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Sustainable Urban Mobility: Corridor Optimization to Promote Modal Choice, Reduce Congestion, and Enhance Livability in Hyderabad, Pakistan

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Abstract: This research aims to optimize corridors in Hyderabad, Sindh, to promote modal choice, reduce congestion, and enhance livability. This study focused on developing and evaluating multimodal wide corridor routing methods, analyzing the modal choice behavior of travelers using a generalized cost model and a mixed constant and separate user balance model, and implementing and assessing innovative road space management strategies. The data were collected using GIS (Geographical Information System) to compare the performance and impacts of the proposed methods and techniques with existing ones, such as shortest path, minimum interference, maximum capacity, and lane addition, using various performance measures, such as travel time, modal share, congestion level, environmental impact, safety, and equity. This research aims to optimize corridors in Hyderabad, Sindh, to encourage various transportation options, such as the BRT system and Peoples Bus Service, to reduce congestion and enhance livability by developing and accessing different methods and strategies. This study analyzed available data through a geospatial perspective to optimize corridors in Hyderabad, Sindh, focusing on multimodal routing methods, modal choice behavior, and innovative road space management strategies to enhance urban livability rather than relying on simulation software or field-collected data.

Keywords: Peoples Bus Service (PBS); sustainable urban mobility; bus rapid transit (BRT); health and well-being; urban road network optimization; environmental sustainability; livability; multimodal corridor planning; Hyderabad; Sindh; Pakistan

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1. Introduction

Hyderabad, a city in Sindh, Pakistan, is changing rapidly with more people moving in, but this growth brings challenges. Issues like traffic jams, dirty air, and difficulty getting around are becoming more common. The main problem seems to be that more and more people are relying on their vehicles, taking up a lot of space on the roads and creating a lot of pollution [1]. This calls for a more innovative approach, where we optimize the city's main routes for sustainable travel choices. That means using modes of transportation that are environmentally friendly, accessible to everyone, economically affordable, and safe.

Choosing sustainable ways of getting around can solve many of these problems. It means encouraging folks to use public transport or eco-friendly options like cycling and walking. Public transportation is not only efficient but also affordable and easy to access. On the other hand, walking or cycling promotes physical activity, socializing, and community bonding. To make this happen, cities like Hyderabad need to develop policies and plans that support these types of transportation [2].

Specific areas in Hyderabad, like the N-5 National Highway and Auto Bhan Road, Qasimabad, as well as the city center, serve significant traffic volumes, especially during rush hours. This mess with people's travel plans affects how productive the city is and harms the environment. The large number of vehicles on these routes also makes the air dirty. Hyderabad has been flagged for having the highest levels of harmful particles (PM2.5) in the air among major cities in Pakistan. It's more than six times higher than what the World Health Organization says is safe [3].

This study is grounded on the following hypotheses: It assumes that the enhancement of multimodal corridors will lead to a drastic cut in the time spent on the roads and the congestion levels in the city (H1). Implementing the BRT system means there will be a change in the mode of transport from single-occupancy vehicles to public transport, enhancing the quality of air (H2). Moreover, the use of space in roads can be rerouted by, for instance, having dedicated bus lanes. It is expected that the accessibility of public transport will increase the effectiveness and reliability of public transport services (H3). Finally, the theory suggests that the growth of sustainable transport programs will enhance community welfare through improved accessibility and reduce adverse environmental effects (H4).

Thus, answers to these hypotheses contribute to the formulated objectives—providing urban planners and policymakers with recommendations for further sustainable urban development. This strategy correlates with the global agenda of making Hyderabad a more habitable and sustainable city and providing a framework for other struggling cities.

This work claims to address the need for a city-specific solution to the problem of integrated urban mobility for a city in a developing country such as Hyderabad, Sindh. In contrast to prior studies often based on developed environments, this work presents multimodal corridor optimization combined with geographic information system analysis as a potent method for solving particular localized socio-economic and infrastructural issues. It mainly focuses on the innovation of bus rapid transit (BRT) systems and road space management alternatives while assessing social and environmental rebukes. Employing quantitative and qualitative data on commuter behavior with sustainable mobility solutions, this study presents a model that can easily be implemented in other developing cities to handle mobility issues by enriching theoretical and empirical contributions to the scholarly literature. This study provides valuable insights for urban planners and policymakers to support strategic decisions in city development and transportation management [4].

The proposed research aims to optimize corridors in Hyderabad, Sindh, to promote modal choice, reduce congestion, and enhance livability. This study will focus on developing and evaluating multimodal wide corridor routing methods, analyzing modal choice behavior using a generalized cost model and a mixed constant and separate user balance model, and implementing innovative road space management strategies. By comparing the performance of these methods with existing ones, this study aims to identify the most effective strategy for improving corridor performance and enhancing urban livability. This research will contribute to the existing body of knowledge by addressing the lack of comprehensive corridor optimization studies in Hyderabad, the limited application of advanced modeling techniques, the insufficient consideration of socio-economic factors, the limited evaluation of innovative space management strategies, and the lack of focus on equity and accessibility.

2. Literature Review

The research proposal for corridor optimization in Hyderabad, Sindh, is a noble idea that is friendly to the current society. It would help solve city problems today, such as traffic jams, air pollution, and poor living standards. To enhance the analysis and sum up, it is critical to provide corresponding comparative cases and information on the peculiarities of the innovations undertaken in cities with similar socio-economic and spatial conditions.

This study is grounded in established theories of transportation planning, geospatial analysis, and sustainable urban mobility. It draws upon the principles of sustainable urban mobility frameworks, which advocate for integrating multimodal transport systems to balance accessibility, environmental impact, and social equity [5]. This research applies multi-criteria decision making (MCDM) methodologies to optimize transport corridors by evaluating competing objectives such as travel time, congestion, and environmental impact [6]. To analyze commuter preferences, this study utilizes discrete choice models rooted in the utility maximization theory, which posits that travelers select modes based on perceived costs, benefits, and constraints [7]. Furthermore, the Theory of Planned Behavior (TPB) is employed to understand modal shift behavior, emphasizing the role of attitudes, perceived ease of use, and social norms in influencing transport decisions [8]. Geospatial analysis is underpinned by spatial interaction models, which facilitate understanding traffic flow dynamics and spatial relationships between transport nodes [9]. The methodology also incorporates environmental impact models to evaluate emissions reductions and air quality improvements, aligning with global goals for sustainable urban development [10]. By integrating these theoretical frameworks, this study extends the discourse on urban mobility, demonstrating how GIS-based analysis and multimodal planning can address mobility challenges in developing cities like Hyderabad, Sindh. The findings contribute to advancing theories of transportation equity and sustainability by providing empirical insights into applying these frameworks in resource-constrained urban contexts.

2.1. Comparative Case Studies

Many rising cities in Asia and Africa, such as Delhi, Mumbai, and Bengaluru in India; Cairo in Egypt; and Lagos in Nigeria, are similar to Hyderabad in terms of ever-growing traffic congestion and poor and crowded stool transportation facilities. These cities have implemented various strategies to optimize their corridor networks:

Bus Rapid Transit (BRT) Systems: Some cities incorporating BRT systems include Delhi and Bengaluru, which have achieved draconian measures in improving public transport efficiency and cutting down traffic congestion [9]. Other important lessons are priority lanes, bus priority measures, and integrated ticketing.

Metro Rail Systems: Places such as Delhi and Mumbai have embarked on expanding metro rail solutions as a means of mass transport. These systems have greatly helped reduce traffic and improve air clarity [11].

Non-Motorized Transport (NMT) Infrastructure: Some cities like Copenhagen and Amsterdam have prioritized building NMT facilities like cycling tracks and pedestrians to promote the NMT [12].

Intelligent Transportation Systems (ITS): Singapore and Seoul have recently integrated modern ITS technologies, including traffic signal control systems, real-time traffic information, and dynamic route guidance ITS technologies, which enhance smooth traffic flow and minimize congestion [5].

Road Pricing and Congestion Charges: Favorable changes in the accessibility of public transport have generated urban reforms like road pricing and congestion charges in cities such as London and Singapore [13].

Land Use Planning and Urban Design: Other cities, such as Portland in Oregon, United States, and Curitiba, Brazil, have embraced alternative urban development and planning mechanisms to produce integrated human settlements and minuscule car dependence [14].

2.2. Innovative Corridor Optimization Strategies

In addition to the strategies mentioned above, the following innovative approaches can be considered for Hyderabad:

Integrated Corridor Management (ICM): ICM is a comprehensive approach to managing transport corridors without regard to the mode of transport. Recent research has found that ICM can enhance corridors' effectiveness and decrease congestion [15].

Multimodal Transit Systems: Intermodal combining various modes of transport can enhance accessibility and cut time and overall travel satisfaction. The trends and developments of integrated transit systems have been underscored in recent literature, particularly the crucial role that transfers and unified, progressive ticketing strategies play in the efficiency of multiform transit systems [5].

Urban Livability Metrics: Some of the factors in an urban setting that can be employed to evaluate corridor optimization strategies include the ability of the area to support walking, cycling, and access to public transport. Current research and evidence have suggested several positive impacts of urban livability, such as enhancing health, reducing stress, and enabling social contact [10].

Learning from the experiences and challenges other cities face and incorporating new strategies, such as the ICM and the multimodal transit system, and increasing city livability, Hyderabad can effectively enhance the transportation system, bring down congestion, and improve citizens' quality of life. Sustainable mobility in urban areas can, therefore, require both technological solutions and policy and other interventions, as well as involving all the stakeholders in the community.

An improved public transportation system can help alleviate congestion and other transport-related problems by encouraging people to choose public transport over private vehicles [16]. Moreover, it can provide them with a reliable, affordable, and convenient mode of transportation to enhance residents' overall quality of life [17]. Optimizing corridors to promote modal choice, reduce congestion, and improve livability can be achieved through various strategies. One approach is to develop wide-corridor routing multimodal methods that consider the width and arrangement of different modes within the same right-of-way [18]. Another strategy is implementing innovative road space management strategies, such as narrowing lanes and shoulder widths, to add capacity and improve the utilization of existing roadway facilities [6].

Furthermore, studying modal choice behavior in traffic corridors can guide travelers to choose the most economical and beneficial options and help traffic operators make appropriate policies to enhance the share of public transit and alleviate traffic congestion mode for urban trips [7]. The selection of transit modes within developing corridors is crucial. It should consider factors such as capital and operating costs, level of service, transit market development energy use, and environmental impacts [19]. Overall, there is a need for research that integrates these various aspects to optimize corridors for modal choice, congestion reduction, and enhanced livability.

Optimizing corridors in Hyderabad, Sindh, is crucial for promoting modal choice, reducing congestion, and enhancing livability. By studying modal choice behavior, traffic operators can develop proper policies and alleviate traffic congestion and public transit [18,20]. Integrated corridor management (ICM) solutions can effectively promote modal shift by maximizing the use of existing infrastructure [21,22]. Continuous and discrete user equilibrium models can be used on a linear travel corridor to investigate commuters' multimodal and mixed-choice behavior [23,24]. Multimodal wide-corridor routing methods can consider the arrangement of modes within a corridor and outperform existing methods in finding optimal corridors [18].

This research aims to optimize corridors in Hyderabad, Sindh, to promote modal choice, reduce congestion, and enhance livability. This study will focus on the following aspects:

- The development and evaluation of multimodal routing methods for wide corridors that consider the width and planning of modes within a corridor and outperform existing methods in finding optimal corridors.
- The analysis of modal choice behavior of travelers using a generalized cost model and a mixed incessant and detached user equilibrium perfect, as well as the guidance of travelers to choose the most economical and advantageous mode for urban trips.
- The implementation and innovative road valuation of space management policies, such as narrowing lanes and shoulder widths, and analyzing their impact on the traffic flow and congestion in Hyderabad, Sindh.

Research should focus on several key areas to optimize corridors, promote modal choice, reduce congestion, and enhance livability in Hyderabad. Firstly, understanding the factors influencing mode choice behavior in the city, such as age, income, travel time, and travel cost, is crucial.

This research used various methods and techniques to achieve the objectives, such as mathematical programming, optimization, simulation, survey, discrete choice analysis, traffic flow theory, microsimulation, cost–benefit analysis, and multi-criteria analysis. This research used realistic data and parameters from Hyderabad, Sindh, such as traffic demand, network topology, signal timing, and driver behavior, to calibrate and validate the models and strategies.

3. Research Methods

This research involves the ArcGIS 2.8 software, a critical tool for spatial analysis and geographic data visualization. This research used various performance measures, such as travel time, modal share, congestion level, and environmental impact, to evaluate the effectiveness of the methods. Data were collected using various techniques to achieve these objectives, as shown in Figure 1. This step set the foundation for creating route maps integral to optimizing Hyderabad's urban corridors, as shown in Figure 2.

After opening the software, the next step was to add a base map. This base map served as the foundational layer of one's map, providing essential geographic context such as roads, terrain, or satellite imagery. For this study, selecting an appropriate base map was crucial as it allows for a visual reference for analyzing existing corridors and potential improvements in Hyderabad.

Using tools like "Add Data" or "Add XY Data", specific locations of interest are marked on the map. These could represent essential points such as major intersections, public transportation hubs, or high-congestion areas. Identifying these key locations is critical to understanding the urban corridor's spatial relationships and connectivity.

With the critical locations identified, the next step was to create a route using the "Directions" tool, which can generate the most efficient paths between these locations. This step is vital in this research as it helps analyze current route efficiency and explore alternative routes to reduce congestion and enhance mobility.

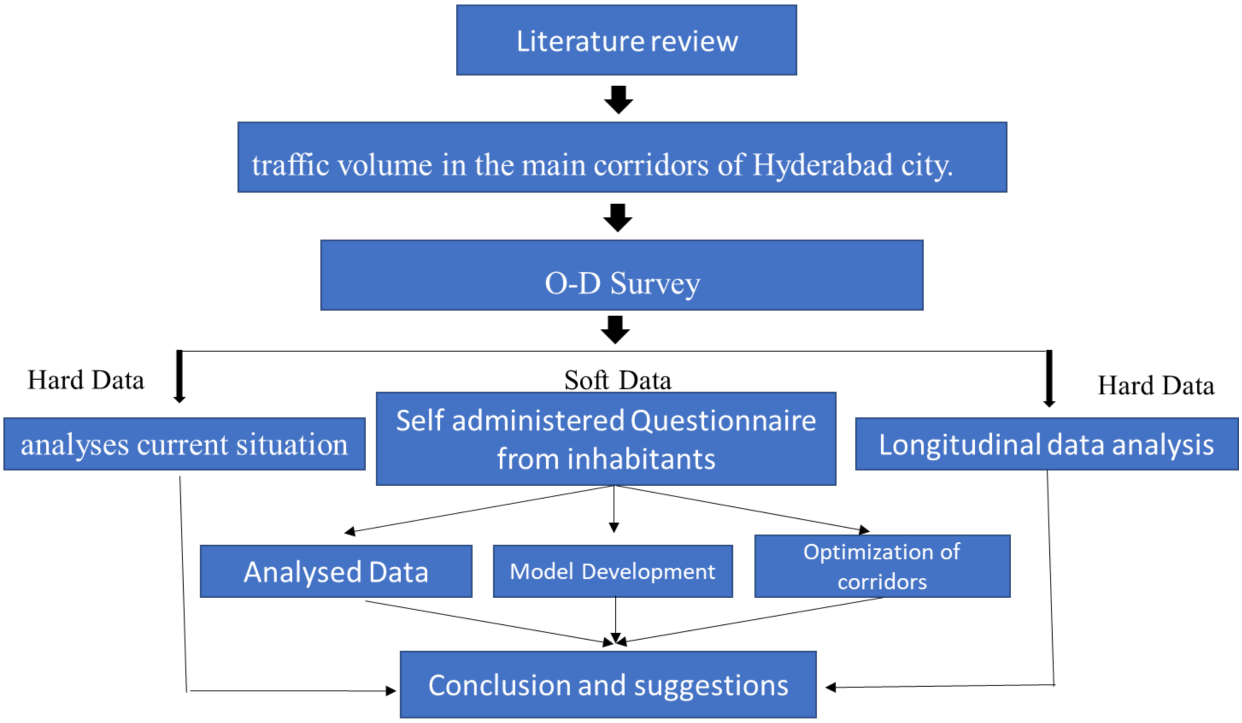

Figure 1. Research methods diagram.

Figure 2. The basic steps in ArcGIS for creating a route map.

After creating a primary route, we proceeded to draw or refine the route manually. This was where adjustments were able to be made based on specific criteria such as minimizing travel time, enhancing accessibility, or prioritizing sustainable transportation modes. Drawing an optimized route is critical to demonstrating potential improvements in the urban corridor network.

Once the route was finalized, customization of its appearance using symbology options enhanced the visual clarity of the map. Different colors, line styles, and symbols can be used to distinguish between various transportation modes, highlight critical sections of the corridor, or denote areas of proposed improvements. This visual distinction supports the presentation of study findings clearly and compellingly.

The final step was to save or share the map. This step ensures that the map can be easily accessed for further analysis, presentation, or publication. In the research context, sharing the maps with stakeholders, such as city planners or transportation officials, could be instrumental in advocating for the proposed corridor optimizations.

3.1. Datasets for GIS Mapping

Data for the GIS mapping were collected through linkages to other authorities dealing with transport systems in the region, field collection of traffic flow, and records on satellite imagery for mapping and analysis. Particular GIS layers consisted of roads, public means of transport, traffic congestion areas, and land utilization. These datasets were overlaid and analyzed to determine the essential corridors and key improvement areas.

3.2. Measurement of Congestion Levels

The extent of congestion was determined from traffic count data and real-time GPS tracking of traffic flow. Vehicle speeds, time taken on the roads, and volume-to-capacity ratios were used to estimate congestion levels. Further, actual traffic records were employed to recognize time frames of traffic congestion and their influence on city transport systems.

3.3. Travel Time and Environmental Impact Assessment

Travel time estimation was based on travel time analysis by GIS-based routing employing actual travel time along the corridors. Emission factors and concentrations of vehicles were obtained from survey data of the composition of a vehicle fleet and traffic intensity for environmental impacts like air quality and greenhouse gas emission. This also involved an assessment of the likely reductions in PM2.5 and CO_2 emissions due to changes in modal choice.

3.4. Optimization Criteria

These routes were determined after considering several factors to obtain a near-perfect score between cost, environmental impact, and fairness. The primary criteria included:

- Travel Time: Reducing travel time along corridors for all the modes.
- Congestion Reduction: Promoting routes that help relieve congestion of other roads.
- Environmental Impact: Identify corridors likely affected by mode changes when implementing emission reduction measures.
- Accessibility: Promoting accessibility for the public in their quest for better transport, perhaps to transit nodes or major cities.
- Safety and Equity: Improving physical protection for users on foot or bikes and justice in representing different subpopulations.

3.5. Algorithms and Techniques Used

The optimization process utilized a combination of GIS-based routing tools and mathematical optimization algorithms:

- Travel Time and Distance: Shortest path algorithms such as Dijkstra and Astar were employed to find the shortest path.
- Multimodal Network Analysis: Using GIS Stream tools, the accessibility of multiform transit, pedestrian, and cycling information was also assessed.

- Mixed-User Equilibrium Models: While these models aimed at helping understand user behaviors inside the optimized corridors, they focused on how different user types, such as public transport users and drivers, engage with one another.
- Environmental Impact Models: The assessment of the ecological impacts of different scenarios of routes was based on models of emissions estimation.

3.6. Trade-Off Considerations

Other factors, such as travel time, environmental impacts, and objectives, were made clear during optimization since they are not mutually exclusive. For example:

- The routes characterized by minimal travel time were compared with those described by maximum CO_2 reduction benefits.
- Multi-criteria decision analysis (MCDA) was used to understand how stakeholders and policymakers perceive these factors and rate their importance.
- A univariate sensitivity analysis was conducted to determine a single criterion effect on the overall decision-making process to make practical and realistic recommendations.

This Arc GIS workflow enables the precise mapping and analysis required to evaluate and optimize urban corridors in Hyderabad. By following this systematic approach, this research can produce detailed visual representations of current and proposed transportation routes, directly supporting study objectives to promote modal choice, reduce congestion, and enhance livability in the city.

4. Results and Discussion

Hyderabad, Pakistan, one of the country's fastest-growing cities, has witnessed high traffic congestion and improved the existing public transportation. To this end, the city has embarked on a project that seeks to bus the city's rapid transit (BRT) system. The possibility and feasibility of the BRT routes identified in the paper were also assessed in light of the connectivity they offer and the benefits and challenges likely to be realized in the proposed Hyderabad BRT system.

The government of Sindh has implemented "Route 1" and proposed "Routes 2, 3, and 4" of the Peoples Bus Service (bus rapid transit) in Hyderabad, Pakistan, to enhance public transportation. The following routes have been proposed and approved. The provided GIS map offers a comprehensive overview of the existing and proposed bus rapid transit (BRT) routes in Hyderabad, Pakistan. These routes are designed to enhance public transportation, reduce traffic congestion, and improve connectivity within the city, as shown in Figure 3.

4.1. Route 1: Hyder Chowk to Hatri Bypass

This route connects Hyder Chowk, a central commercial hub, to Hatri Bypass, a key arterial road. It passes through several important landmarks, which are listed below. This route serves as a vital economic corridor, connecting the bustling commercial center of Hyder Chowk to the Hatri Bypass. It also passes through several educational institutions, making it convenient for students and faculty. The route includes major hospitals like ISRA Hospital, ensuring easy access to healthcare services.

- Fatima Jinnah National Bank
- Gymkhana Hyderabad
- Civic Centre
- Sindh Public Service Commission
- Giddu Chowk
- Polytechnic College
- Qasim Chowk
- Central Jail Hyderabad

- Hala Naka
- ISRA Hospital
- Hatri Police Station

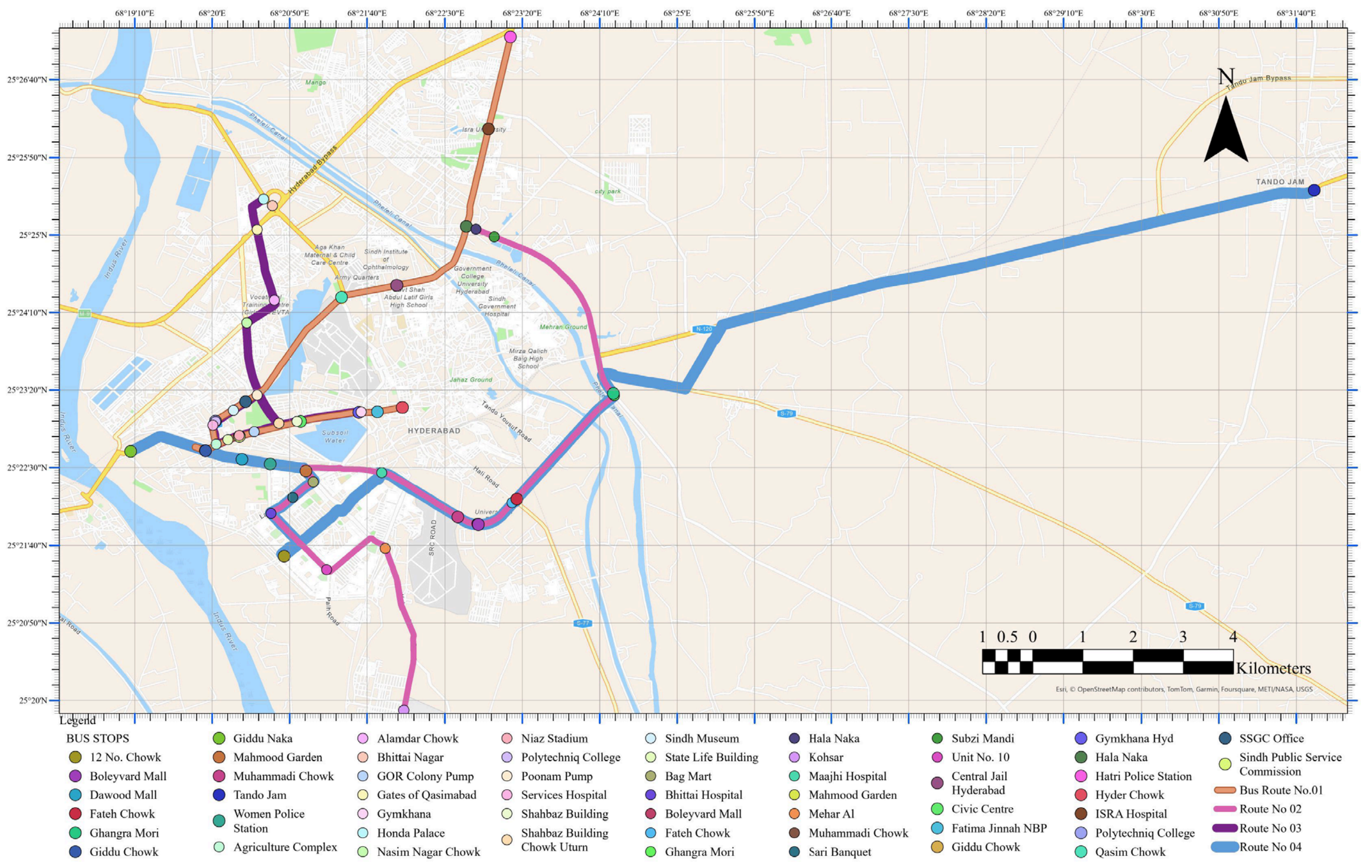

Figure 3. The ArcGIS created route map of all four routes of BRT in Hyderabad, Pakistan.

The GIS map provided in Figure 4 illustrates the first functional BRT route in Hyderabad, Pakistan. This route stretches approximately 15 km, with an estimated travel time of 30 min, as shown in Table 1. It connects Hyder Chowk, a central commercial hub, to Hatri Bypass.

Table 1. Navigating Hyderabad's BRT: Route 1 stop by stop.

Distance	Duration	Bus Stops
454 m	2 min	Hyder Chowk—Fatima Jinnah NBP
336 m	1 min	Fatima Jinnah NBP—Gymkhana Hyd
1.07 km	1 min	Gymkhana Hyd—Civic Centre
1.14 km	2 min	Civic Centre—Sindh Public Service Commission
677 m	1 min	Sindh Public Service Commission—Giddu Chowk
1.11 km	3 min	Giddu Chowk—Polytechnic College
666 m	1 min	Polytechnic College—SSGC Office
2.73 km	3 min	SSGC Office—Qasim Chowk
6.80 km	12 min	Qasim Chowk—Hatri Police Station

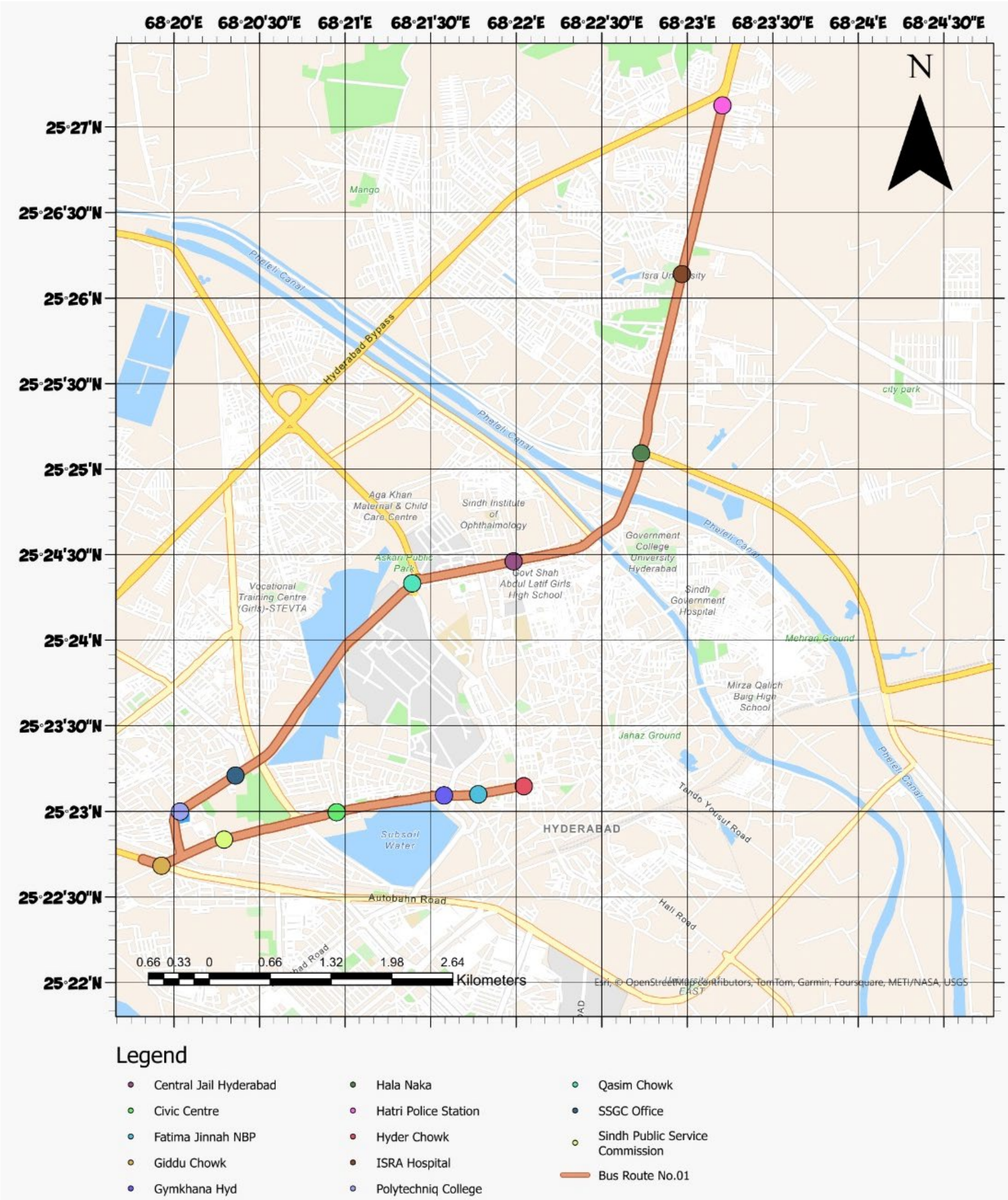

Figure 4. The ArcGISroute map of functional Route 1 in Hyderabad, Pakistan.

4.2. Route 2: Kohsar to Fateh Chowk

This route runs from Kohsar, a residential area, to Fateh Chowk, a commercial intersection. It covers the following key points. The proposed corridor includes several strategic stops, such as Bag Mart, Bhittai Hospital, Fateh Chowk, Hala Naka, Kohsar, Maajhi Hospital, Mahmood Garden, Mohammadi Chowk, Sari Banquet, Subzi Mandi, and Unit No. 10. These stops are strategically located to serve various residential, commercial, and institutional areas within the city, as shown in Table 2 and Figure 5.

Table 2. Navigating Hyderabad's BRT: Route 2 stop by stop.

Distance	Duration	Bus Stops
3.32 km	6 min	Kohsar—Mehar Al
1.42 km	4 min	Mehar Al—Unit No. 10
1.51 km	4 min	Unit No. 10—Bhittai Hospital
1.01 km	2 min	Bhittai Hospital—Bag Mart
276 m	1 min	Bag Mart—Mahmood Garden
1.51 km	3 min	Mahmood Garden—Maajhi Hospital
2.01 km	3 min	Maajhi Hospital—Boleyvard Mall
3.64 km	7 min	Boleyvard Mall—Ghangra Mori
4.46 km	8 min	Ghangra Mori—Hala Naka

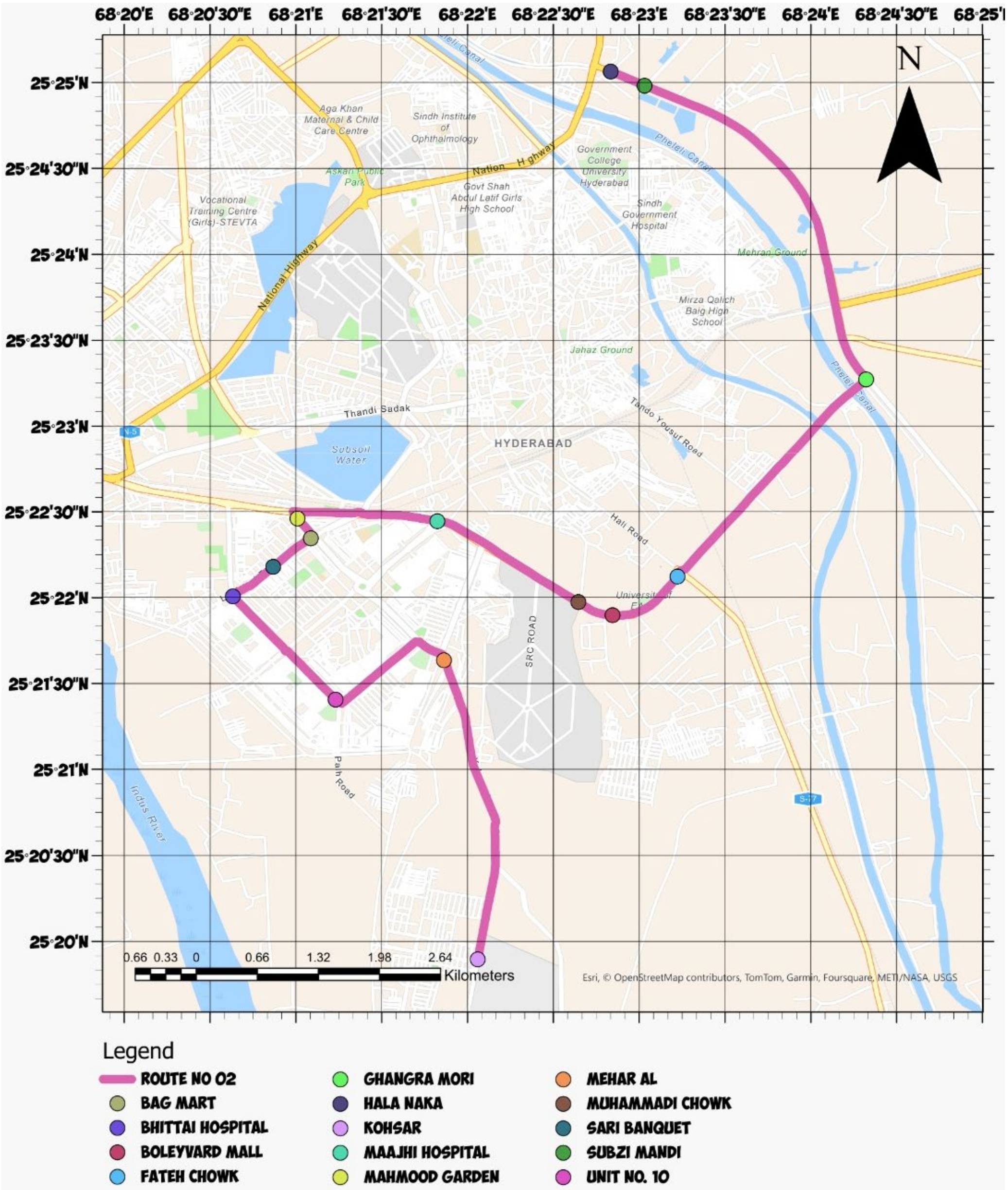

Figure 5. The ArcGIS created the proposed route map of Route 2 in Hyderabad, Pakistan.

- Mehar Ali
- Unit No. 10
- Bhatti Chowk

- Bhittai Hospital
- Sari Banquet
- Bag Mart
- Mahmood Garden
- Latifabad 1/4
- Maajhi Hospital
- Latifabad No. 12 Chowk
- Muhammadi Chowk
- Boulevard Mall
- Ghangra Mori
- Subzi Mandi
- Hala Naka

Route 2 is extended up to 19 km, which consumes around 42 min and connects residential areas in Kohsar to the commercial center of Fateh Chowk, providing a convenient commuting option for residents. This route also includes shopping malls like Boulevard Mall, making it attractive for leisure activities.

4.3. Route 3: Honda Palace to Gymkhana Hyderabad

The BRT Route proposed in Hyderabad, Pakistan, is Route No. 03, covering a distance of 10 km in 24 min. This road links the residential area of Honda Palace to the recreational club of Gymkhana Hyderabad, running through other points like commercial zones.

- Bhittai Nagar
- Gates of Qasimabad
- Alamdar Chowk
- Nasim Nagar Chowk
- Shahbaz Building Chowk U-turn
- Poonam Pump
- Sindh Museum
- Polytechnic College
- Agriculture Complex
- State Life Building
- Niaz Stadium
- GOR Colony Pump
- Shahbaz Building through Flyover
- Civic Centre

It will include connecting the residential areas to recreational places, learning institutions, and business entities, thus improving the mobility of people in such areas, as shown in Figure 6 and Table 3.

Table 3. Navigating Hyderabad's BRT: Route 3 stop by stop.

Distance	Duration	Bus Stops
166 m	1 min	Honda Palace—Bhittai Nagar
559 m	2 min	Bhittai Nagar—Gates of Qasimabad
1.44 km	4 min	Gates of Qasimabad—Alamdar Chowk
717 m	2 min	Alamdar chowk—Nasim Nagar Chowk
2.85 km	5 min	Nasim Nagar Chowk—Poonam Pump
524 m	1 min	Poonam Pump—Sindh Museum
865 m	2 min	Sindh Museum—Agriculture Complex
1.55 km	3 min	Agriculture Complex—Shahbaz Building
1.18 km	1 min	Shahbaz Building—Gymkhana

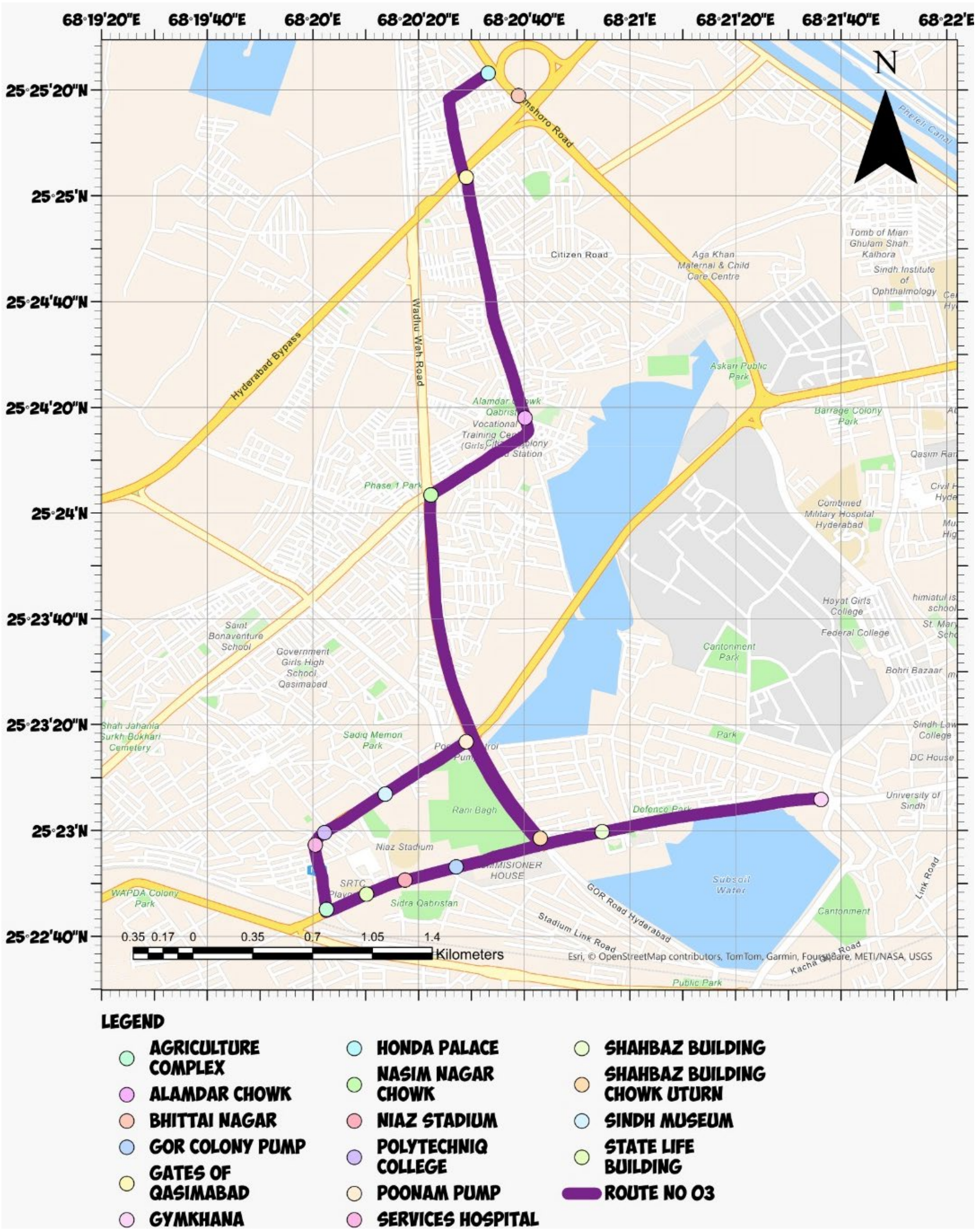

Figure 6. The ArcGIS created the proposed route map of Route 3 in Hyderabad, Pakistan.

4.4. Route 4: Tando Jam to Kotri Bridge

BRT Route No. 04 as shown in Figure 7 and Table 4 is located in Hyderabad, Pakistan, and measures 29km, with an estimated time of 52 min. This link is Tando Jam, a city in Sindh province, and Hyder Chowk, a central business in Hyderabad. The route passes through several key areas, including Ghangra Mori.

- Fateh Chowk
- Boulevard Mall
- Muhammadi Chowk
- 12 No. Chowk
- Mahmood Garden
- Women Police Station
- Dawood Mall
- Giddu Chowk

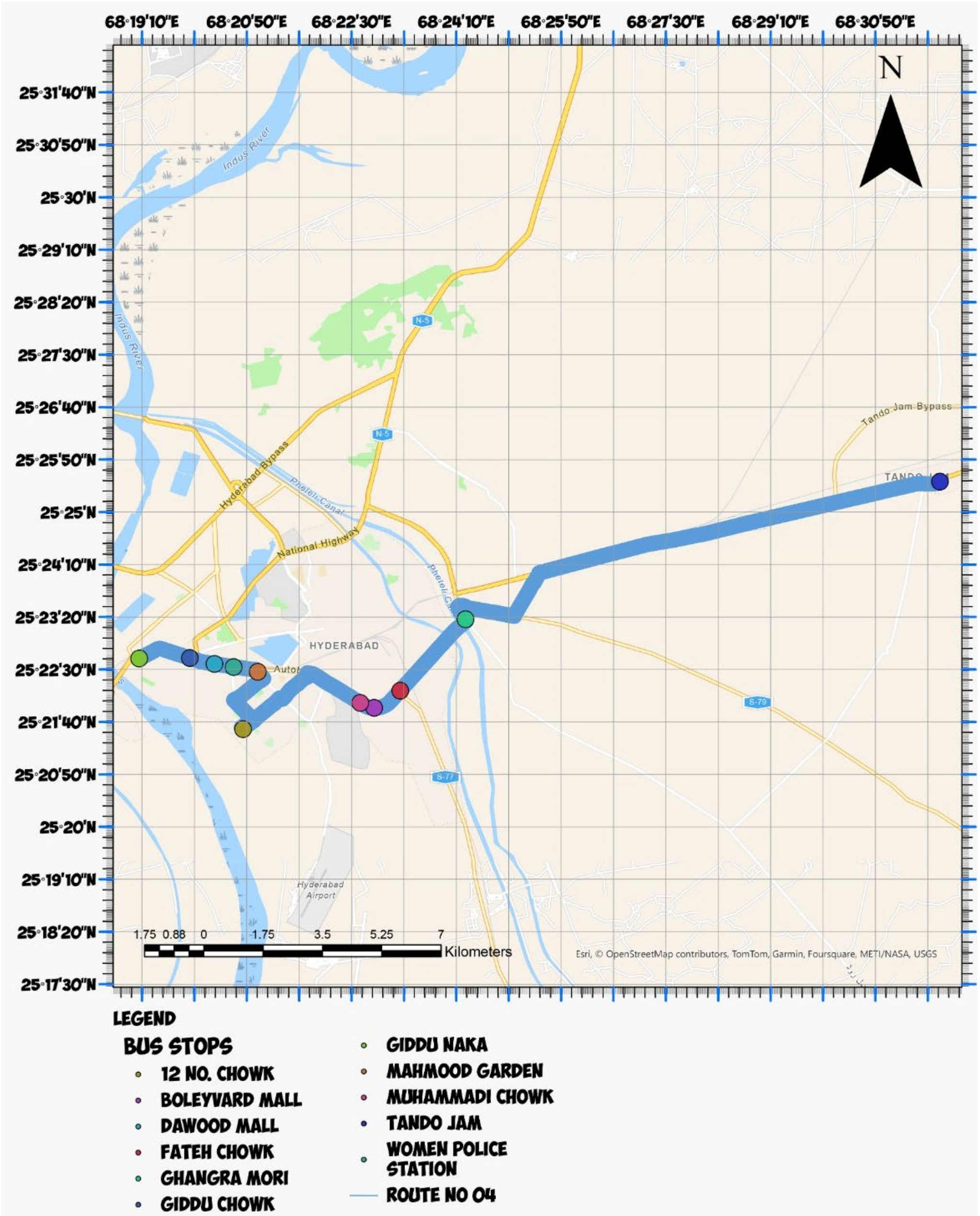

Figure 7. The ArcGIS created a route map of all four routes of BRT in Hyderabad, Pakistan.

Table 4. Navigating Hyderabad's BRT: Route 4 stop by stop.

Distance	Duration	Bus Stops
14.4 km	15 min	Tando Jam—Ghangra Mori
2.76 km	7 min	Ghangra Mori—Fateh Chowk
1.33 km	2 min	Fateh Chowk—Muhammadi Chowk
4.19 km	11 min	Muhammadi Chowk—12 No. Chowk
2.56 km	7 min	12 No. Chowk—Mahmood Garden
681 m	1 min	Mahmood Garden—Women's Police Station
521 m	1 min	Women Police Station—Dawood Mall
680 m	1 min	Dawood Mall—Giddu Chowk
1.48 km	3 min	Giddu Chowk—Giddu Naka

The BRT Route No. 04 is one of the longest BRT proposed corridors in Hyderabad, with a length of 29 km. The route links Tando Jam with Hyderabad and is vital to transporting people from one city to another. It touches several facilities such as residential places, business districts, parklands, and civil administrations.

Following this route, the transport link between Tando Jam and Hyderabad will improve and benefit its citizens and commerce. The BRT system is known to have the potential to produce substantial cost savings compared with other common means of transport or private cars for people traveling from Tando Jam to Hyderabad and other big cities. It is proposed that Route No. 4 should be implemented to reduce traffic flow on the city's roads by constructing a bus lane.

Thus, the present study focused on understanding the impact of the implementation of BRT Route No. 04 on enhancing public transport arrangements in Hyderabad. However, the infrastructure development, the demand for ridership, and efficiency in operations should be noted to affect this project in the future for it to succeed.

The functional and proposed routes sum up a considerable amount of time that passes through the city, connecting essential points and providing access to various facilities. The latter traverses several different areas of land use, including residential, commercial, industrial, and institutional areas. Another goal of BRT is to increase the availability of public transportation use by the population, including those residing in outskirt neighborhoods.

Since BRT is run on a dedicated lane, this system will effectively help prevent traffic congestion since it will take less time as it will be specific to the bus. In contrast to conventional bus systems, BRT enables higher efficiency and service reliability.

Environmental Benefits: In this case, BRT can lower carbon emissions and enhance air quality by encouraging more people to commute using public means. It has been postulated that BRT can positively impact this aspect of economic development by improving accessibility and increasing access to commerce in industrial areas, thus attracting investment. On social equity, BRT has the potential to enhance the ability of all residents to access affordable transport services.

A BRT scheme involves a substantial infrastructure investment, including corridors, stations, and priority signals. That is, access to land necessary for BRT infrastructure development may be problematic in many cases, particularly in areas of high population density. This is why public acceptance and support are critical success factors for the BRT system. This paper established that proper management and operation are required to retain this BRT system's reliability and efficiency.

4.5. Rationale for Corridor Choices

- Route Prioritization
  Route 1 (Hyder Chowk to Hatri Bypass): Chosen because it is a major business center with passenger traffic. It links schools and colleges, hospitals, and other social amenities as well as significant economic points, solving the problem of traffic jams and the lack of accessibility.
  Route 2 (Kohsar to Fateh Chowk): Favored due to its access route to the residential places and business crusade zones. Therefore, it is a critical player in daily traffic patterns.
  Route 3 (Honda Palace to Gymkhana): Selected for the perceived positive association with residential neighborhoods and recreational and institutional facilities to enhance quality and interaction of the livelihood.
- Comparative Impacts on Congestion and Livability
  Out of the two routes, Route 1 is expected to have a maximum effect on congestion alleviation because of high traffic turnover.
  Route 2 supports facets of the livability perspective in that residential commuters experience shorter travel distances and, therefore, fewer trips to services.

Route 3 highlights service generation and enhancement of accessibility to educational and recreational services, thereby enhancing community participation.

4.6. Economic and Social Benefits of Modal Shifts

- Economic Benefits:
  Cost Savings: Less fuel consumption and traveling time is expected to cost commuters about USD 5 million annually.
  Job Creation: It is believed that the job market will be expanded through the construction of infrastructures and the provision of the BRT system.
- Social Benefits:
  Improved Accessibility: Due to the BRT system, more vulnerable people are reached in terms of employment, education, and healthcare services.
  Community Well-Being: By managing stress associated with travel and creating an opportunity for people to interact as they use the transport facilities, the system leads to better health in the body.
  Equity: Choosing private to public transport reduces inequality because society's vulnerable groups have access to transport in the economy's public means.

5. Validation

5.1. Validation of Models and GIS Outputs

- Accuracy of GIS Data: The results generated from the GIS were checked against ground truthing and independent data sources from the local transport authorities. Problems like the noncoincidence of routes or the absence of nodes were adjusted.
- Model Calibration: The corridor optimization models were initially verified by employing near-real traffic and travel data to discharge realistic results. Other driving variables, including vehicle speeds, traffic densities, and emission factors, were modified to match the field situations.
- Scenario Testing: Multiple optimization scenarios were tested to evaluate the models' stability in different conditions, peak and non-peak times, and different levels of transit demand. To determine their feasibility and effect, they were compared with baseline situations.
- Comparative Analysis: The impact assessment of optimized routes was conducted by referring to the figures of the existing corridors, thus optimizing travel time, congestion level, and emission. This made it possible that the recommended solutions described an evident change from the status quo.

5.2. Stakeholder Involvement

- Engagement with Local Authorities and Planners: Plans defining priority corridors were discussed with transportation planners and local authorities at the beginning of the study so that the optimization criteria used in this study are most relevant to the planning goals of the region. They contributed significantly to elaborating on the niche of the models.
- Community Feedback: Quantitative research was also carried out to identify those carrying out their daily activities in the area or those using various means of transport. This feedback was used to adjust the weights of such factors as time to travel and accessibility when establishing the optimization models.
- Workshops and Discussions: The first findings were discussed in a series of workshops with representatives of the main stakeholders, such as urban and transport planners. Recommendations gathered from these sessions were adopted in the final models.

5.3. Limitations of Stakeholder Involvement

Although the stakeholders were significant in determining the models, the possibility of performing real-time validation and engaging the broader community was constrained by time and resources. However, the key solutions developed have been planned for scalability with the validation foresight in the form of pilot solutions and involving wider stakeholders.

6. Conclusions

New BRT routes in Hyderabad, Pakistan, are one way the city is enhancing its existing communications and public transport means. This research aims to establish that through the directional bus rapid transit supply of BRT, including offering a bus lane, shortening travel time, and increasing accessibility, BRT may avoid traffic congestion, pollution, and economic stagnation.

All the same, the successful tapping of the full potential of BRT is heavily dependent on proper planning, sufficient funding, and efficient management. Infrastructure development, land acquisition to achieve a favorable location, public acceptance, and operational efficiency are critical in determining the project's sustainability.

Thus, Hyderabad's overcoming these challenges and leveraging these opportunities will foster the construction of a model BRT system for other regional cities. The development of the BRT system means it can help enhance the city's sustainable development, increase the population's welfare, and contribute to the more significant implementation of such social mission on behalf of the city's inhabitants.

The BRT corridors planned for Hyderabad have the potential to enhance mobility within the city and complement the approach to multiple urban issues. However, it will be paramount to note that adequate preparation and funding should be implemented for the strategies to work as planned, which also calls for sufficient management in the whole process. Hyderabad must try to overcome the challenges while relishing the opportunities so that the city can provide a proper and efficient method through the BRT system for the comfort of the people of Hyderabad.

6.1. Actionable Policy Recommendations

A combination of strategies is proposed to ensure the successful implementation and operation of the BRT system.

- Public–Private Partnerships (PPPs):

Collaboration between government ministries, organizations, and private entities is essential for financing, planning, and managing the BRT system. PPPs transfer cost burdens from public institutions while leveraging private sector expertise and efficiency. Concession agreements, where private operators manage BRT lines under regulatory oversight, can guarantee service quality and fair fare structures.

- Financial Models:
  - Farebox Revenue and Subsidies: Establishing fare levels that balance affordability for low-income groups with the financial viability of transportation providers is crucial. Targeted subsidies during peak hours can increase ridership and accessibility.
  - Green Bonds: Issuing bonds to sustainable infrastructure projects can attract investment and build public trust in BRT initiatives.
  - Congestion Charges: Taxing in high-traffic areas can discourage private car usage while generating revenue to enhance public transport systems.

- Community Engagement Methods:

Engaging with the public is critical for ensuring the BRT system meets community needs. Periodic sessions and discussions can provide insights into user experiences and expectations. Leveraging web-based tools and social media campaigns can promote sustainable transport adoption. Additionally, structured feedback mechanisms, such as surveys after implementation, can identify areas for improvement and inform subsequent phases of the project.

6.2. Applicability to Other Cities and Generalizability

- Transferability to Other Cities in Pakistan

The approaches and results can be directly applied to cities like Karachi, Lahore, and Faisalabad because they experience comparable traffic management issues, including congestion, air pollution, and limited resources. GIS tools and multimodal optimization can inform further tailoring of the framework in specific areas.

For example, different population densities or the layout of infrastructure in the cities could involve updating the optimization models by specifying other more relevant parameters like land use or peak period traffic.

- Applicability to Similar Developing Countries

The suggested framework can be applied to developing countries with similar socio-economic characteristics. This includes cities in South Asia, Sub-Saharan Africa, and Southeast Asia, where urban growth and low provision of public transport systems means cost-efficient and environmentally friendly solutions are needed.

Policymakers in these regions may adopt the funding models, community engagement strategies, and methods of optimizing the multimodal corridors described in this study.

6.3. Localized vs. Generalized Recommendations

Although the identified routes and the roles of involved stakeholders described in this chapter belong to the Hyderabad context, several principles can be used in other contexts: multimodal transport as a top priority, engaging stakeholders, and incorporating GIS-based decision making. These strategies emphasize the need to form strategies that fit the local needs while keeping the framework close to replicable for scalability purposes.

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