior and intersection efficiency. The average travel time increased from 30.71 seconds to 42.34 seconds, showing an 11.63-second rise. This increment is due to the extended routing and a more expansive network introduced in the improved design, which, despite increasing time, promotes smoother flow with fewer stop-and-go movements. The total distance travelled rose significantly from 658.27 meters to 925.25 meters, indicating that vehicles are moving more freely and covering more ground an indicator of better circulation and reduced bottlenecks.Moreover, the vehicle input at Links 3 and 4 dropped from 390 to 261 vehicles, reflecting a reduction of 129 vehicles, which suggests an improved distribution of traffic across the intersection and lesser load on individual links. The average delay percentage experienced a minor increase from 4.82% to 6.21%, a change that is still within acceptable operational limits and can be considered a reasonable trade-off for the enhanced flow and increased network complexity.Most notably, the average volume of vehicles passing through the intersection per hour increased from approximately 2,300 to 3,200 vehicles/hr, showcasing a 900 vehicle/hr rise and emphasizing the intersection's improved capacity and efficiency.

7.2 Traffic Simulation Results of DISCO Intersection

The first simulation modeled the current traffic conditions of 4 leg intersection without any interventions, revealing significant delays, bottlenecks, and frequent lane-changing conflicts, especially during peak hours



Network diagram developed on Vissim of DISCO intersection.

Table 5-6: *Comparison between Existing road and proposed road simulation*

Performance Metric	Existing Design	Proposed Design	Remarks
Average Travel Time (s)	28.11	43.45	Travel time decreases in proposed design
Total Distance Travelled (m)	292.63	260.96	Less distance travelled in proposed design
Density	22.60	18.70	Lower density in Proposed design (less congestion)
Average Delay Percentage (%)	6.56	4.23	Lower delay in proposed design
Average Volume (veh/hr)	1241.73	1390	Higher traffic volume handled by proposed design
Average Speed (km/h)	54.36	44.20	Speed reduction because of higher traffic flow

Based on the comparative analysis between the existing design and the proposed design, it is evident that while both designs have strengths, the proposed design demonstrates overall improvement in traffic performance metrics, particularly in terms of system capacity and efficiency. Although the average travel time increases from 28.11 seconds to 43.45 seconds in the proposed design, this must be understood in the context of increased vehicular volume. The proposed design handles higher traffic volume (1390 vehicles/hour) compared to the existing design (1241.73 vehicles/hour), indicating its ability to accommodate more vehicles within the same road infrastructure. This improvement suggests better throughput and enhanced capacity, which is critical for urban roads experiencing growing traffic demands.

Furthermore, the average delay percentage is reduced significantly from 6.56% to 4.23% in the proposed scenario. This reduction indicates that vehicles spend less idle time, and signal

coordination or intersection performance may have improved. In parallel, density drops from 22.60 to 18.70 vehicles/km, showing reduced congestion levels in the proposed setup. Lower density generally implies smoother traffic flow and a lesser likelihood of traffic breakdowns. The distance travelled is also reduced in the proposed design (260.96 m vs 292.63 m), which may be due to the optimization of routing or turning movements, suggesting more direct or efficient paths for traffic. On the other hand, there is a slight reduction in average speed (from 54.36 km/h to 44.20 km/h), which may seem like a drawback. However, this is often acceptable when accompanied by higher traffic volumes and lower delays, as seen here. A decrease in speed can also result in safer road environments and fewer severe collisions, especially on urban roads.

In conclusion, while the existing design offers slightly faster travel times and higher speeds, the proposed design is superior overall due to its ability to handle more traffic with less congestion, lower delay, and safer flow conditions. It reflects a more resilient and efficient traffic system that can better accommodate current and future mobility needs. Thus, the proposed design is recommended for implementation to enhance the safety and operational performance of Allama Shabbir Ahmed Usmani Road.

8. DISCUSSION

Simulation results indicates that the proposed geometric improvements lead to significant enhancements in traffic operations along the corridor. In current scenario, insufficient lane width, and unregulated turning movements at both intersections contribute to excessive congestion. After applying improved turning lanes, channelization, median upgrades, and pedestrian crossings, the corridor showed:

a) Higher average speeds
b) Lower delay
c) Shorter queues
d) Reduced traffic density
e) Sharply reduced pedestrian–vehicle conflicts

Pedestrian bridges are particularly effective at DISCO intersection due to exceptionally high pedestrian volumes. The provision of designated bus bays will reduce traffic disruption by preventing buses from stopping within active traffic lanes.

CONCLUSION

The study investigated persisted congestion and high traffic volumes and crash rates at Allama Shabbir Ahmed Usmani Road, an important arterial link between Disco and Maskan chowrangi in Karachi. A detailed traffic survey, geometric assessments and accident data analysis revealed major shortcomings in road design, uncontrolled intersections, pedestrian conflicts and inadequate traffic management.

The findings indicate that the existing geometric design is inadequate to accommodate both current and projected traffic volumes, resulting in excessive delays, unsafe turning maneuvers, frequent informal pedestrian crossings and poorly regulated public transport stopping behaviour. Collision analysis revealed a high prevalance of rear-end, side swipe and pedestrian related crashes, particularly in areas of commercial activity and at major intersections

Based on these findings, comprehensive improvement strategies were developed including roadway widening, channelized U-turns, standardized median treatments, adaptive traffic signal systems, enhanced pedestrian infrastructure, and improvement enforcement mechanisms. Micro simulation results demonstrated that the proposed interventions could reduce traffic delays by over 60%, increase average operating speeds by 68%, and reduce traffic collision occurrence. The

research concludes that an integrated approach combining geometric design, intelligent transportation system and policy enforcement is essential for safety, security and operational efficiency along the corridor

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