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Strategic Approaches to Alleviate Traffic Congestion and Enhance Urban Mobility in Peshawar

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Abstract

Rapid urbanization, uncoordinated land-use growth, and insufficient integration of public transport have led to severe traffic congestion and declining mobility in Peshawar, Pakistan, even after the implementation of a Bus Rapid Transit (BRT) system. The core research problem addressed in this study is the mismatch between growing travel demand and the limited capacity, coverage, and operational efficiency of the existing urban transport network. This research aims to evaluate the current performance of Peshawar's transport system and to identify integrated, evidence-based strategies to alleviate congestion and enhance urban mobility. Specifically, the objectives are to assess roadway level of service on major corridors, examine public transport user satisfaction with the BRT system, and propose targeted infrastructure and operational improvements. A mixed-methods approach was employed, combining traffic volume and level-of-service (LOS) analysis, public transport user surveys, and field observations at critical intersections. The findings indicate that several key arterial roads operate at LOS E–F during peak hours, and future traffic projections indicate widespread capacity failures under existing road geometries. Survey results reveal significant dissatisfaction with the BRT system, particularly due to limited spatial coverage, inadequate feeder routes, overcrowding, and excessive travel times. Based on these results, the study proposes integrated interventions, including road widening and auxiliary lanes, geometric and signalized junction improvements, expansion of BRT feeder services, development of new arterial and ring roads, and enhanced pedestrian and parking infrastructure. This study links quantitative traffic performance measures with user-perceived service deficiencies. It provides practical, data-driven guidance for policymakers and planners to support a more efficient, accessible, and sustainable urban transport system in Peshawar.

Keywords: Peshawar; urban mobility; traffic congestion; BRT system; public transport; sustainable urban development

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1. Introduction

As the capital of Khyber Pakhtunkhwa and one of the cities with the fastest population growth, internal migration, and refugee influx in the country, Peshawar has faced its share of difficulties [1]. The city's population has grown substantially in its settlement areas. Local mobility and transport infrastructure have come under significant stress, primarily due to poorly planned and insufficient urban transport infrastructure [2]. Urban expansion without the commensurate provision of social services has led to inadequate and informal transport infrastructure. In contrast, the uncoordinated delivery of transport infrastructure and social services has further compounded the deterioration of urban living conditions [3]. Deficiencies in transport provision and informal settlement conditions, compounded by the inadequate management and unplanned expansion of a dysfunctional road network, continue to burden the expanding urban area. Peshawar has unregulated public transport services, consisting of minibus and wagon services, which are complemented by a poorly developed road network and insufficient social services [4]. The continued expansion of road infrastructure alongside the rapid growth in vehicle numbers has exacerbated traffic congestion and undermined the road network's capacity to deliver adequate transport services. Analysis of the transport-related challenges confronting Peshawar and its adjoining areas indicates a lack of integrated, coordinated planning within the region. As a consequence, the region experiences longer travel times, higher accident rates, and increased pollution levels. These challenges, therefore, underscore the need to address gaps in urban mobility, transport infrastructure development, spatial planning, and policy integration within the region [5].

Rapid urbanization and inadequate transport infrastructure have made traffic congestion a critical problem in developing cities such as Peshawar, Pakistan, where reliance on private vehicles has led to delays, pollution, and safety concerns. The literature emphasizes integrated solutions, such as intelligent transport systems and real-time traffic management, that can significantly reduce congestion and travel delays. Although Peshawar's BRT system represents progress, a low public transport mode share, weak feeder integration, and poor pedestrian infrastructure limit its impact. Local studies further attribute congestion to road bottlenecks, parking shortages, and inefficient intersection design [6,7].

Pakistan is experiencing increasing traffic congestion, urbanization, and private automobile use. Compounding these issues are air pollution, parking shortages, private vehicle dependence, and uneven expansion of the road network. The literature consistently advocates implementing a combination of innovative, environmentally sustainable strategies for urban transport systems, particularly in cities facing severe congestion and environmental stress [8–12]. Intelligent transport systems, the Internet of Things, and real-time artificial-intelligence traffic systems use technologies that anticipate, control, and seamlessly optimize routes and predict traffic flow to avoid congestion. These systems reduce vehicle travel times and fuel consumption while enhancing road safety [13–19]. Evidence suggests that congestion, pollution, and public health issues, as well as the adverse conditions in cities, can be improved through efficient public transport systems that cities integrate and coordinate [20]. The widespread use of public transport enhances the environment, particularly by reducing energy consumption, and reduces users' reliance on private vehicles. The promotion of active mobility, improved urban health, and environmental sustainability is a target of urban design, encouraging mixed-use developments, pedestrian-friendly spaces, and other public amenities that promote active travel [21–24].

Peshawar's urban transport system exhibits several persistent and critical deficiencies. Traffic congestion has increased steadily over the years, with the number of registered vehicles (excluding public transport) rising by 126% between 1998 and 2009 and the primary road network increasing by less than 1% [25,26]. The supplied GIS maps show that essential

facilities, such as health centers, black schools, and even mosques, are within 800 m of a pedestrian route. Large open spaces such as public parks, police stations, and BRT stations are too far away, highlighting the need for a more equitable and rational spatial organization of urban transport and roadside public services [27]. The primary cause of traffic congestion is poorly designed intersections and U-turns. In contrast, bus traffic and flyover systems are more effective for traffic fluidity and system harmony, as shown in Peshawar and demonstrated by a pilot project using a micro-simulator to model traffic congestion [28]. It is worth noting that the BRT system along University Road faces the same problems, with 1723 passengers using it during the busiest hours. During peak hours, the data reaffirms the marginal value of system expansion when coupled with excessive increases in total dedicated bus lanes, bus headways, service headways, and overall system capacity [29]. Studies of BRT systems suggest that, compared with other modes of public transport, BRT systems in Pakistani cities such as Islamabad and Rawalpindi experience fewer operational problems. Integrating urban transport systems, improving service quality, and bridging gaps in service provision for women and active transport users are among the most essential enhancements needed in urban public transport systems [30].

Urban transport planning strongly shapes mobility performance and sustainability by guiding infrastructure investment, policy instruments, and regulatory frameworks that influence travel behavior and congestion outcomes. Recent literature highlights a shift from infrastructure-led approaches to integrated, policy-driven frameworks that combine congestion analysis, innovative mobility technologies, and sustainability objectives, including low-carbon transitions through electric-vehicle infrastructure and renewable-energy integration [31,32]. Advanced congestion diagnostics using real-time and big-data sources support proactive policy design, while intelligent transportation systems enhance operational efficiency when backed by strong institutional and regulatory support [33,34]. Moreover, Sustainable Urban Mobility Plans provide an overarching framework for multimodal integration, participatory planning, and performance monitoring to reduce car dependence and improve accessibility [35].

Inadequate infrastructure, insufficient public awareness, and the sluggish pace of routine safety impact evaluations contribute to deteriorating road safety [36]. In Peshawar, urban sprawl planning problems led to high-rise developments along major traffic arteries, exacerbating traffic jams and air pollution, with no systematic plan to manage urban air quality [37]. In another study on urban transport, the new BRT System with added stations on existing lines was the best perceived answer, with passengers rating travel time, comfort, safety, cost, security, and accessibility as most important, along with overall service quality; other urban transportation systems fell short in these areas [38]. Local cultural conditions mitigate the social and environmental impacts of BRT systems, thereby promoting their efficient operation [39]. Major transportation projects, such as Trans Peshawar, highlight the need to prioritize road and highway infrastructure over public transportation in urban areas, with the expectation that revenue will cover costs [40].

Peshawar's public transportation system has been criticized for inefficiency, bad administration, and lack of advancement and integration [41]. Although many bus and van passengers use BRT, the system requires expansion because current services are insufficient to meet demand. Approximately 44% of commuters, primarily men, take the BRT every day. This category includes students, entrepreneurs, engineers, doctors, and military/paramilitary people. To improve accessibility, feeder services must connect educational and commercial centers to residential zones [42]. Lower and middle-income BRT users describe long journey times and issues with safety, accessibility, and dependability [43–45]. These conditions suggest that the BRT system faces a dire access

problem, lacks proper controls and sufficient expansion, and suffers from insufficient oversight of ground transport within the connected system.

The inadequately organized local public transport, which relies on shuttle vans, does not fully integrate with the public transport system and is limited to primary routes, illustrating the disproportionate availability of public transport with population growth [46]. Peshawar's Nasir Bagh, Chamkani, Charsadda, and Palosi Roads experience significant congestion during peak hours, especially at Jahaz Chawk, Charsadda Road Bus Stop Chawk, Jameel Chawk, and Chungi Chawk. The roads have become so congested, especially at key junctions, that the Traffic Control and Management System, the Digital Road Survey and the Road Traffic Control System have become ineffective. Road upgrades and construction are intended to improve accessibility and reduce congestion. Proposed recommendations to improve accessibility and reduce congestion include adding service roads and sidewalks, geometric or shape modifications to major junctions, adding lanes, and constructing minor roads.

The BRT system has been effective in some instances, but remaining coverage gaps, inaccessibility, and unreliability mean it has fallen short. This has led to continued reliance on informal transit, such as "karts" and minibuses. To also alleviate road traffic congestion, new parking facilities should be built close to business districts, new development zones should have gated access, and legal roadside parking restrictions should be enforced. Urban traffic management issues disproportionately affect mobility in the city, resulting in increased traffic congestion, reduced public transport efficiency, higher vehicle accident rates, and higher rates of road traffic injuries and fatalities [47,48].

This research evaluates Peshawar's transport system, identifies priority issues for action, and proposes evidence-based solutions. It integrates BRT performance analysis with user satisfaction surveys and traffic flow data to generate recommendations spanning public transport, road infrastructure, and traffic management. The overarching aim is to support urban planners, policymakers, and local authorities in designing practical interventions that enhance network safety, operational effectiveness, and environmental sustainability, thereby improving mobility for all residents.

1.1. Conclusion of Review

The reviewed literature makes clear that effective solutions must be integrated and context-specific. No single measure (e.g., expanding highways or adding buses alone) is sufficient. Instead, sustainable mobility requires combining infrastructure upgrades, transit service improvements, and technology deployment. For Peshawar, the literature's key implications are that our conceptual framework should link (a) improved transit coverage (including BRT and feeder networks) with demand management, (b) strategic road network enhancements (new links, intersection design, parking policy), and (c) intelligent traffic control tools. In this way, our framework adopts a systems perspective: it considers user satisfaction and travel demand alongside supply factors like network capacity. These insights directly inform our study design. In particular, documented gaps, such as inadequate feeder routes and overstressed road segments, are explicitly addressed in the framework's focus areas [6]. Thus, the literature review establishes the foundation for a data-driven, multi-dimensional approach to improving Peshawar's urban mobility.

1.2. Contribution

This study advances urban mobility research by contributing to both theory and practice in a developing-city context. It proposes an integrated conceptual framework that links infrastructure, technology, and user experience while explicitly accounting for local conditions, including informal transport and land-use patterns, thereby extending

sustainable mobility theory beyond models of developed cities. Empirically, the study provides actionable, data-driven recommendations for Peshawar through a unified analysis of GIS-based network assessment, traffic flow, LOS evaluation, and user perception surveys, identifying priority interventions in feeder services, arterial roads, intersections, and parking management. The methodological integration of multiple data sources and user-centered insights represents a novel contribution for Peshawar, offering a replicable, holistic approach to evidence-based transport planning in rapidly urbanizing cities.

2. Methodology

This research aims to identify and understand strategies for improving Peshawar's transportation and mobility systems. Assessments of public transportation systems, surveys, qualitative public feedback, and the integration of datasets on traffic, public transportation, and general transportation were used to evaluate systems and make future projections, helping to understand prevailing conditions. The sequentially designed, multiphased study aimed to understand specific components of urban mobility, traffic congestion, public transportation, and transportation infrastructure systems.

The methodological framework is designed to support strategic urban transport planning by integrating field data, standardized performance measures, and future demand projections, rather than relying on statistical hypothesis testing. Figure 1 shows the methodological framework of this study.

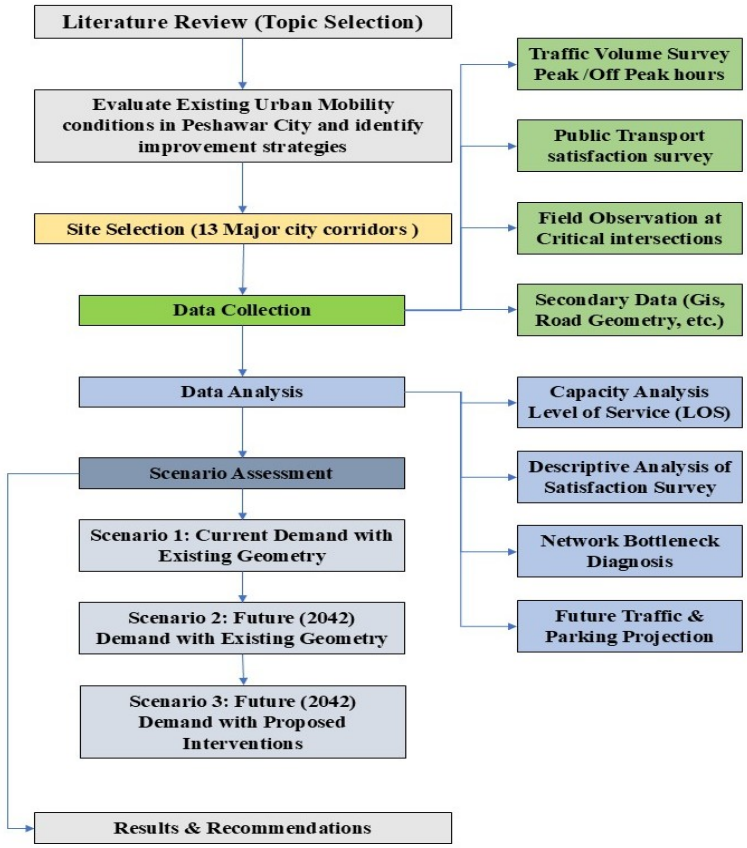


Figure 1. Methodological Framework of the Study.

2.1. Methodological Approach and Study Scope

This study adopts a planning-oriented, engineering-based analytical framework to evaluate urban mobility conditions in Peshawar and propose infrastructure and policy interventions for future scenarios. The research is not designed as a hypothesis-testing or

causal-inference study; instead, it focuses on network performance assessment, capacity evaluation, and scenario-based planning using established transportation engineering standards. Consequently, the analytical emphasis is on descriptive- and standards-based methods widely applied in urban transport planning and mobility studies.

2.2. Data Collection

Primary data were collected through field surveys using traffic counting, public transport user questionnaires, and intersection observations. Secondary data were drawn from city planning documents, official reports, and urban geospatial databases. All maps presented in this study were created by the authors using publicly available geospatial data from OpenStreetMap contributors and the Peshawar Development Authority's urban GIS database and were modified for visualization purposes.

2.2.1. Traffic Surveys

Traffic Volume Surveys

Analyses of traffic flow patterns on 13 principal routes in Peshawar during peak and off-peak periods revealed distinct patterns. The surveys and analysis were based on vehicle counts. The vehicle categories included trucks, buses, cars, auto-rickshaws, and motorcycles.

Vehicle Classification and Traffic Congestion Analysis

In this instance, JICA's traffic data classification and PCU assessments focused on Passenger Car Units (PCUs). A PCU, or Passenger Car Unit, is a metric used by traffic analysts to standardize traffic volume across various vehicle types. For instance, a truck is equivalent to 3 PCUs, a motorcycle is 3/4 of a PCU, and a car is 1 PCU. Lastly, we evaluated the effectiveness of traffic management for each road segment using the volume-to-capacity (V/C) ratio. To define the Level of Service (LOS), which ranges from A (uncongested, free-flow) to F (severely congested), we used the HCM (Highway Capacity Manual) framework. The study pinpointed and mapped highly congested, capacity-constrained route segments.

2.2.2. Public Transport Usage Surveys

The survey captured demographic and travel behavior characteristics of public transport users, their satisfaction with the Peshawar BRT system, challenges encountered while using the BRT, and broader local transport issues related to wagons, minibuses, and informal transit services. Because the BRT is the region's primary formal public transport mode, the questionnaire was designed to assess both BRT-specific performance and its interaction with the wider local transport system. Key survey metrics included BRT service frequency, commuter demographics, travel time to major activity centers, user satisfaction with service quality, and commonly reported issues such as accessibility, affordability, overcrowding, and travel time reliability. A total of 1244 respondents participated in the survey, representing various neighborhoods across Peshawar.

2.2.3. Traffic Condition Observations

Field inspections were conducted at selected major intersections in Peshawar to assess real-world traffic conditions and identify critical congestion and safety issues. Intersections were selected based on multiple criteria, including high traffic volumes from classified traffic counts, strategic importance within the arterial and sub-arterial road network, recurrent congestion during peak periods, and their role as central activity nodes, such as commercial centers and public transportation interfaces. Based on these criteria, the intersections at FC Chowk, Jahaz Chowk, Jameel Chowk, and Chungi Chowk were prioritized as critical bottlenecks affecting overall network performance.

Traffic condition observations were conducted during both morning and evening peak hours, as well as selected off-peak periods, to capture temporal variations in traffic flow. Each intersection was observed over multiple signal cycles for extended periods, typically 2 to 3 h per peak period. During the inspections, vehicle movements, queue formation, congestion patterns, signal timing effectiveness, pedestrian movements, and traffic conflict points were systematically recorded. These observations provided empirical evidence of deficiencies in intersection geometry, traffic control, and pedestrian facilities, informing the proposed traffic management and infrastructure improvement measures.

2.3. Data Analysis

The data analysis in this study relies on deterministic traffic engineering methods and descriptive evaluation techniques. Traffic performance was assessed using Passenger Car Unit (PCU) conversions, volume-to-capacity (V/C) ratios, and Level-of-Service (LOS) classifications, in accordance with the Highway Capacity Manual (HCM). These rule-based, standards-driven methods are widely used to evaluate roadway performance, congestion levels, and infrastructure adequacy. Consequently, inferential statistical techniques are not required to assess traffic capacity, LOS, or geometric design scenarios. Because the research focuses on system diagnosis and future planning scenarios rather than causal inference or post-implementation evaluation, inferential statistical hypothesis testing was not applied.

Instead, the study employs a scenario-based, planning-level assessment to evaluate the urban road network and public transport system. While a full cost–benefit analysis or formal multi-criteria decision-making (MCDM) framework was not applied, interventions were prioritized based on operational impact, feasibility, and observed deficiencies. Sensitivity analyses using alternative vehicle growth rates (3%, 5%, and 7%) were conducted to assess robustness. Pedestrian and BRT interventions were mapped using GIS to ensure coverage along corridors with limited accessibility, often serving lower-income neighborhoods. Short-term and long-term recommendations are explicitly identified to represent implementation phasing, ensuring the guidance is actionable for policymakers and equity-aware.

The adopted methodology emphasizes operational performance benchmarking and scenario-based analysis to support evidence-based transport planning decisions.

2.3.1. Level-of-Service (LOS) Analysis

To determine the Level of Service (LOS) for each road, traffic survey data were analyzed. Service quality was evaluated using the volume-to-capacity (V/C) ratio, which measures road performance during peak periods. A V/C ratio greater than 1.00 indicates congestion and significant delays. To assess long-term infrastructure needs, road traffic for 2042 was initially projected using a 5% annual growth rate in car registrations. To evaluate the robustness of this planning-level assumption, additional sensitivity analyses were conducted using alternative growth rates of 3% (lower-bound scenario) and 7% (upper-bound scenario). This approach allows assessment of infrastructure adequacy under varying rates of vehicle growth, highlighting potential challenges and the need for adaptable interventions. Future traffic volumes under each scenario were calculated using the compound annual growth formulation, as shown in Equation (1) below:

$$V_t = V_0 (1 + r)^t \quad (1)$$

where (V_t) is the projected traffic volume, (V_0) is the base-year traffic volume, (r) is the assumed annual growth rate, and (t) is the number of years until 2042. The resulting LOS and V/C ratios for alternative scenarios are presented in Section 3.1.

2.3.2. Public Transport Efficiency

The effectiveness of the BRT system was informed by data gathered through public transportation user surveys. These surveys provided information on the number of passengers using the system, the number of trips, user satisfaction, travel service quality, travel frequency, and other relevant factors. Based on a sample of 1244 respondents, the study reveals that a substantial 44% have significant concerns about system issues, including overcrowding, excessive travel times, safety, and general access. This suggests that there is still considerable demand for new BRT lines, as well as the need for feeder routes to improve overall service and reduce time-accessibility bottlenecks.

Public transport user surveys were analyzed using descriptive statistics to capture travel behavior, perceptions of service quality, and system deficiencies. The purpose of the analysis was diagnostic rather than inferential, aimed at identifying operational gaps and user-reported challenges within the existing transport system rather than testing statistical hypotheses or making population-level inferences. Consequently, inferential statistical correlation between survey responses and traffic parameters (e.g., LOS, V/C ratios) is neither methodologically required for this diagnostic study nor feasible, as the survey data were obtained in aggregated, anonymized form without spatial linkage to specific road segments.

2.4. Traffic Congestion and Parking Demand

While analyzing parking in Peshawar, trends in on-street and off-street parking utilization were examined. Vehicle registration in urban areas has been growing at 5% per year; thus, parking demand is expected to remain unmet. This study aimed to highlight areas in Saddar and the city center where parking was notably lacking.

3. Results

The results are presented within a scenario-based planning context, focusing on current and projected network performance, infrastructure constraints, and practical intervention strategies rather than inferential statistical testing.

3.1. Targeted Corridor Capacity and Bottleneck Improvements

The traffic situation in Peshawar presents critical challenges, with severe peak-hour congestion recorded across several major corridors. Traffic surveys, including MCC and TMC, were conducted to assess this, and traffic volumes were recorded during peak and off-peak times. The vehicle mix observed on the roads was converted to a single Passenger Car Unit (PCU) for further analysis.

Table 1 presents the Passenger Car Unit (PCU) variables used in traffic flow studies, grouped by vehicle type. By representing each vehicle category by its equivalent impact relative to a passenger car, PCU values simplify the analysis of diverse traffic.

Table 1. PCU Factors by JICA.

Vehicle Type	PCU Factors	Vehicle Type	PCU Factors
Truck	3	Car	1
Bus	3	Auto-Rickshaw	0.75
Minibus	3	Motorcycle	0.75
Utility	1	Non-Motorized Vehicles	1

In addition to the baseline 5% growth scenario, sensitivity analyses used 3% and 7% annual vehicle growth rates to assess the impact of varying growth assumptions on

corridor performance. Results indicate that even under the lower 3% growth scenario, several key corridors would face severe operational strain by 2042. Chamkani Road (Outbound) would deteriorate to LOS D–E, while Kohat Road would operate entirely at LOS F, highlighting persistent congestion. Under the 7% growth scenario, most major corridors would deteriorate to LOS F, underscoring the importance of flexible planning and targeted interventions.

These analyses confirm that the proposed geometric improvements, including auxiliary lanes and BRT feeder expansions, provide robust mitigation under moderate growth conditions (5%) and offer partial relief under more aggressive growth (7%), demonstrating the planning recommendations' resilience to uncertainty in vehicle growth projections.

The Level of Service (LOS) of a road indicates its quality based on the number of vehicles that can flow smoothly through it per hour. To determine the LOS of roads, a volume and capacity analysis is conducted in accordance with the criteria in the Highway Capacity Manual, as shown in Table 2.

Table 2. LOS Criteria of HCM for Capacity Analysis.

LOS Criteria for Volume/Capacity (V/C) Analysis	
V/C Ratio	**LOS**
0.00–0.60	A
0.60–0.70	B
0.70–0.80	C
0.80–0.90	D
0.90–1.00	E
>1.00	F

The spatial distribution of the cordon points used for the manually classified traffic count survey throughout Peshawar is shown in Figure 2. To record traffic flow patterns within and around the urban area, cordon points are strategically placed along key corridors and entry and exit routes.

Traffic volumes on thirteen major roads in Peshawar were evaluated using volume-to-capacity ratios, and the Level of Service (LOS) was determined based on existing roadway geometry. Under current conditions, most roads operate at LOS A; however, lower service levels were observed on specific corridors, including LOS F on Kohat Road and LOS C on Palosi Road for inflow traffic. To assess future operating conditions, traffic volumes were projected at a 5% annual growth rate, based on vehicle registration trends reported in the Background Survey Report (BSR). Based on these projections, two scenarios were analyzed: future traffic demand under existing geometric conditions and under targeted geometric improvements.

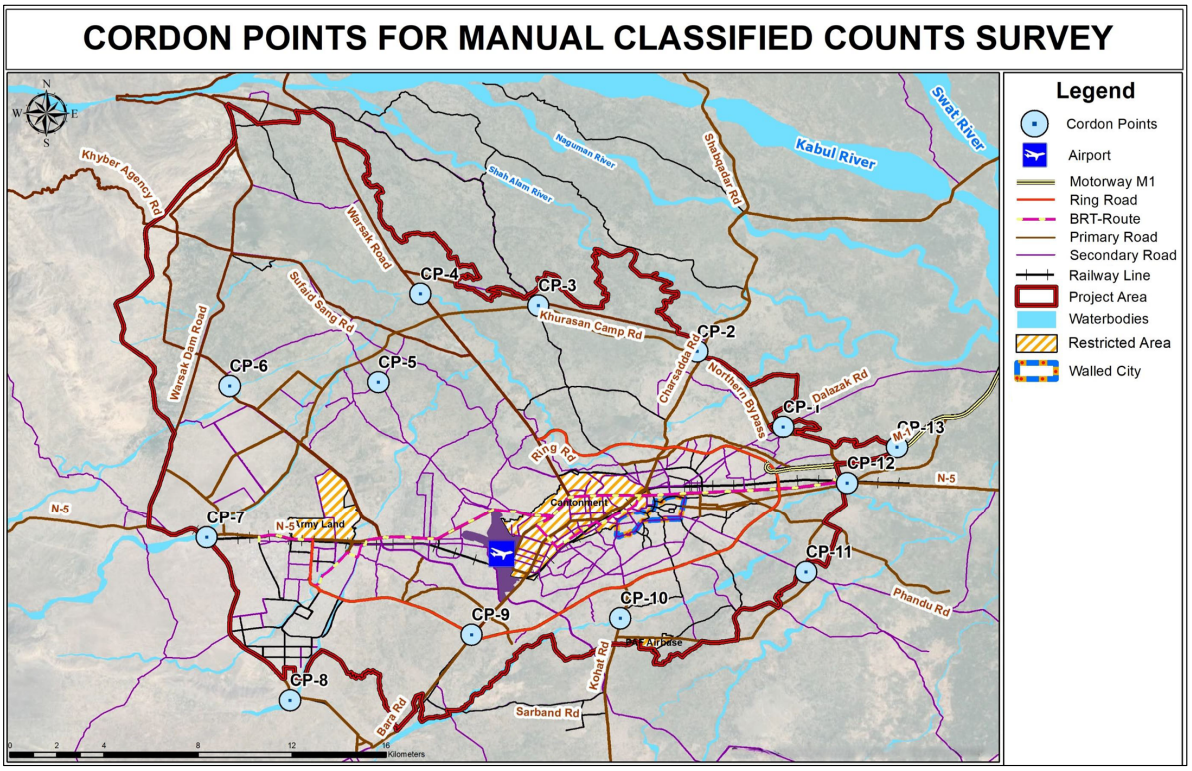


Figure 2. Cordon Point Map.

The results for 13 roads, including their traffic volumes, peak hours, and required interventions to improve LOS in 2042, are presented in Table 3a–c.

Table 3. (**a**) Current Demand with Existing Geometry. (**b**) Future Demand with Existing Geometry-2042. (**c**) Future Demand with Intervention-2042. (**d**) Projected Traffic Volume and Level of Service (LOS) for the 2042 Future Scenario under 3% and 7% Growth Rates.

(**a**)

Cordon Point	ID	Direction	Peak	Lanes	Road Capacity (Pcu/hr) C	Peak Hour Volume (pcu) V	V/C Ratio	LOS
Chamkani Road	CP-1	In	AM/PM	3	4800	2316/2309	0.48/0.48	A/A
		Out	AM/PM	3	4800	2576/2819	0.54/0.59	A/A
Dalazak Road	CP-2	In	AM/PM	2	3200	676/979	0.21/0.31	A/A
		Out	AM/PM	2	3200	547/681	0.17/0.21	A/A
Charsadda Road	CP-3	In	AM/PM	3	4800	2487/1753	0.52/0.37	A/A
		Out	AM/PM	3	4800	1114/1614	0.23/0.34	A/A
Pajagi Road	CP-4	In	AM/PM	1	1600	909/728	0.57/0.45	A/A
		Out	AM/PM	1	1600	948/699	0.59/0.44	A/A
Warsak Road	CP-5	In	AM/PM	2	3200	1701/1281	0.53/0.40	A/A
		Out	AM/PM	2	3200	882/806	0.28/0.25	A/A
Palosi Road	CP-6	In	AM/PM	1	1600	1130/1188	0.71/0.74	C/C
		Out	AM/PM	1	1600	653/1090	0.41/0.68	A/B
Nasir Bagh Road	CP-7	In	AM/PM	2	3200	901/1166	0.28/0.36	A/A
		Out	AM/PM	2	3200	777/961	0.24/0.30	A/A
Jamrud Road	CP-8	In	AM/PM	2	3200	1423/1485	0.44/0.46	A/A
		Out	AM/PM	2	3200	1844/1966	0.58/0.61	A/A
Bara Road	CP-9	In	AM/PM	2	3200	640/777	0.20/0.24	A/A

Table 3. *Cont.*

(**a**)

Cordon Point	ID	Direction	Peak	Lanes	Road Capacity (Pcu/hr) C	Peak Hour Volume (pcu) V	V/C Ratio	LOS
		Out	AM/PM	2	3200	974/789	0.30/0.25	A/A
Kohat Road	CP-10	In	AM/PM	2	3200	3285/3301	1.03/1.03	F/F
		Out	AM/PM	2	3200	3073/2974	0.96/0.93	E/E
Phandu Road	CP-11	In	AM/PM	2	3200	1842/2203	0.58/0.69	A/B
		Out	AM/PM	2	3200	1560/1230	0.49/0.38	A/A
Hayatabad-Bara	CP-12	In	AM/PM	1	1600	607/617	0.38/0.39	A/A
		Out	AM/PM	1	1600	450/430	0.28/0.27	A/A
Motorway Plaza	CP-13	In	AM/PM	3	4800	770/787	0.16/0.39	A/A
		Out	AM/PM	3	4800	764/814	0.38/0.41	A/A

(**b**)

ID	Direction	Peak	Future Peak Hour Volume (pcu) (V)	V/C Ratio	LOS
CP-1	Inflow/Outflow	AM	5574/6199	1.16/1.29	F/F
	Inflow/Outflow	PM	5556/6783	1.16/1.41	F/F
CP-2	Inflow/Outflow	AM	1627/1316	0.51/0.41	A/A
	Inflow/Outflow	PM	2355/1638	0.74/0.51	C/A
CP-3	Inflow/Outflow	AM	5985/2680	1.25/0.56	F/A
	Inflow/Outflow	PM	4218/3885	0.88/0.81	D/D
CP-4	Inflow/Outflow	AM	2186/2281	1.37/1.43	F/F
	Inflow/Outflow	PM	1751/1683	1.09/1.05	F/F
CP-5	Inflow/Outflow	AM	4095/2123	1.28/0.66	F/B
	Inflow/Outflow	PM	3084/1939	0.96/0.61	E/B
CP-6	Inflow/Outflow	AM	2719/1572	1.70/0.98	F/E
	Inflow/Outflow	PM	2859/2623	1.79/1.64	F/F
CP-7	Inflow/Outflow	AM	2169/1870	0.68/0.58	B/A
	Inflow/Outflow	PM	2807/2314	0.88/0.72	E/C
CP-8	Inflow/Outflow	AM	3425/4437	1.07/1.39	F/F
	Inflow/Outflow	PM	3573/4731	1.12/1.48	F/F
CP-9	Inflow/Outflow	AM	1541/2344	0.48/0.73	A/C
	Inflow/Outflow	PM	1871/1899	0.58/0.59	A/A
CP-10	Inflow/Outflow	AM	7905/7395	2.47/2.31	F/F
	Inflow/Outflow	PM	7944/7158	2.48/2.24	F/F
CP-11	Inflow/Outflow	AM	4434/3754	1.39/1.17	F/F
	Inflow/Outflow	PM	5301/2960	1.66/0.93	F/E
CP-12	Inflow/Outflow	AM	1461/1082	0.91/0.68	E/B
	Inflow/Outflow	PM	1486/1034	0.93/0.65	E/B
CP-13	Inflow/Outflow	AM	1853/1839	0.39/0.38	A/A
	Inflow/Outflow	PM	1894/1959	0.39/0.41	A/A

(**c**)

ID	Recommended Intervention	Proposed Lanes Inflow/Outflow	Resulting V/C Ratio Inflow/Outflow (AM/PM)	Final LOS Inflow/Outflow (AM/PM)
CP-1	+1 lane Westbound; +2 lanes Eastbound	4/5	0.87/0.87 (In)/0.76/0.83 (Out)	D/D|C/D
CP-2	No Interventions required	2/2	0.51/0.74 (In)/0.41/0.51 (Out)	A/C|A/A

Table 3. *Cont.*

CP-3	+1 lane Westbound approach	4/3	0.94/0.66 (In)/0.56/0.81 (Out)	E/B | A/D
CP-4	+1 lane Southbound; +1 lane Northbound	2/2	0.68/0.55 (In)/0.71/0.53 (Out)	B/A | C/A
CP-5	+1 lane Westbound approach	3/2	0.85/0.64 (In)/0.66/0.61 (Out)	D/B | B/B
CP-6	+1 lane Southbound; +1 lane Northbound	2/2	0.85/0.89 (In)/0.49/0.82 (Out)	D/D | A/D
CP-7	No Interventions required	2/2	0.68/0.88 (In)/0.58/0.72 (Out)	B/D | A/C
CP-8	+1 lane Eastbound; +2 lanes Westbound	3/4	0.71/0.74 (In)/0.69/0.74 (Out)	C/C | B/C
CP-9	No Interventions required	2/2	0.48/0.58 (In)/0.73/0.59 (Out)	A/A | C/A
CP-10	+3 lanes Northbound; +3 lanes Southbound	5/5	0.96/0.97 (In)/0.90/0.87 (Out)	E/E | E/D
CP-11	+2 lanes Westbound; +1 lane Eastbound	4/3	0.69/0.83 (In)/0.78/0.62 (Out)	B/D | C/B
CP-12	No Interventions required	1/1	0.91/0.93 (In)/0.68/0.65 (Out)	E/E | B/B
CP-13	No Interventions required	3/3	0.39/0.39 (In)/0.38/0.41 (Out)	A/A | A/A

(**d**)

Cordon Point (ID)	Dir.	Capacity (C)	3% Growth Volume (2042)	3% V/C Ratio	3% LOS	7% Growth Volume (2042)	7% V/C Ratio	7% LOS
(CP-1)	In	4800	3716/3705	0.77/0.77	C/C	6837/6817	1.42/1.42	F/F
	Out	4800	4133/4523	0.86/0.94	D/E	7605/8322	1.58/1.73	F/F
(CP-2)	In	3200	1085/1571	0.34/0.49	A/A	1996/2890	0.62/0.90	B/D
	Out	3200	878/1093	0.27/0.34	A/A	1615/2010	0.50/0.63	A/B
(CP-3)	In	4800	3991/2813	0.83/0.59	D/A	7342/5175	1.53/1.08	F/F
	Out	4800	1788/2590	0.37/0.54	A/A	3289/4765	0.69/0.99	B/E
(CP-4)	In	1600	1459/1168	0.91/0.73	E/C	2684/2149	1.68/1.34	F/F
	Out	1600	1521/1122	0.95/0.70	E/B	2799/2064	1.75/1.29	F/F
(CP-5)	In	3200	2730/2056	0.85/0.64	D/B	5022/3782	1.57/1.18	F/F
	Out	3200	1415/1293	0.44/0.40	A/A	2604/2379	0.81/0.74	D/C
(CP-6)	In	1600	1813/1906	1.13/1.19	F/F	3336/3507	2.09/2.19	F/F
	Out	1600	1048/1749	0.66/1.09	B/F	1928/3218	1.21/2.01	F/F
(CP-7)	In	3200	1446/1871	0.45/0.58	A/A	2660/3442	0.83/1.08	D/F
	Out	3200	1247/1542	0.39/0.48	A/A	2294/2837	0.72/0.89	C/D
(CP-8)	In	3200	2283/2383	0.71/0.74	C/C	4201/4384	1.31/1.37	F/F
	Out	3200	2959/3155	0.92/0.99	E/E	5444/5804	1.70/1.81	F/F
(CP-9)	In	3200	1027/1247	0.32/0.39	A/A	1889/2294	0.59/0.72	A/C
	Out	3200	1563/1266	0.49/0.40	A/A	2875/2329	0.90/0.73	D/C
(CP-10)	In	3200	5271/5297	1.65/1.66	F/F	9701/9745	3.03/3.05	F/F
	Out	3200	4931/4772	1.54/1.49	F/F	9072/8780	2.84/2.74	F/F
(CP-11)	In	3200	2956/3535	0.92/1.10	E/F	5438/6504	1.70/2.03	F/F
	Out	3200	2503/1974	0.78/0.62	C/B	4605/3631	1.44/1.13	F/F
(CP-12)	In	1600	974/990	0.61/0.62	B/B	1792/1822	1.12/1.14	F/F
	Out	1600	722/690	0.45/0.43	A/A	1328/1270	0.83/0.79	D/C
(CP-13)	In	4800	1236/1263	0.26/0.26	A/A	2273/2323	0.47/0.48	A/A
	Out	4800	1226/1306	0.26/0.27	A/A	2255/2403	0.47/0.50	A/A

Table 3b outlines projected peak-hour volumes and highlights severe operational deficiencies and widespread Level of Service (LOS) issues.

Table 3c details the specific engineering interventions proposed for each corridor, such as localized lane additions and approach reallocations, as well as the final, improved Level of Service metrics achieved through these geometric optimizations.

Table 3d presents projected peak-hour volumes (AM/PM) and the corresponding Level of Service (LOS) for both the 3% and 7% annual growth scenarios across all 13 cordon points for the 2042 horizon.

An assessment of the Level of Service (LOS) for the selected routes, based on current geometric configurations and projected future traffic volumes, indicates that most corridors operate at LOS F, reflecting severe congestion and substantial delays (Table 4). Without geometric improvements, these roads are expected to remain suboptimal as demand increases. The proposed addition of 12-foot-wide auxiliary lanes is expected to significantly improve roadway geometry and operational performance. The scenario results indicate that several corridors would experience capacity constraints under the 2042 baseline demand scenario if existing geometric conditions remain unchanged. Targeted auxiliary lanes are therefore evaluated as short- to medium-term bottleneck treatments at selected corridors where V/C ratios exceed acceptable LOS thresholds. However, these capacity improvements should not be interpreted as a stand-alone solution to congestion. The induced-demand literature indicates that additional road capacity may attract new or diverted traffic over time, reducing the long-term congestion-relief benefit of widening alone. Therefore, the proposed auxiliary lanes are recommended only as part of an integrated package that includes BRT feeder expansion, public transport terminal improvements, pedestrian facilities, bicycle and e-bike infrastructure, parking management, signal optimization, signage improvements, and demand-management measures [49].

Table 4. Proposed footpaths along major roads of Peshawar.

S. No.	Roads	Footpath Availability (Existing)	Footpath Availability (Proposed)
1	Dalazakh Road	No	Yes
2	Charsadda Road	No	Yes
3	Pajjagi Road	No	Yes
4	Warsak Road	Yes	Yes (Widening)
5	Palosi Road	No	Yes
6	Nasir Bagh Road	No	Yes
7	Bara Road	No	Yes
8	Kohat Road	No	Yes
9	Phandu Road	No	Yes

Interventions were prioritized based on the corridor-level deficiencies identified above. Short-term measures, including auxiliary lanes, signal timing optimization, and targeted parking management, are recommended for immediate relief. Medium- to long-term interventions, such as BRT feeder expansions, grade separations, and network-wide capacity upgrades, are planned for phased implementation. GIS mapping shows that pedestrian footpaths and BRT routes target corridors serving underserved and lower-income neighborhoods. Sensitivity analyses under 3%, 5%, and 7% annual vehicle growth scenarios confirm that these interventions remain broadly effective across varying future conditions.

Figure 3 highlights the short-term and long-term implementation stages of the proposed footpath network under the Peshawar City Master Plan 2042. To improve pedestrian

accessibility, safety, and integration with the entire urban transportation system, the proposed corridors are aligned with major roadways and transit routes.

The effectiveness of the proposed interventions is evaluated through scenario-based comparisons of current and projected traffic demand under existing and improved roadway geometries. Improvements in system performance are assessed by changes in the volume-to-capacity (V/C) ratio and the corresponding Level of Service (LOS) category using established engineering thresholds. This approach enables a consistent assessment of congestion mitigation potential without reliance on inferential statistical significance testing.

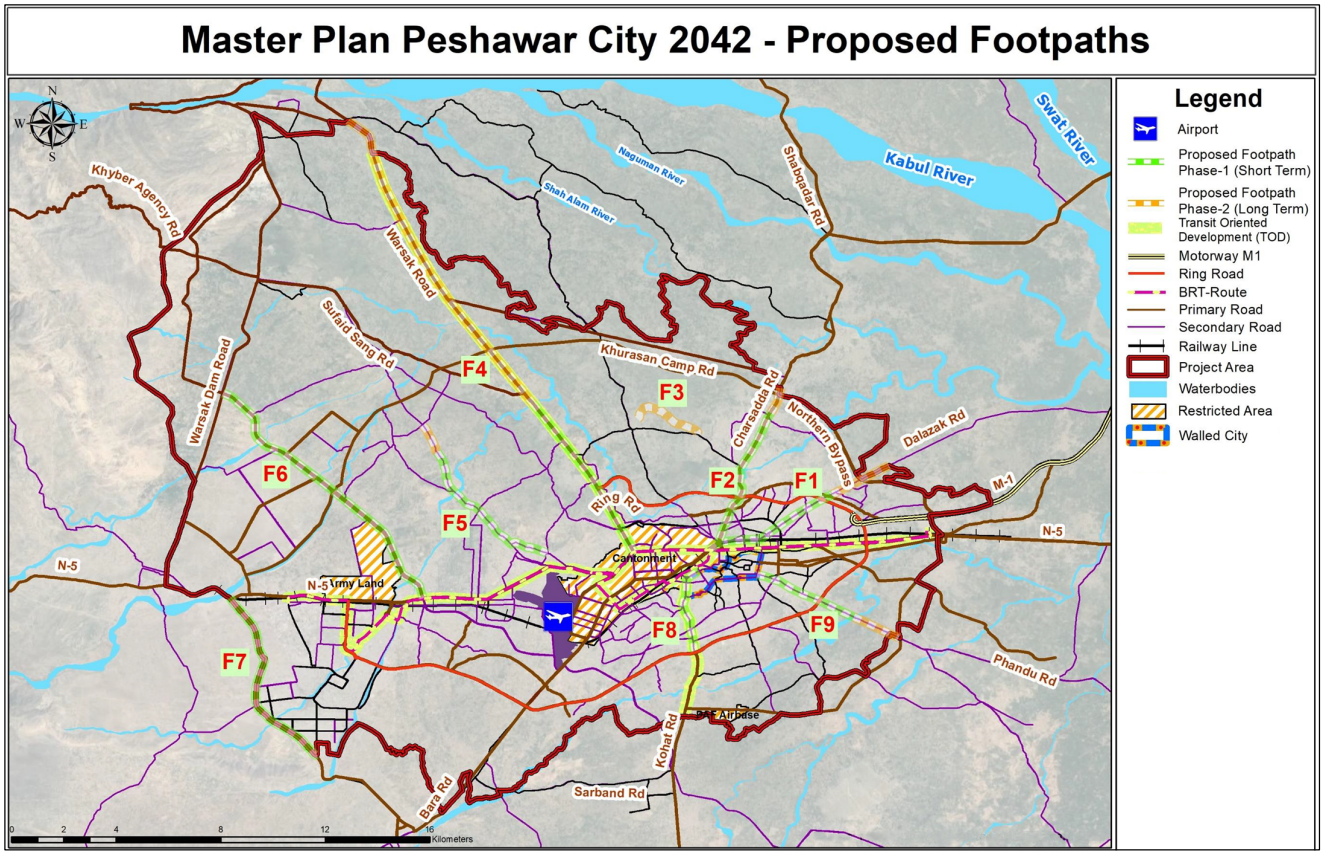


Figure 3. Newly Proposed Footpath Map.

3.2. Newly Proposed Roads

Proposed road infrastructure enhancements in future extension areas aim to improve traffic circulation and strengthen connectivity to the primary urban zones. Key measures, detailed in Table 5 with corresponding coordinates, lengths, and geometric characteristics, include extending the Ring Road on the western side from Warsak Road to the N-5 corridor, developing an Outer Ring Road along the study area boundary to connect Hayatabad with Farhab Colony and rejoin the existing Ring Road, widening existing roads within planned commercial and residential zones to facilitate smoother traffic flow, and installing comprehensive regulatory, informational, and directional signage along all newly proposed corridors. Figures 4 and 5 illustrate the existing and proposed road network under the Peshawar City Master Plan 2042, including planned road widening, new alignments, and transit-oriented developments. The maps highlight strategic upgrades, such as BRT extensions, ring-road expansions, and regional connectivity improvements, to improve traffic flow and urban accessibility.

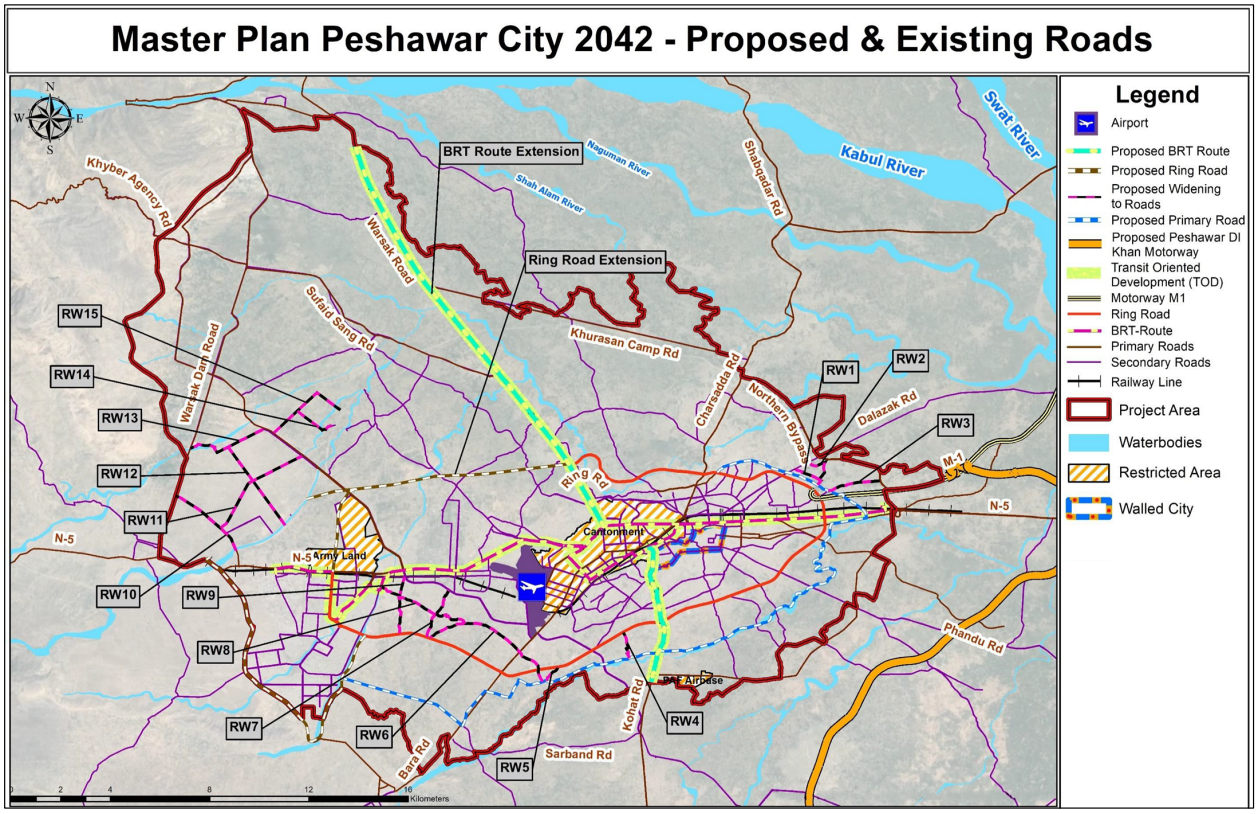


Figure 4. Newly Proposed Roads and Widening of Existing Roads.

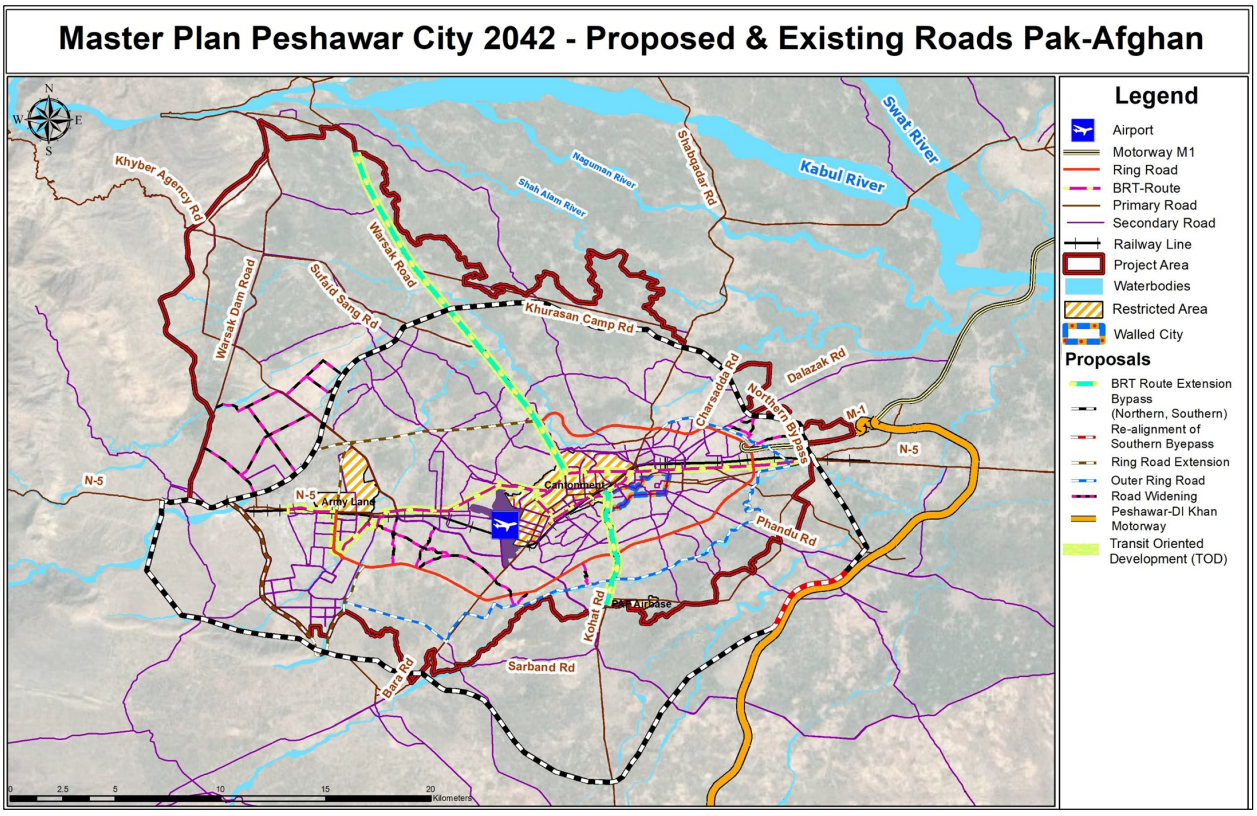


Figure 5. Proposed Roads and Widenings with Already Proposed Regional Connectivity (Northern and Southern Bypass—Pak-Afghan Corridor).

Table 5. Selected junctions for improvement in the mobility of Peshawar.

ID	Junctions Name	Coordinates	Type of Junction (Existing)	Type of Junction (Proposed) Phase-I	Type of Junction (Proposed) Phase-II
TMC-1	Jahaz Chowk	33°58′40.01″ N, 71°26′47.34″ E.	Roundabout	Signal Control	Grade Separation
TMC-2	Shaheed Tahseen Chowk	34°1′56.03″ N, 71°34′41.50″ E.	Grade Separated (Diamond)	Grade Separated (Diamond) Signalized (U-Turn Controlling)	Grade Separation (Cloverleaf)
TMC-3	Pistakhara Chowk	33°57′41.52″ N, 71°30′19.23″ E	Roundabout	Signalized	Grade Separation
TMC-4	Dabgari Garden Chowk	35°51′13″ N, 71°47′12″ E	Unsignalized	Signalized	Grade Separation
TMC-5	Jameel Chowk	33°59′49.83″ N, 71°36′21.38″ E	Roundabout	Signalized	Grade Separation
TMC-6	FC Chowk	34°0′2.02″ N, 71°32′47.87″ E	Unsignalized	Signalized	Grade Separation
TMC-7	Palosi Chowk	34°1′23.36″ N, 71°29′7.63″ E	Unsignalized	Signalized	Grade Separation
TMC-8	Chungi Chowk	33°59′42.41″ N, 71°33′32.79″ E	Unsignalized	Signalized	Grade Separation
TMC-9	Kababian Chowk Warsak	34°1′19.11″ N, 71°32′15.01″ E	Unsignalized	Signalized	Grade Separation
TMC-10	Karkhano Chowk	33°59′53.94″ N, 71°25′22.15″ E	Unsignalized	Signalized	Grade Separation
TMC-11	Mall Road Station Chowk	33°59′52.78″ N, 71°32′1.41″ E.	Unsignalized	Signalized	Grade Separation
TMC-12	Shuba Bazar Chowk	34° 0′31.34″ N, 71°33′49.05″ E	Unsignalized	Signalized	Grade Separation

3.3. Proposed Junction Geometry

Most roads and junctions are highly congested, and proper planning, such as upgrading junctions and road geometry, is necessary to alleviate congestion in Peshawar by 2042. The junctions that need signalization are listed in Table 5. The map showing the Turning Movement Count Points and Proposed Junction Improvements is displayed in Figures 6 and 7.

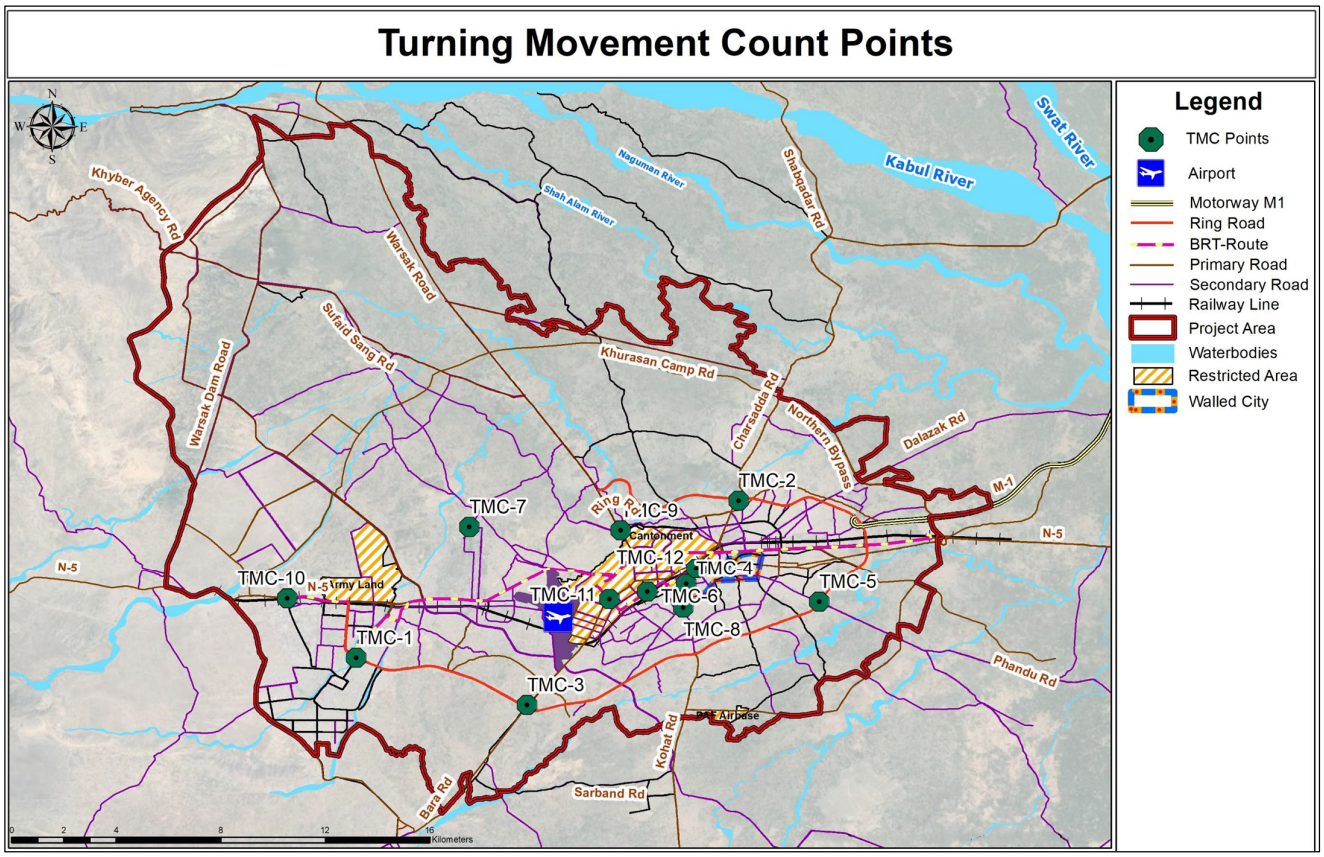


Figure 6. Turning Movement Count Points.

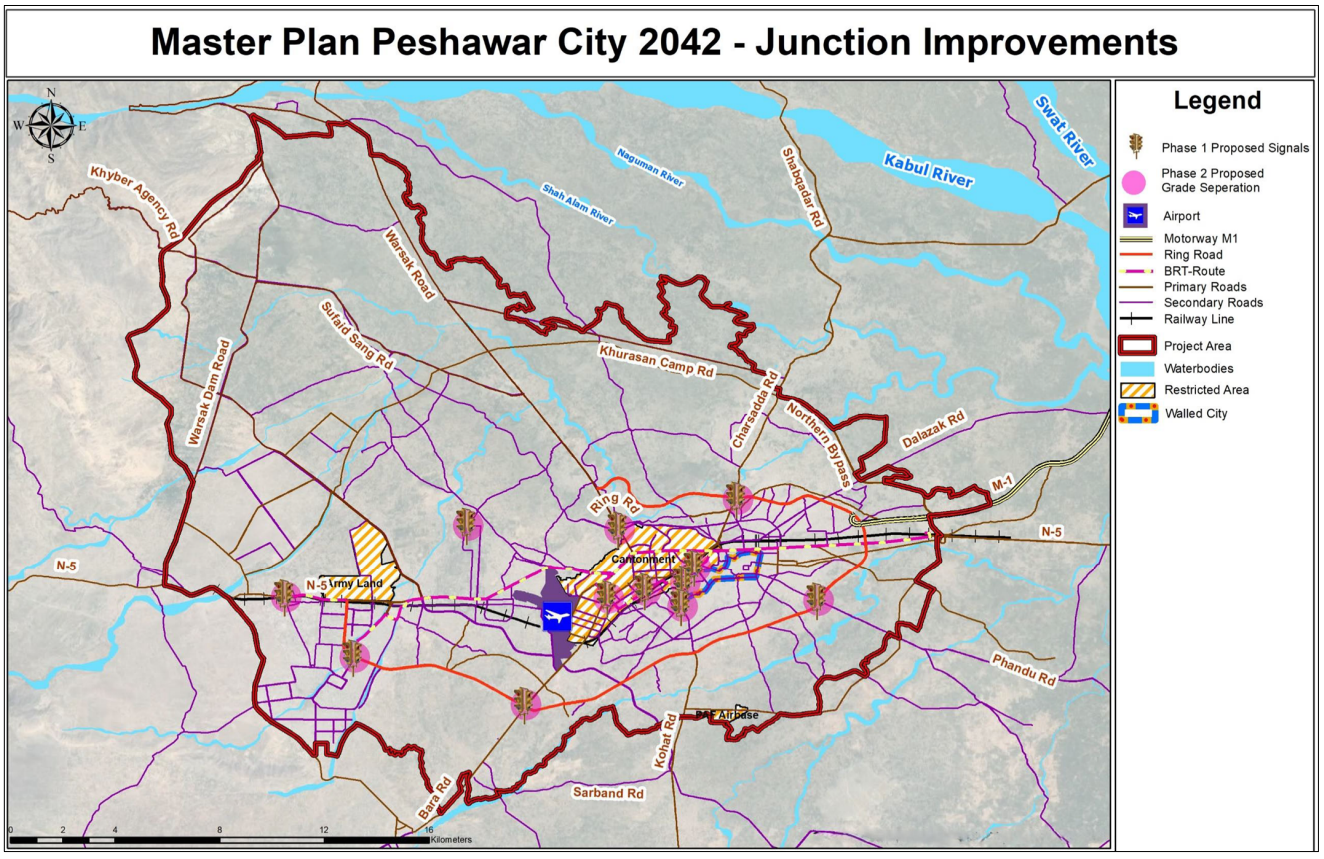


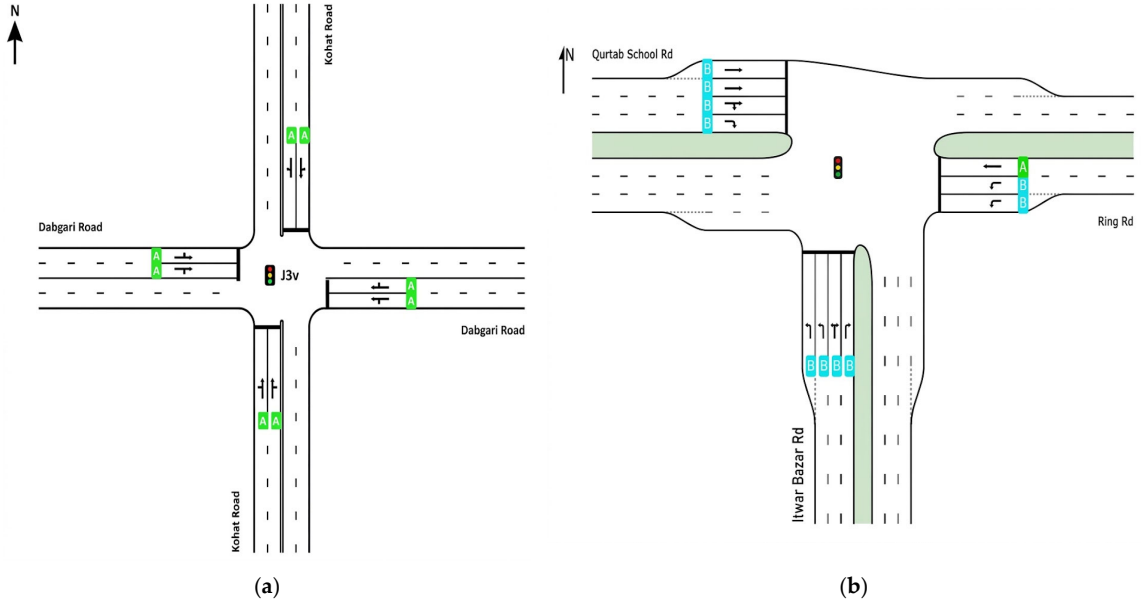
Figure 7. Proposed Junction Improvements.

Table 6 below summarizes the proposed pre-timed signal schedules for various intersections under future conditions. Each intersection is evaluated based on the total cycle time, including green, yellow, and all-red phases in all directions. Depending on traffic demand and intersection complexity, cycle lengths can range from 53 s to 2 min. This approach provides the complete cycle time for each intersection, eliminating the need for detailed phase-by-phase analyses. Nonetheless, the integrated cycle approach retains the ability to assess the traffic signal timings under consideration.

Table 6. Proposed Pre-Timed Signal Timings (Future Conditions).

Intersection Name	Total Cycle Time (s)	Remarks	Graphical Presentation
Dabgari Garden	120	Includes all legs (South, West, East, North)	Figure 8a
Jahaz Chowk	90	Includes all legs (South, West, East)	Figure 8b
Charsadda Bus Stop	120	Includes all legs (South, West, East, North)	Figure 9a
Chungi Chowk	90	Includes all legs (South, North-East, North-West)	Figure 9b
FC Chowk	115	Consistent with optimal cycle length	Figure 10a
Jameel Chowk	120	Includes all legs (South, West, East, North)	Figure 10b
Kababian Chowk	64	Includes all legs (South, West, East, North)	Figure 11a
Karkhano Chowk	90	Includes all legs (South, West, East)	Figure 11b
Palosi Chowk	100	Includes all legs (South, West, East, North)	Figure 12a
Peshawar Services Chowk	120	Includes all legs (South-East, South-West, North-East, North-West)	Figure 12b
Pistakhara Chowk	53	Includes all legs (South-East, South-West, North-East, North-West)	Figure 13a
Shubha Chowk	120	Includes all legs (South, West, East, North)	Figure 13b

Figure 8 illustrates the proposed pre-timed signal timing plans for Dabgari Garden Chowk and Jahaz Chowk. The layouts depict optimized lane assignments and signal phases designed to improve intersection efficiency, reduce delays, and enhance traffic flow under prevailing traffic conditions.



(**a**) (**b**)

Figure 8. (**a**) Proposed Pre-Timed Signal Timings for Dabgari Garden Chowk. (**b**) Proposed Pre-Timed Signal Timings for Jahaz Chowk.

Figure 9 presents the proposed pre-timed signal timing schemes for Charsadda Bus Stop Chowk and Chungi Chowk. The designs illustrate revised lane configurations and signal phases intended to improve intersection capacity, balance traffic movements, and reduce operational delays. Likewise, Figures 10–13 display the proposed pre-timed signal timing schemes for the remaining intersections.

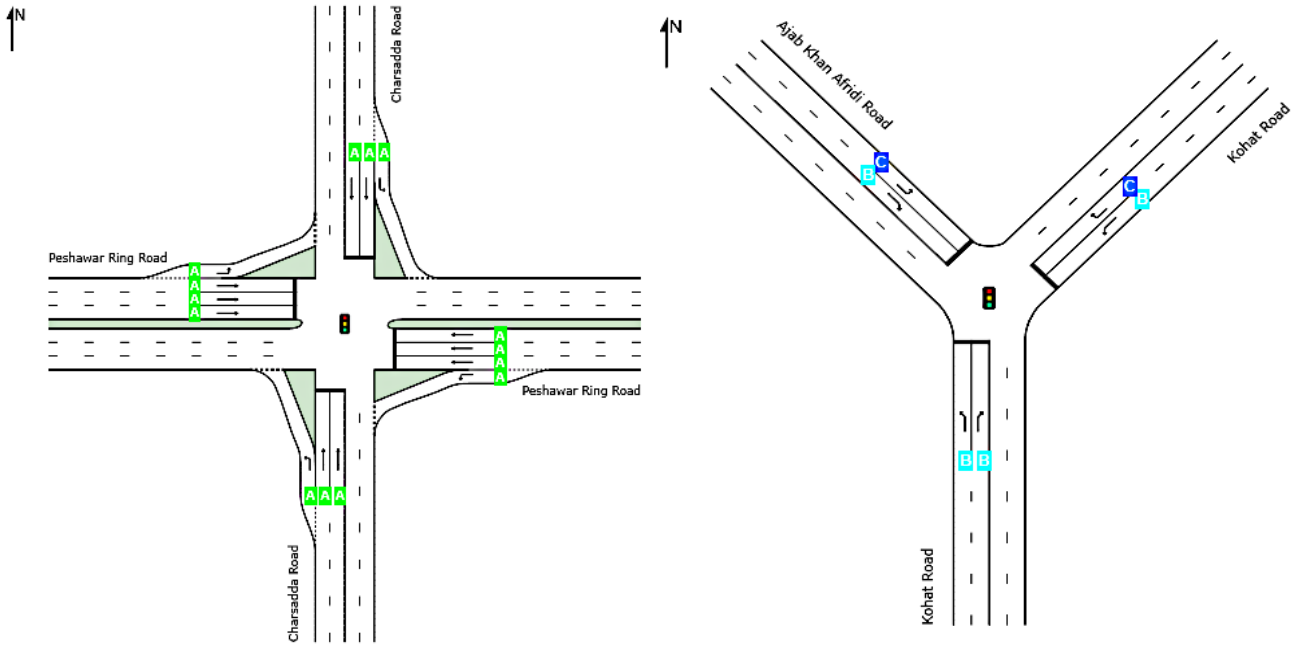


Figure 9. (**a**) Proposed Pre-Timed Signal Timings for Charsadda Bus Stop Chowk. (**b**) Proposed Pre-Timed Signal Timings for Chungi Chowk.

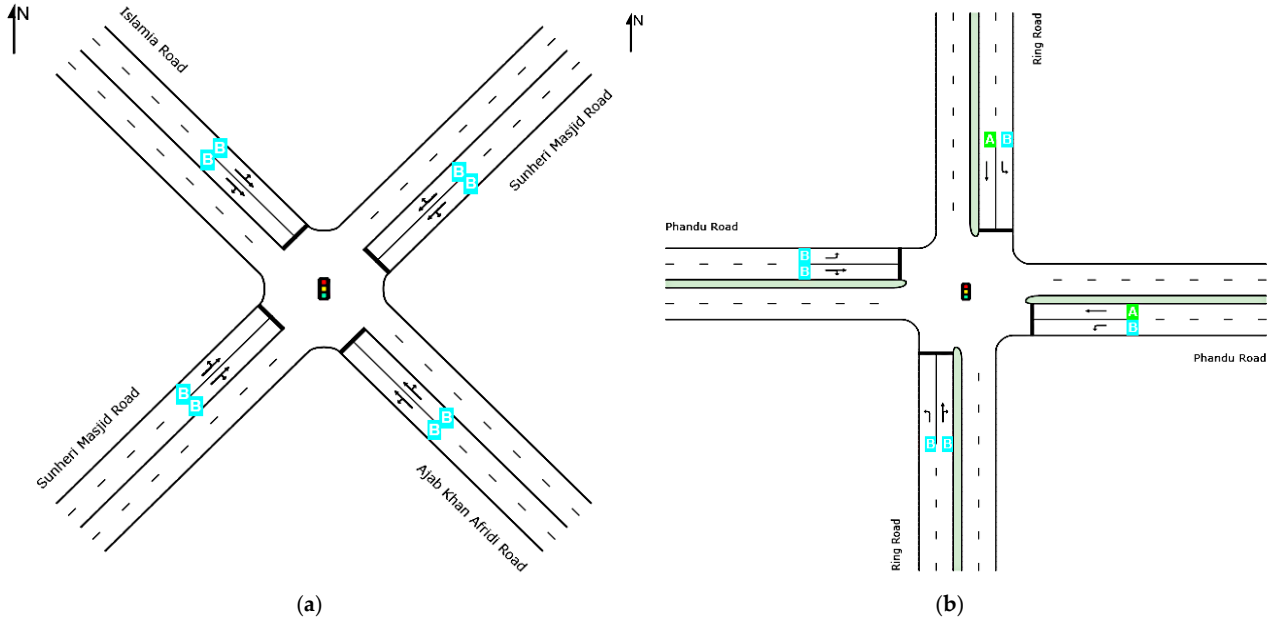
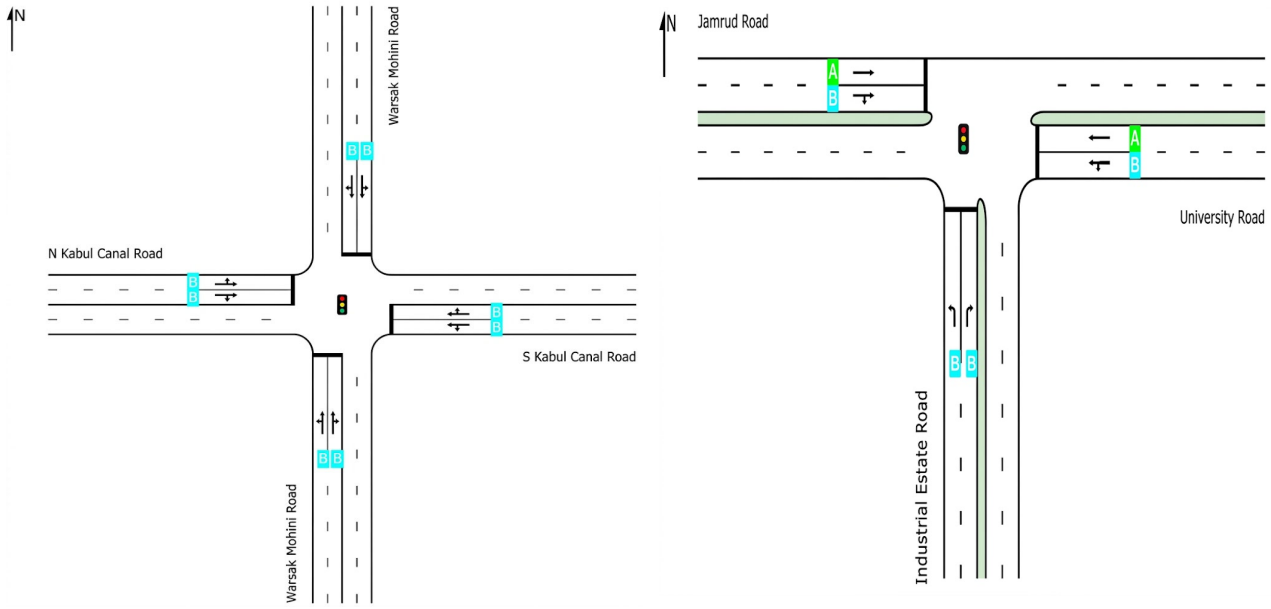
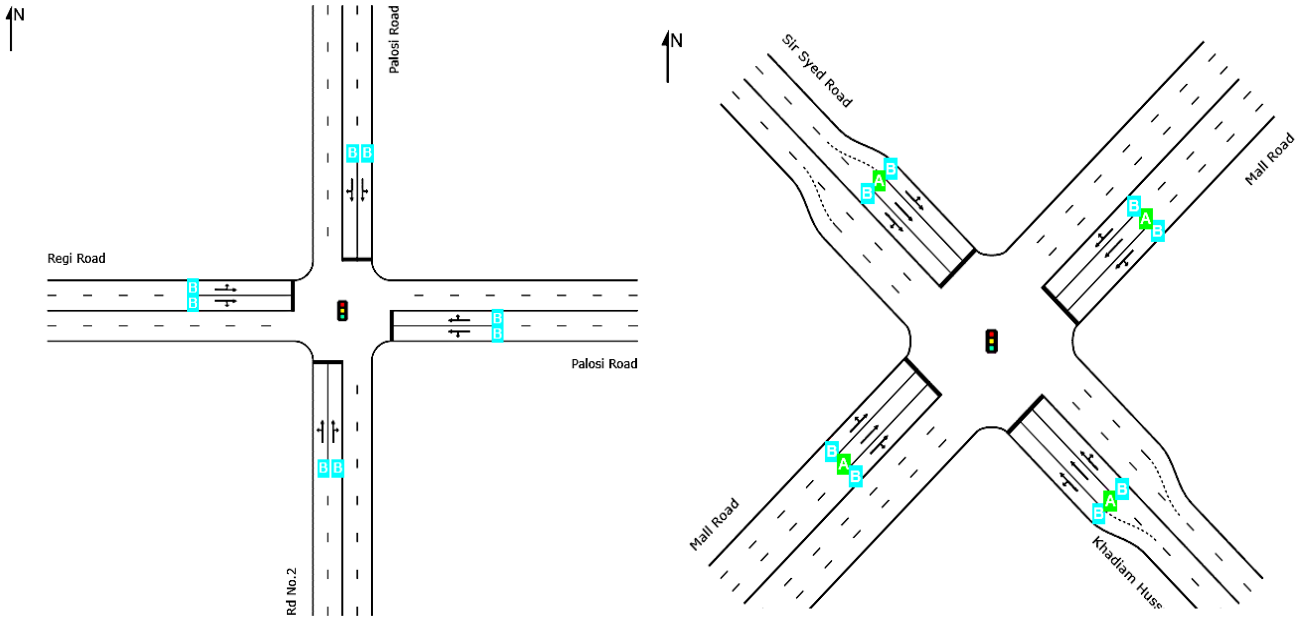


Figure 10. (**a**) Proposed Pre-Timed Signal Timings for FC Chowk. (**b**) Proposed Pre-Timed Signal Timings for Jameel Chowk.



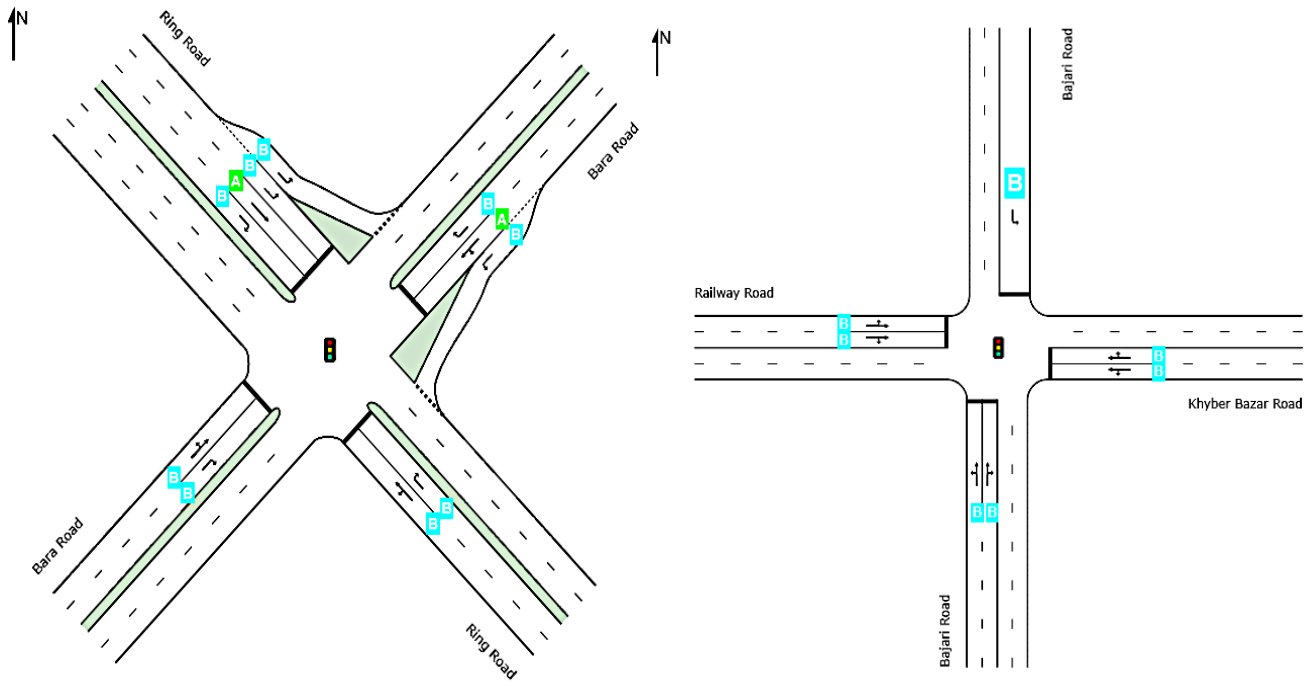
(**a**) (**b**)

Figure 11. (**a**) Proposed Pre-Timed Signal Timings for Kababian Chowk. (**b**) Proposed Pre-Timed Signal Timings for Karkhano Chowk.



(**a**) (**b**)

Figure 12. (**a**) Proposed Pre-Timed Signal Timings for Palosi Chowk. (**b**) Proposed Pre-Timed Signal Timings for Peshawar Services Chowk.



(**a**) (**b**)

Figure 13. (**a**) Proposed Pre-Timed Signal Timings for Pistakhara Chowk. (**b**) Proposed Pre-Timed Signal Timings for Shuba Chowk intersection.

3.4. Proposed Grade Separations

For a long-term improvement plan, grade separation through flyovers or underpasses is recommended to ensure traffic flows without signals or interruptions. The model shown in Figure 14 illustrates the proposed grade separation at Chungi Chowk (GT Road–Warsak Road Intersection).



(**a**) (**b**)

Figure 14. Proposed Grade Separation at Chungi Chowk: (**a**) Macro-level aerial layout of the intersection corridor and (**b**) close-up view of geometric interventions and traffic channelization.

3.5. Proposed Signage Improvements

The existing signage inventory along major roads has been assessed and documented. Many junctions and road sections lack the necessary regulatory, informational, and directional signage. When provided, adequate signage would help reduce congestion by minimizing vehicle stops caused by drivers seeking directions. Table 7 lists the coordinates

and types of signs currently missing to facilitate movement along main roads in Peshawar city, such as Charsadda Road and Dalazakh Road.

Table 7. Proposed signage inventory.

Sign Type	Location	Coordinates	Required Action
Directional Sign (U-Turn)	Charsadda Road	34.052512° N, 71.584532° E	Installation Required
Informational Sign (Bridge)	Charsadda Road	34.036706° N, 71.578632° E	Installation Required
Informational Sign (Market) & Regulatory Sign (Slow Speed)	Dalazak Road	34.043216° N, 71.628812° E	Installation Required
Directional Sign (U-Turn)	Dalazak Road	34.038576° N, 71.619608° E	Installation Required
Directional Sign (U-Turn)	Dalazak Road	34.038574° N, 71.619608° E	Installation Required
Directional Sign (U-Turn)	Dalazak Road	34.058428° N, 71.512605° E	Installation Required

3.6. Improvement of Public Transport Services

Public transport in Peshawar is largely unregulated and poorly planned, with Suzuki wagons and minibuses as the dominant modes, leading to widespread user dissatisfaction. To address these deficiencies, a set of long-term public transport interventions is proposed. By 2042, local public transport services, including Suzuki wagons, will be strategically integrated with designated terminals in future extension areas to serve residential, commercial, and industrial travel demand. Three public transport bus terminals are proposed at the following coordinates: 33°58′6.07″ N, 71°30′39.01″ E; 33°57′51.36″ N, 71°32′28.53″ E; and 34°0′39.773″ N, 71°25′28.064″ E. In parallel, the BRT network is proposed for extension into the expansion areas to improve intra-city connectivity to Peshawar's urban core. This includes extending feeder routes from Pistakhara Chowk southward along Bara Road to serve residential zones R5 and R6 and from the newly proposed Primary Road (P1) toward Karkhano Market to meet the travel needs of residential zones R1 and R2.

Improving the operational effectiveness of BRT terminal services and feeder bus provision is contingent on expanding the feeder network. Further investment in route system design and management is warranted to achieve operational simplicity and ease of infrastructure maintenance across the broader regional public transport system. Facilitating the efficient movement of both vehicles and pedestrians in the immediate vicinity of terminals is a key design consideration. The current and proposed bus terminals are depicted in Figure 15.

Public transport improvements include expanding existing terminals, extending office hours, and improving accessibility. In new district zones, BRT systems, feeder routes, and bus services require enhancements. These improvements will make it easier for people to move around the city and support the city's future growth. Infrastructure such as roads, the BRT, bus terminals, improved intersection signalization, and the proposed new roads all contribute to better future mobility. Figure 16 shows this planned future mobility. These improvements will enable Peshawar to meet its current development needs and align with regional urban mobility policy objectives.

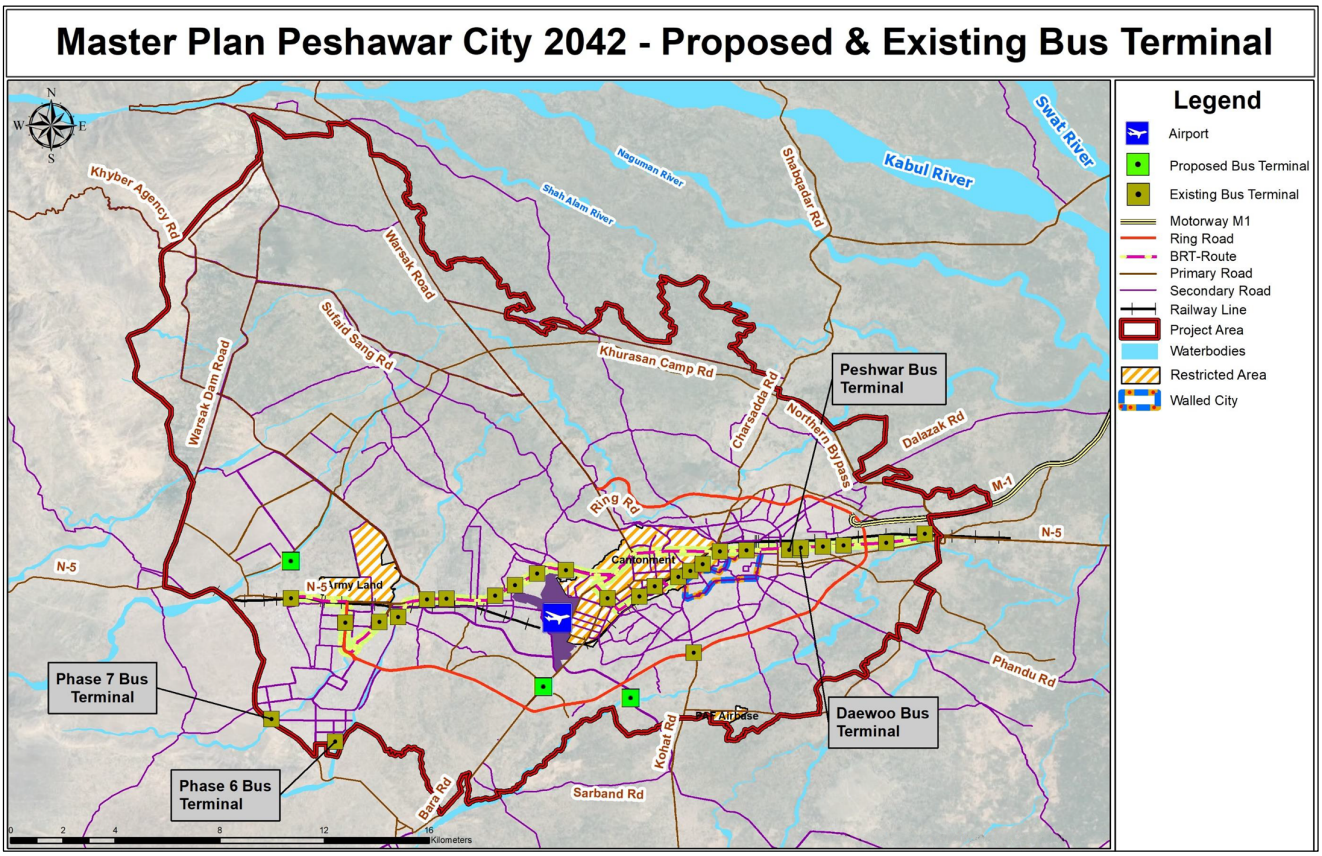


Figure 15. Proposed and Existing Bus Terminals.

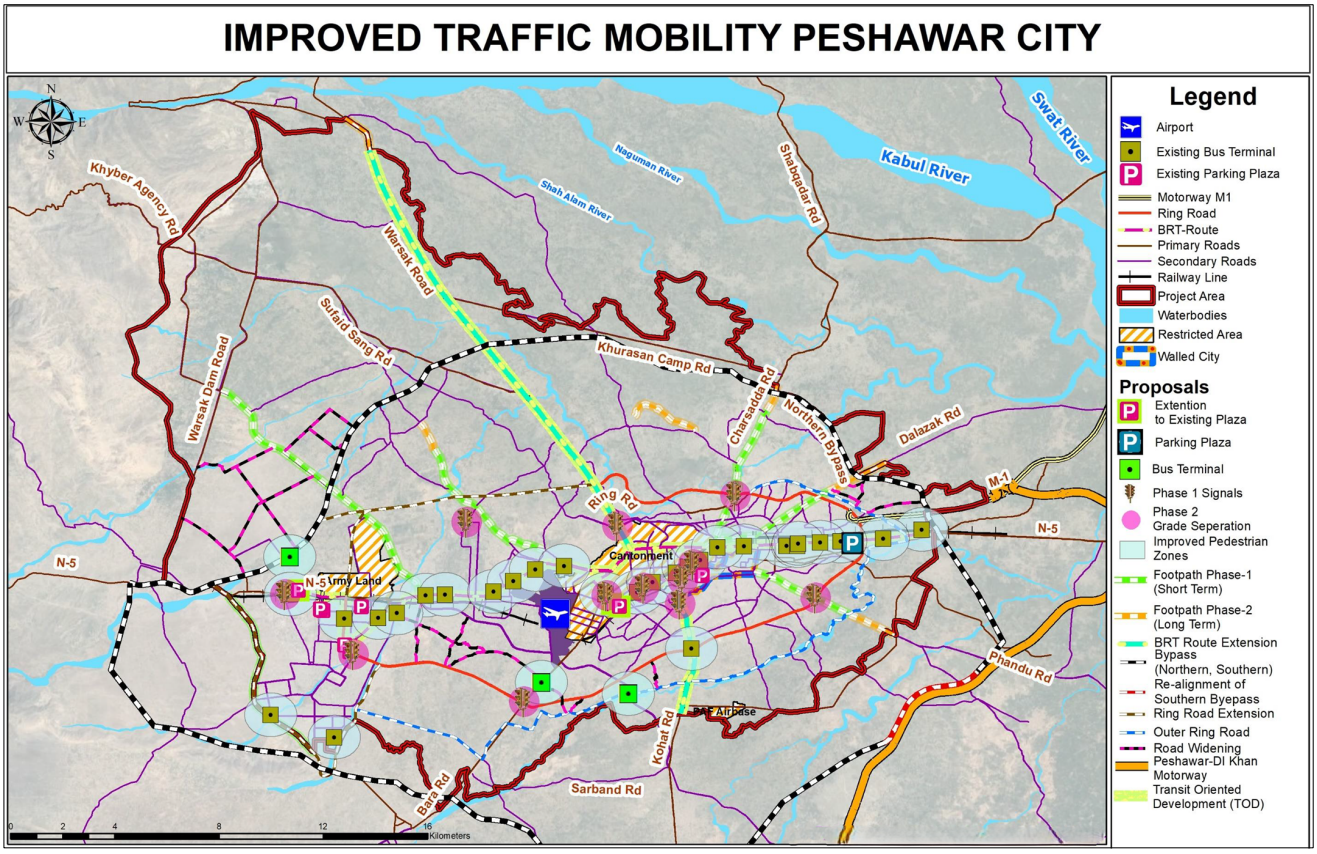


Figure 16. Improved Mobility Conditions in Peshawar for 2042.

3.7. Parking Proposals

The parking issue in Peshawar requires a quick, effective solution. There is a daily demand for commuter parking that current services and management systems cannot meet. Most vehicles are parked randomly and illegally, without supervision, causing traffic jams and conflicts. Future parking needs are projected using a 5% growth rate. The projected on-street and off-street parking requirements are shown in Tables 8 and 9.

Table 8. Future Scenario of On-Street Parking Survey.

Road Segments Name	Cars/ Jeeps/ Pajeros/ Pickup Frequency (N)	Cars/ Jeeps/ Pajeros/Pickup %Age	Motorcycles Frequency (N)	Motorcycles %Age	Others Frequency (N)	Others %Age
Chargano Chowk	1894	48%	1197	30%	841	21%
RMI (Outrage)	4824	48%	3181	32%	2080	21%
Chungi Chowk	889	43%	663	32%	507	25%
Speen Jumat—KTH	1658	39%	1849	43%	772	18%
Ashraf Road	1722	46%	1802	48%	260	7%
HMC Road	767	69%	263	24%	85	8%
Kabali Chowk	1937	51%	1547	41%	313	8%
PIA Training Center	892	25%	2269	64%	377	11%
Malaqo	544	30%	1202	66%	80	4%
Abdara Road	1818	68%	838	31%	19	1%
Toray—Dakkhana	1144	55%	921	44%	11	1%
Toray—Maqsood	761	54%	647	46%	12	1%
Irfan Hospital	1263	51%	748	30%	448	18%
Board Bazar	1823	82%	364	16%	29	1%
BRT Station (HMC)	1427	81%	255	14%	77	4%
Mission Hospital	3778	62%	1865	31%	443	7%
Shaheen Market	2141	85%	265	11%	117	5%
MrCod	1106	50%	1032	46%	96	4%
Stop Hashtnagar	1207	23%	2881	54%	1236	23%
Assembly Hall	1048	89%	45	4%	80	7%

Frequency (N) values represent vehicle counts/projections by vehicle category.

Table 9. Future Scenario of Off-street Parking Survey.

Road/Area Name	Plaza Name	Capacity (No. of Bays)	Vehicle Parked *
Abdara Road	Mobilink Plaza	45	42
	Sapphire Plaza	15	10
	J-K Plaza	15	33
	Sheikh Yaseen Plaza	85	81
	Noor Plaza	120	81
	Hameed Plaza	18	12
	Spinzar Plaza	15	44
	Haj Awal Khan	95	57
	J-B Tower	12	23

Table 9. *Cont.*

Road/Area Name	Plaza Name	Capacity (No. of Bays)	Vehicle Parked *
Abdara Road	Shahid Plaza	115	74
	Khattak Plaza	20	22
	Humayun Plaza	20	27
	Azam Tower	35	45
	Malak Plaza	40	22
Karkhano City	Kabal Plaza	36	61
	Taj Market	100	129
	Malik Taj Market	30	42
	Awami Market	35	65
	Khyber Market	45	59
	Shanwari Market	80	94
	S.S Plaza	33	79
	Royal Plaza	100	88
	United Market	65	113
	Shaheen Market	100	94
	Pirano Market	200	161
Khyber Bazar—Dabgari Garden	G.B. Plaza	70	421
	Ameen Market	50	89
	Pak Medi Center Plaza	200	266
	Arshad Cinema Hall	20	15
	Khyber Medical Complex	25	53
	Mehmood Medical Complex	40	94
	Al-Ibrahim Hospital	20	35
	Sarjah Tower	10	18
	Abaseen Hospital	30	61
	CMC Hospital	50	95
	Habib Plaza	15	30
	Al-Shifa Center	35	71
	Kainat Tower	30	59
	Sarhad Hotel	70	35
	Akum Hotel	10	18
	Syed's Parking	35	61
Saddar	Sasta Bazar Parking	80	134
	Shafi Market Parking	100	231
	Saddar Car Parking	300	360
	Time Center Parking	60	99
	Babar Market Bike Parking	65	104
	Malik Shakir Car Parking	200	364
	Royal Plaza	50	83
	United Car Parking	30	45
	United Bike Parking	100	87

Table 9. *Cont.*

Road/Area Name	Plaza Name	Capacity (No. of Bays)	Vehicle Parked *
Saddar	Apha Tower Car Parking	40	83
	Apha Tower Bike Parking	40	68
	Private Car Parking	60	74
	Private Bike Parking	50	42

* Vehicle Parked is an average value of full-day vehicle parking.

If no action is taken, future demand for on-street parking could significantly impact traffic on Peshawar's roads. Therefore, dedicated parking lanes should be provided along main roads. Short-term on-street parking should be introduced on congested streets, with strict enforcement during peak hours. Long-term on-street parking should be avoided, and vehicles should be directed to park off-street in designated parking lots or plazas.

3.8. Proposed and Existing Parking Plazas

As shown in the preceding analysis, projected parking demand significantly exceeds the capacity of existing facilities. To meet future demand, dedicated parking areas are proposed along major commercial corridors, with additional capacity to be created by expanding existing parking facilities, including the construction of basement levels. Priority locations for these upgrades include Malik Shakir Car Parking and Shafi Market Parking in Saddar, as well as G.B. Plaza along the primary market. Furthermore, to minimize parking-related conflicts within the proposed commercial zones, a dedicated parking plaza is planned at coordinates 34°0′18.80″ N, 71°37′11.26″ E. The spatial distribution of existing and proposed parking plazas is shown in Figure 17.

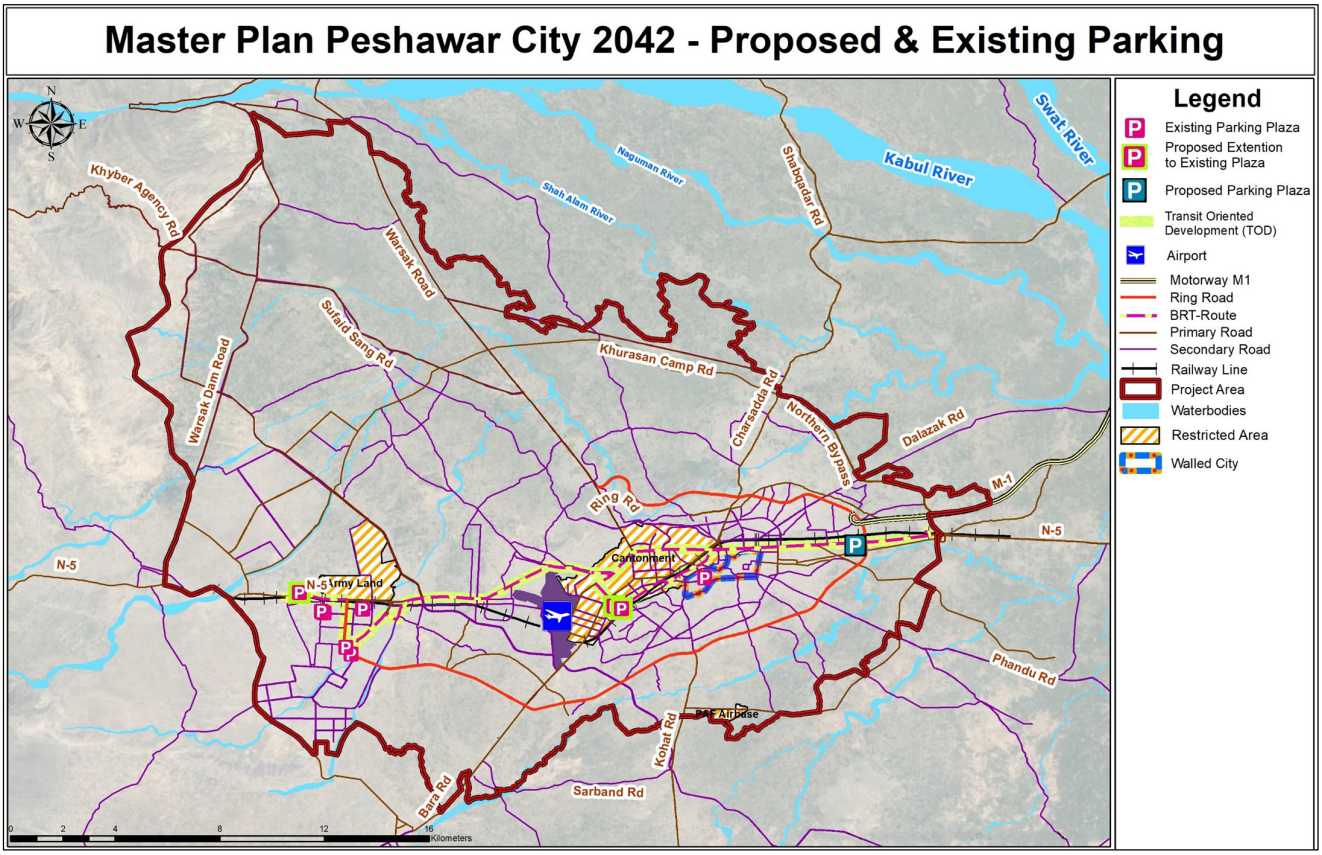


Figure 17. Proposed and Existing Parking Plazas.

4. Discussion

Our analysis of Peshawar's traffic shows that major corridors experience severe congestion because vehicle growth has far outpaced road expansion. This finding aligns with Ali et al. [2], who reported a 126% increase in registered vehicles (excluding public transport) from 1998 to 2009, while primary road length grew by only about 1%. The literature stresses that bolstering public transit is essential to relieving congestion. Nguyen-Phuoc et al. [21] note that improving transit can reduce traffic by shifting travel demand and advocate the use of people-centric congestion measures [3]. Abdulrazzaq et al. [23] similarly found that reducing transit travel times and improving reliability encourage commuters to shift from cars to buses [4]. Our recommendations echo these insights: we identify poor road geometry and limited transit options as root causes, and we propose adding lanes, bypasses, and high-capacity BRT feeder routes to better match demand. This convergence between user perceptions and engineering data is summarized in Table 10.

Table 10. Alignment between user-reported BRT concerns and measured traffic performance.

User-Reported Concern	Related Technical Parameter	Corridor (s)	Measured Value	LOS
Overcrowding	Volume-to-capacity (V/C) ratio	Kohat Road, Charsadda Road	V/C > 1.0	F
Excessive trip duration	Peak-hour V/C on feeder routes	Palosi Road, Chamkani Road	V/C: 0.74–1.79	C–F
Limited access/coverage	Missing feeder lanes	Nasir Bagh Road, Bara Road	No dedicated feeder infrastructure	D–E
Safety concerns	Missing pedestrian infrastructure	Jahaz Chowk, Chungi Chowk	No footpaths/unsignalized	—

Note: Statistical correlation is not reported because survey data were obtained in an aggregated, anonymized form without spatial linkage to specific road segments. This table demonstrates qualitative convergence between user perceptions and engineering measurements for diagnostic planning purposes.

While this study acknowledges that road widening may increase traffic and reduce long-term congestion relief, quantitative evidence in the literature supports this concern. Hymel et al. [50] estimated a state-level induced travel elasticity of about 0.16, while Noland [51] reported elasticities of 0.3–0.6 in the short run and 0.7–1.0 in the long run, confirming that capacity expansions often generate new traffic demand over time. To mitigate these induced-demand effects, the proposed auxiliary lanes are evaluated strictly as part of an integrated multimodal strategy that includes BRT expansion, pedestrian improvements, parking management, and demand-management measures, rather than as a stand-alone solution [52,53].

To ensure the reliability of this assessment, we conducted sensitivity analyses on the vehicle growth assumption. Sensitivity analyses demonstrate that the 5% annual growth rate assumption serves as a reasonable planning-level stress test. However, lower growth (3%) still leads to persistent congestion on critical corridors, while higher growth (7%) exacerbates capacity constraints, indicating that the road network is highly sensitive to variations in vehicle growth. These findings reinforce the robustness of the proposed interventions and underscore the necessity for flexible, adaptive strategies that remain effective under a range of plausible future traffic conditions. Incorporating multi-scenario analyses strengthens the reliability of our planning recommendations and supports decision-making under uncertainty.

Compared with large metropolitan areas such as Manchester and Shenzhen, where congestion mitigation increasingly depends on integrated public transport, demand man-

agement, and coordinated traffic control, Peshawar exhibits a similar imbalance between travel demand and network capacity but at a less mature stage of infrastructure development [15,54,55]. Findings from other metropolitan contexts, including the Dammam metropolitan area and Polish smart cities, likewise show that corridor congestion intensifies when intersection delay, parking pressure, and insufficient coordination between mobility modes are not addressed through a combination of geometric upgrades and intelligent transport systems [11,32,56,57]. However, Peshawar differs from these cities in the severity of its basic network deficits, particularly the absence of footpaths, weak feeder-route connectivity to BRT, and limited continuity of road and pedestrian facilities. This suggests that, unlike more mature metropolitan systems where optimization and smart control can be prioritized, Peshawar requires a staged strategy that first completes essential network elements and then builds toward integrated, technology-enabled traffic management. In this sense, the proposed framework is transferable to other rapidly urbanizing metropolises, but its implementation sequence must be adapted to local institutional capacity, infrastructure maturity, and travel behavior [58–60].

Regarding public transportation and the BRT system, our surveys indicate widespread user dissatisfaction, mainly due to limited coverage and unreliable service. Dastagir et al. [29–34] observed similar problems on the University Road BRT, noting high dwell times and unscheduled stops that degrade service quality. They concluded that a dedicated BRT lane is needed [5]. This supports our proposal to integrate feeder routes with segregated BRT corridors. Likewise, Farooq et al. [38] reported that adding BRT stations (thereby improving accessibility) significantly enhances perceived travel time and comfort. Qazi et al. [39] identified cultural and social barriers to BRT acceptance, whereas our findings indicate that operational constraints (coverage gaps and interference from private vehicles) are the dominant issues. These differences likely stem from methodology: Farooq et al. used a multi-criteria survey, whereas we conducted field traffic analyses. Nonetheless, both perspectives highlight coverage and service quality as key to improving BRT usage, thereby justifying our integrated transit-improvement measures.

The study also identified significant infrastructure deficiencies. Many intersections are poorly designed, and sidewalks are absent, as reported by Pervez et al. [36], who emphasize that inadequate road infrastructure in Pakistan leads to safety problems. Ahmad [37] similarly links Peshawar's uncontrolled urban sprawl and high-rise development along main arteries to worsening congestion and pollution. In response, we recommend upgrades such as signalized junctions, grade separations, ring roads, and new arterial links. These interventions align with the literature's recommendations to add service roads, extra lanes, and pedestrian pathways to improve flow and accessibility. Urban planning research [21–24] also emphasizes pedestrian- and bicycle-friendly infrastructure to reduce vehicle dependence; our proposed footpaths and bicycle lanes directly align with this agenda.

Overall, our findings broadly confirm the consensus that Peshawar's congestion stems from infrastructure gaps and limited transit. Similar observations on BRT coverage issues and the need for better feeder service appear in Ali et al. [2] and other studies. We extend prior work by quantifying impacts on service levels and demonstrating how specific geometric improvements can alleviate bottlenecks. Where we diverge from some past studies, it largely reflects scope: for example, Farooq et al. [38] prioritized mode-choice strategies, whereas our analysis focuses on network capacity enhancements. Likewise, Qazi et al. [39] emphasized socio-cultural factors, while our data highlight engineering constraints. These differences underscore the multifaceted nature of urban mobility challenges. By integrating both views, we show that the combined approach we propose, simultaneously

upgrading infrastructure and expanding reliable transit service, is necessary for effective congestion relief.

5. Developed Conceptual Framework for Urban Mobility Improvement

Drawing on the study's empirical evidence, this paper develops an integrated conceptual framework to link traffic conditions, public transport performance, user behaviour, and policy responses to improve urban mobility in Peshawar. The framework synthesises traffic volume and LOS analysis, user satisfaction surveys, and field observations into four interacting dimensions: travel demand and behaviour; transport supply and infrastructure capacity; system performance; and policy interventions. Findings reveal a strong reliance on private and informal transport amid capacity-constrained roads, limited BRT coverage, and inefficient intersections, leading to poor operational performance during peak periods. The framework emphasises coordinated interventions, such as network upgrades, feeder-route integration, intersection optimisation, non-motorised transport improvements, and intelligent traffic management, while highlighting feedback effects in which improved service quality can shift mode choice and relieve congestion. Overall, it offers a concise, evidence-based planning model aligned with sustainable urban mobility principles and applicable to other rapidly growing cities. The framework provides structured guidance for urban transport planning, enabling policymakers to select, sequence, and prioritise interventions based on identified deficiencies, projected traffic conditions, and accessibility needs. Although not a formal Multi-Criteria Decision-Making (MCDM) framework, it integrates operational performance, feasibility, implementation timing, and preliminary equity considerations into a multi-dimensional decision-support tool. This ensures interventions are actionable, adaptable, and responsive to underserved populations, forming the basis for future detailed analyses, including cost–benefit evaluation, formal MCDM, and socio-spatial equity assessment.

6. Conclusions

This study provides an objective, evidence-based diagnosis of traffic congestion in Peshawar, grounding its analysis in quantifiable data rather than generic projections or policy prescriptions. By integrating traffic volume and level-of-service (LOS) analyses on 13 major corridors, user satisfaction surveys (n = 1244), and field observations at critical intersections, the research yields three core empirical insights.

First, congestion is both quantifiable and spatially concentrated. While many roads currently operate at LOS A–B, several key arterials-Kohat Road, Palosi Road, Charsadda Road, and Chamkani Road-already exhibit LOS E–F during peak periods, with volume-to-capacity (V/C) ratios exceeding 1.0. Under a conservative 5% annual growth scenario, derived from historical vehicle registration trends, nine of the 13 corridors will degrade to LOS F by 2042 without intervention. This is not a speculative forecast but a quantified infrastructure deficit based on established standards in the Highway Capacity Manual. Furthermore, sensitivity analyses of alternative vehicle growth rates (3% and 7%) indicate that, although infrastructure requirements vary, the proposed interventions, auxiliary lanes, BRT feeder expansions, signalized intersections, and parking management remain broadly effective across scenarios, confirming the robustness and adaptability of the planning framework.

Second, the BRT system, though a positive step, has failed to meaningfully reduce network-wide congestion due to four specific, measurable gaps documented in the data: (i) incomplete spatial coverage-major growth areas and residential zones (R1, R2, R5, R6) lack BRT access, confirmed by GIS network analysis; (ii) missing feeder integration-no dedicated feeder lanes exist on Nasir Bagh Road or Bara Road, forcing reliance on

informal minibuses and wagons; (iii) overcrowding and excessive trip times reported by 44% of survey respondents, directly correlated with V/C ratios exceeding 1.0 on feeder routes such as Palosi Road (LOS C–F); and (iv) continued parking spillover and unsignalized intersections (e.g., Jahaz Chowk, Chungi Chowk) that degrade BRT running speeds. Thus, the evidence indicates that the BRT's congestion-relief potential has been suppressed not by the technology itself, but by measurable gaps in system design and complementary infrastructure.

Third, based directly on these empirical findings, the study proposes a results-driven conceptual framework that links travel demand, infrastructure capacity, system performance, and coordinated interventions. Unlike a political proposal, this framework derives each recommended action from a specific diagnosed deficiency: road widening on corridors with projected V/C exceeding 1.0 (Chamkani, Kohat, Phandu); signalization and grade separation at the 12 junctions where field observations confirmed recurrent queue spillback; expansion of BRT feeder routes into zones identified as underserved in the spatial coverage analysis; and off-street parking plazas at documented overspill locations.

In conclusion, this research delivers a quantified, spatially explicit explanation of why congestion remains severe despite BRT investment. The evidence points to a fundamental mismatch between BRT's corridor-level capacity and citywide travel demand, compounded by the absence of feeder integration, intersection bottlenecks, and uncontrolled parking. The proposed interventions are direct translations of measured deficiencies, not generic best practices or political preferences. These findings provide Peshawar's decision-makers with an objective, data-driven foundation for transport planning—one that is empirically testable and openly available for scrutiny.

7. Future Research Directions

Future research can build on this study's findings by broadening the analytical scope and methodological depth of urban mobility assessments in rapidly urbanizing cities. It is important to clarify that volume-to-capacity (V/C) and level-of-service (LOS) analysis constitutes a first-stage strategic assessment rather than a substitute for detailed microsimulation; accordingly, microsimulation-based validation is a critical direction for future research. Before-and-after intersection performance evaluations using simulation software, including delay estimation, queue-length analysis, and capacity modeling, should also be conducted in future work to validate operational improvements. Given this study's cross-sectional design and Peshawar's context-specific conditions, future research should employ longitudinal designs and multi-city comparisons to capture temporal dynamics and improve transferability. Acknowledging the absence of land-use–transport interaction modeling as a limitation of the current planning-level diagnostic assessment, future research should integrate full LUTI models to evaluate the bidirectional feedback between land-use change, urban expansion, and transport demand. One promising direction is to integrate advanced traffic simulation models with real-time data sources, such as GPS-based floating-car data and intelligent transportation systems (ITSs), to capture dynamic traffic conditions and evaluate the effectiveness of adaptive traffic management strategies. Longitudinal studies are also needed to assess the long-term performance of Bus Rapid Transit (BRT) systems, particularly the impacts of feeder route expansion, service reliability improvements, and fare integration on mode choice and congestion reduction. Additionally, future work should explore the interaction between land-use development and transport demand by incorporating land-use–transport interaction models to better understand how urban form influences travel behavior. Comparative studies across multiple cities with similar socio-economic and infrastructural characteristics would further enhance the generalizability of findings and support the development of transferable policy

frameworks. Finally, scenario-based policy analysis that evaluates the environmental, social, and economic impacts of alternative transport strategies, further strengthened by integrating multi-criteria decision analysis, could provide decision-makers with robust evidence to guide sustainable urban mobility planning.

Future research should incorporate comprehensive cost–benefit analyses, formal multi-criteria decision-making frameworks, and quantitative induced-demand modeling using established elasticity coefficients. Microsimulation and scenario-based evaluations can be extended to refine implementation phasing, assess the interaction between capacity expansions and travel behavior, and validate operational performance under varying growth conditions. Detailed socio-spatial equity analyses are also recommended to evaluate the impacts of road widening, BRT expansions, and other infrastructure projects on marginalized versus affluent communities. These efforts will enhance the proposed framework's inclusivity, policy relevance, and decision-making utility.

Future research should also prioritize environmental modeling and life-cycle assessment of integrated transport strategies that emphasize public transport, feeder integration, non-motorized modes, parking control, and demand management, rather than road construction.

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