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Evaluation of commuter perception and optimization of public transit routes in Hyderabad using TOD applications

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K E Y W O R D S

TOD applications

Transportation planning

Network analysis

Urban growth

Route information

ArcGIS

A B S T R A C T

The accessibility, efficiency, and convenience of public transit in Hyderabad are significantly hindered by inadequate infrastructure, overcrowding, insufficient funding, inconsistent service, traffic congestion, and limited coverage. Urban engineers/urban planners widely recognize the Transit-Oriented Development (TOD) applications as an effective strategy for promoting maintainable urban growth. TOD focuses on situating populations near public transportation hubs to reduce dependence on private vehicles. Hyderabad's public transportation system (buses and trains) currently falls short of meeting commuter needs due to the absence of TOD principles, leading to increased private vehicle usage, traffic congestion, and air pollution. This study aims to evaluate commuter perceptions regarding transportation facilities' availability. It illustrates the service area coverage of the existing public Transit route network based on walkable distances converted to travel times using ArcGIS. Data was collected using an extensive questionnaire survey involving 400 respondents, selected using the Taro technique. Route information was gathered from the Regional Transportation Authority (RTA) and on-site surveys detailing the available public transportation routes. The collected data was analyzed using SPSS software, employing statistical methods such as Chi-Square tests, correlation analysis, normality checks, and ANOVA. The study identified the catchment areas for existing public transportation routes in Hyderabad, emphasizing regions where passengers have easy access to transit in alignment with TOD applications.

1. Introduction

Unplanned accelerated urbanization, narrow and overly populated road networks, and inadequate public transport contribute to congestion, traffic jams, poor air quality, accidents, and insufficient parking in urban centers [1]. While there have been many initiatives to promote sustainable urban transportation, transit-oriented development (TOD) is certainly one of the most effective [2]. Research suggests that growth in urbanization resulted in urban sprawl, amplified use of private cars, and inadequate services [3, 4].

The term TOD has been a subject of much exploration since its introduction in the early 1990s. Recently, the concept has gained much attention as a way to curb

urban sprawl and dependence and achieve a sustainable urban form [5]. Gradually, the idea gained popularity in Europe, Sweden, Germany, Italy, Australia, and Canada [6]. The popularity and evolution of transit-oriented development have reached developing countries in recent times. Jakarta (Indonesia), Dhaka (Bangladesh), Ahmedabad, Belagavi, Bhopal, and Bhubaneswar (India) are a few examples of cities that developed considering the principles of transit-oriented development [7, 8]. Developed countries started urban regeneration and transit-oriented development decades ago; however, developing countries strive to develop rapid and efficient means of mobility, which is an integral part of economic development and job creation [9]. Cities like London, Paris, and Washington are the best examples of transportation development and job creation [10, 11]. Research identifies that developing countries consume about 15% of their GDP in the transportation sector only, which is a huge cost incurred by the public; Efficient mobility can reduce prices by 5 to 10% [12].

When parking is restricted and private transportation is prohibited on pedestrian-only routes, public transportation is an essential tool for restoring retail activity in city centers. Improving personal connectivity and reducing traffic congestion are the main goals of the general public transportation accessibility assessment [13]. Additionally, walking lengths might change based on locales, social groups, and the modes of transportation that are available [14].

Pakistan is an underdeveloped country of 221 million. According to the Census 2017, about 37% of the country's population lives in urban centers [15]. However, these figures go up to nearly 70% if we include the urban sprawl and suburbia [16, 17]. The urbanization growth rate is recorded as 3-4% per annum. The number of registered vehicles is increasing annually in Pakistan. 6,628,063 Units were registered in Dec 2021 and 6,398,249 Units for Dec 2020, averaging 2,681,289 Units from Dec 1990 to 2021, which adds a high load on public transport [18]. Furthermore, the system has 263,775 km of roads and highways for a population of 220 million, corresponding to 1.17 meters. Globally, the transportation sector is one of the major fossil fuel consumers, contributing about 14% to greenhouse gases [19].

Hyderabad is the second-largest settlement in Sindh, Pakistan. No study has yet to discover the spatial accessibility of public transport services in Hyderabad [20].

Hence, this study answered the following research questions:

i. What are the key issues that commuters in Hyderabad experience when it comes to urban transit, and how accessible, reliable, affordable, and sustainable is Hyderabad's present public transit system?

ii. How to compute pedestrian accessibility standards to reach public transport stops with the help of GIS?

The goal is to make Hyderabad an economically planned city that can greatly enhance people's quality of life and accessibility to transportation. A network-based spatial research application called ArcGIS network analysis is used to manage complex transport difficulties, and the service area analysis method is used to competently assess and organize enormous amounts of connections of network analysis. As a result, the study produced an interactive map using GIS tools.

1.1 TOD Applications

Transit-oriented development (TOD) is a one-of-a-kind development strategy combining Smart Growth, New Urbanism, and Location-Efficient Development elements [22]. Transit-oriented development is a multidisciplinary strategy involving professionals, planners, academia, researchers, public office holders, government representatives, etc. Various planners have defined transit-oriented development at different periods and places [23]. This concept, which arose in the USA in the 90s, is the most rational and acceptable form of urban development. According to Calthorpe TODs, mixed-use communities are within an average walking distance of a transit stop and a core commercial area. Fig. 01: illustrates the concept of TOD based on Calthorpe [24]. It is an interesting tool to reduce car use by developing compact, mixed-use neighborhoods around existing or new public transit stops offering frequent and high-quality public transportation [25]. TOD is an approach that promotes high-density, mixed-use development and walkable neighborhoods clustered around transit stations and corridors [26].

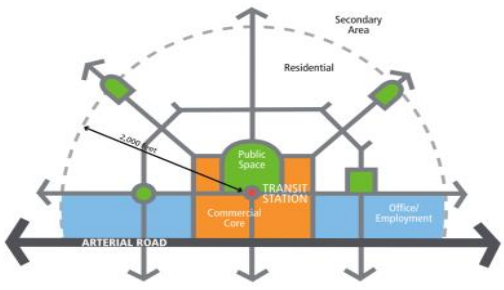

Fig. 1. Illustration of TOD Based on Calthorpe (1993)

According to the TOD standard, 2000 ft is the parameter set for the service area, such as a walking distance of about 10 minutes and 0.6 kilometers [27].

The most important ingredient to the success of TOD planning is land and transit integration. Unless the development interacts with the mass rapid transit system, the two systems (land use and transit) stand alone and independently. It has been increasingly promoted and implemented as a solution to mitigate urban sprawl and to save the agricultural land acquired for urban development [28].

1.2 GIS Approach to Network Analysis

A technique for resolving system issues, such as navigability, serviceability, flow rate, or making use of transport systems' availability, is network analysis. Data sets from graphs or transport networks can also be analyzed by network analysts. These evaluations could include determining the best location, the least expensive route, the quickest route, the most accessible locations, the nearest facilities, the greatest site, or the best routes for a fleet of cars. Service area analysis is a key component of ArcGIS Network analysis. [29]. Network issues are also revealed via GIS-based network analysis. It can show details like the lack of facilities, infrastructure, and transportation services, as well as inaccessible locations.

There are six ways to conduct network analysis with ArcGIS:

i. Route analysis,
ii. Investigation of the nearby feature,
iii. Analysis of the service area,
iv. Analysis of the origin-destination (OD) cost grid,
v. Investigation of the vehicle directing issue, and
vi. layers of the area allocation investigation.

The primary benefit of network analysis is its ability to evaluate and arrange an enormous number of connections effectively.

1.3 Evaluation of Mass Transportation Systems

By 2050, the World Bank projects that 68% of the world's population, or more than 50% of all people, will reside in urban regions. One of the biggest worldwide issues today is rapid urbanization, which has led to population growth and urban sprawl. Demand for travel and urban mobility rises as a result of urban sprawl and population growth [30].

The main issues brought on by the rising demand for mobility include air pollution, fuel consumption, commute time increases, economic losses, and traffic congestion [31]. The capacity of the current road network can be increased in the short term by adding additional infrastructure facilities like flyovers, underpasses, and extra lanes, as well as by better traffic management [32]. The establishment of high mobility and the determination of traffic issues through the provision of dependable, economical, and sustainable methods of transportation are mass transportation is regarded as being one of the primary solutions for TOD [33]. Designing walkable neighborhoods is the foundation of TOD, and all of the TOD literature proposed that TOD be created within a normal comfortable walking distance [34].

Research on GIS-based Transit-Oriented Development (TOD) models remains limited, particularly in addressing accessibility challenges faced by residents. While TOD concepts have been explored extensively, their integration with GIS for resolving travel and transportation issues has not been widely discussed in the literature. This gap is particularly evident in the context of Hyderabad, Sindh, where a systematic GIS-based TOD model has not yet been developed. Therefore, this study aims to bridge this gap by introducing a GIS-based TOD modelling approach to enhance accessibility and improve transportation planning in the region.

2. Research Methodology

2.1 Study Area and Present Scenario

Hyderabad is selected as the study area; the city's map can be seen in Fig. 02. Hyderabad is Sindh's second major city and economic hub. It suffers from rapid urbanization, urban sprawl, congestion, road traffic, pollution, and unplanned road infrastructure [35].

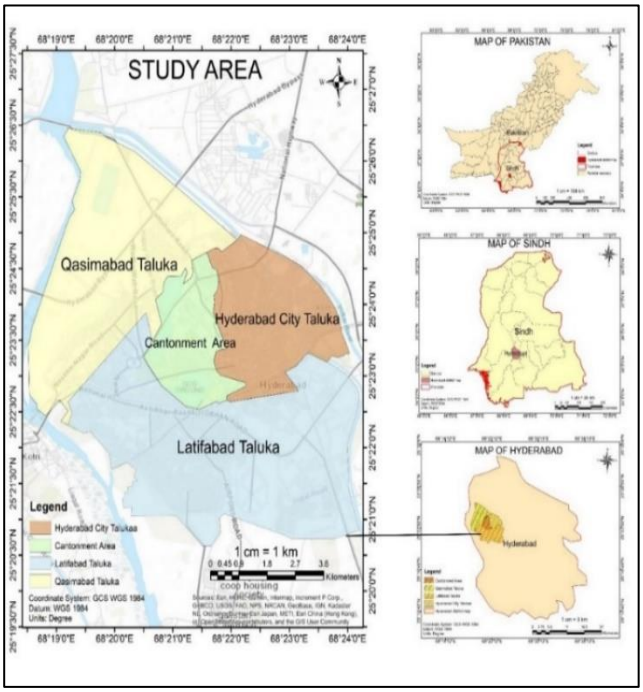

Fig. 2. GIS-Based Map – Hyderabad, Sindh, Pakistan [35]

Hyderabad is a city of 20,223,79 inhabitants, having a growth rate of 1.72% recorded in the years from 2017 to 2023. The total area of Hyderabad is 993 sq km (Pakistan Bureau of Statistics). The city is growing rapidly. In the last three decades, its urban population has grown by 44 percent. Fig. 03 shows the population growth and density trend in the upcoming years [36].

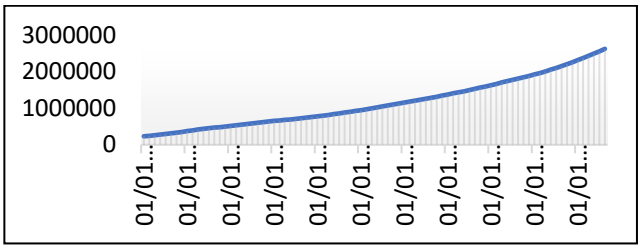

Fig. 3. UN Projection on Population Growth in Hyderabad[36].

With an ever-growing population, the absence of a decent public transport system is a major inconvenience for residents. Besides, the deplorable condition of these vehicles is often the cause of accidents and traffic jams in the city [37]. According to Talpur et al. (2025), the Chi-square test is suitable for evaluating associations between categorical factors, making it an appropriate choice for assessing travel behavior patterns [38]. The information about modes of transportation can be depicted in Fig. 04.

Families with lower incomes use public transit, whereas those with greater incomes use private transportation. 50% of people used to travel in private vehicles like cars and motorbikes. Only a small percentage of individuals still utilize taxis or buses in Hyderabad [39].

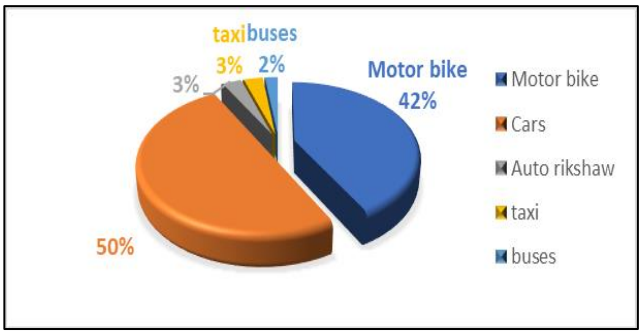

Fig. 4. Modes Of Transportation in the 4th Largest Urban Center of Pakistan [39]

Fig. 05 shows the types of Transport Vehicles used in Hyderabad City, where bus coaches, Suzuki (type of van), and mini-busses are parked on the street next to the homes because none have a proper place to park them. The accessibility to these stations is unsuitable since buses that turn inside or around frequently cause obstructions on these main roads, contributing to blocking and noise issues at specific bus-preventing concepts across the town.

Fig. 5. The Types of Transport Vehicles in Hyderabad City

The GIS-based TOD model is not discussed so often in the literature, focusing on the accessibility issues of the residents. Hence, for the first time, this study is framing TOD modelling concepts concerning GIS that could help resolve the travel and transportation issues in Hyderabad, Sindh.

2.2 Research Design

This method combines SPSS and GIS, which provide a perceptive examination of Hyderabad public transportation perceptions and route efficiency. Fig. 06 shows these steps.

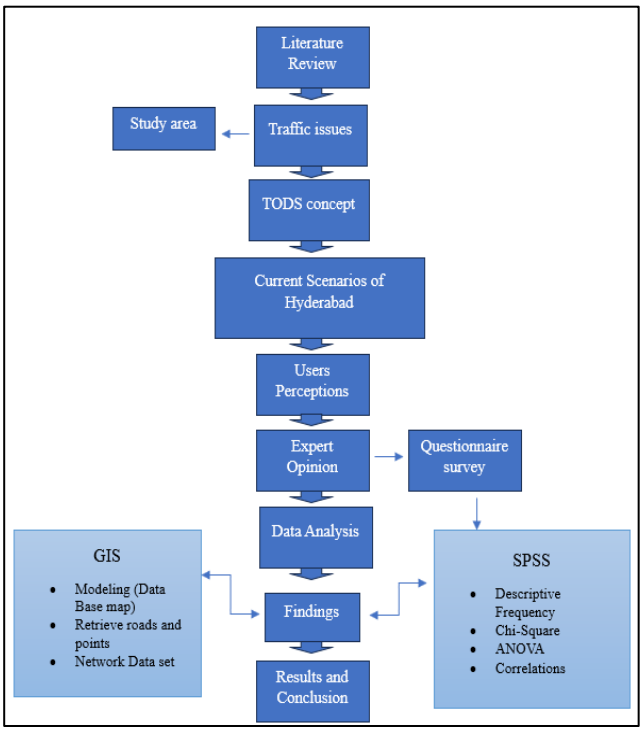

Fig. 6. Research Design

2.3 Data Collection

The data regarding the perceptions of transportation facilities and route Information is obtained from regional transportation authorities (RTA Department), and on-site surveys are conducted for public

transportation. The survey data was obtained through a questionnaire survey from respondents in the study region of Hyderabad City. Hyderabad's forecasted population was 1,968,000 in 2023, using an annual growth rate of 2.18%. The Taro Yamane technique was used to determine a meaningful sample size by Khahro, S. H. et al., 2023 [40].

$$n = \frac{N}{1+N(e)2}$$

$$n = \frac{1{,}968{,}000}{1+1{,}968{,}000\ (0.05)2}$$

$$n = 399.999 \approx 400$$

n sample size.

N = population size.

e = level of precision. A confidence level of 95% with P=0.05 is considered.

The sample sizes are calculated using Equation. 400 sample sizes are selected from the study area. Fig. 07 shows the existing transportation stops from where the survey is collected.

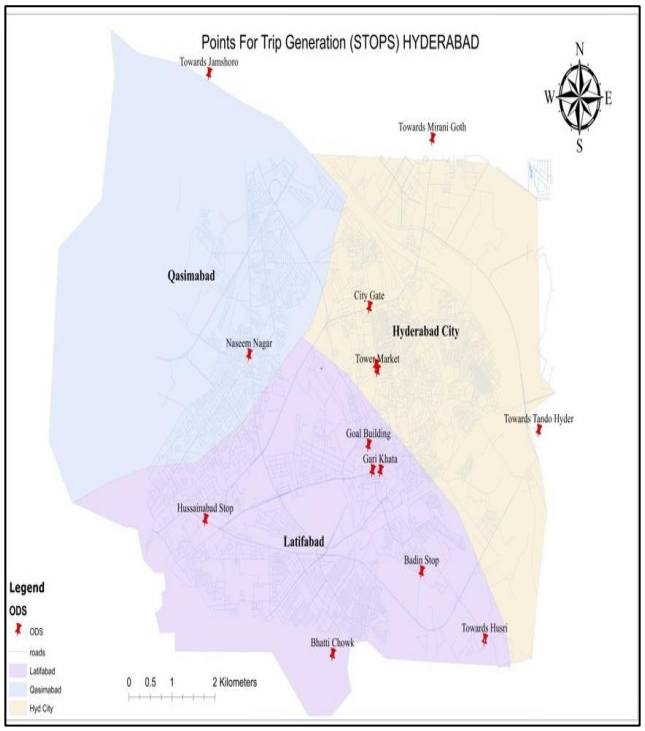

Fig. 7. Existing Points for Trip Generation (Transportation Stops) in Hyderabad

2.4 Data Analysis

The collected data were examined using SPSS software, which analyzed Descriptive statistics in the form of Chi-Square, correlation, normality Test, and ANOVA methods. The existing route map of Hyderabad was drawn using GIS software to examine Hyderabad's current transit development scheme. In the study region of Hyderabad, 400 questionnaires were filled out from selected study areas, and 50 were chosen from each area, as depicted in Table 01.

Table 1

Bus stops wise survey from respondents

S.No	From	To	Type of public transport	No of Respondent
01	Haider chowk	Ayubia restaurant	Red Buses/Pink bus	50
02	Channel Mori	LMC Jamshoro	Coaster	50
03	Gol building	Khuda ki basti	Suzuki Van	50
04	Giddu chowk	Latifabad	Suzuki Van	50
05	Gari Khatta	Naseem Nagar	Suzuki Van	50
06	Civil hospital	LMC Jamshoro	Suzuki Van	50
07	Tower market/civil hospital	Miani Goth/Hyderabad Bypass	Suzuki Van	50
08	Badin General Bus station	Hala Naka	Mini Taxi	50

3. Results and Discussion

The results section describes the basic descriptive results about the variables. Close-ended questions were mostly queried. Descriptive results include demographics and Monotonous Responses.

3.1 Commuters Perception of Public Transportation in Hyderabad

According to the frequency analysis of respondents from demographic Table 02, over 27% of the population travel from nearby areas of Hyderabad, and 26% of respondents travel from Qasimabad. The highest of respondents w.r.t age group were 15-25 who travel in public transport and the majority have a monthly income of up to 10,000.

Table 2

Demographic information of the respondent

Data types	Respondents				
Residence	Qasimabad	Latifabad	Hyd Rural	Hyd urban	Nearby
	105	80	35	71	109
Age Group	56-65	46-55	36-45	26-35	15-25

	9	16				
			27	60	288	
Education	Uneducated	Primary	HSC	Bachelor	PG	Other
					40	
	42	18	41	258		1
Monthly income	Upto-10,000	10,001-15000	15001-20,000	20,001-25000	25001-50,000	50,001-100,000
	149					
		53	44	68	44	25

The examination of Table 03 demonstrates that over 60% of respondents don't have transportation as they mostly use public transportation for traveling purposes. Most people did not find particular transport to reach their destination as 233 of the respondents changed their different modes of transportation.

Table 3

Analysis of Data W.r.t to Transportation Mode

Data	Yes	No	May be
Ownership of transportation	169	231	
Change of transport mode	233	167	
Easy to get the bus	190	210	
Required other locations for T.M	236	81	83

Fig. 08 breaks down the number of respondents based on how many days per week they travel. Along with that, most respondents travel every day, with 46% and 28% of the total respondents traveling several times a week.

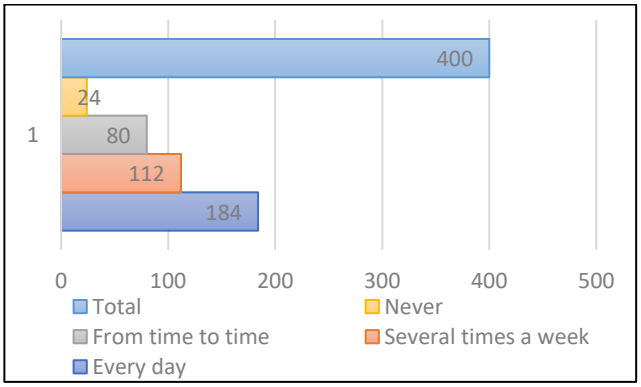

Fig 8. Commuter's Traveling Info During A Week

In Fig. 09, 45% of respondents travel from 6 a.m. to 9 a.m., indicating a high level of commuting or travel-related activities. This group likely includes full-time workers and students with regular schedules. Insights into early morning travel patterns can be praised in traffic flow management, as they increase congestion during peak hours.

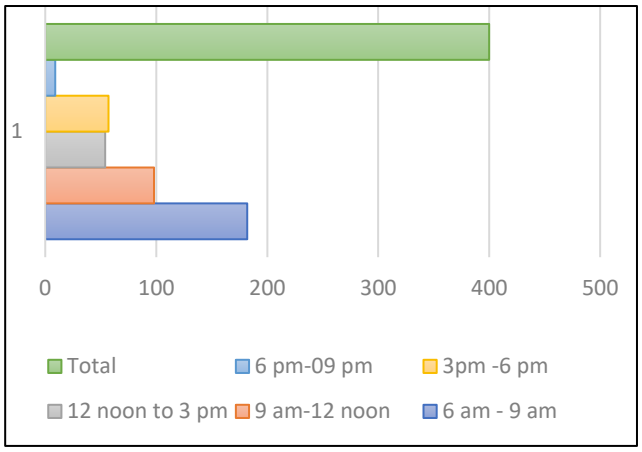

Fig. 9. Traveling Time Of The Respondent

As per respondent data, 34% of respondents change two modes to reach their destination, most people get easy transport by a single mode as shown in Fig. 10.

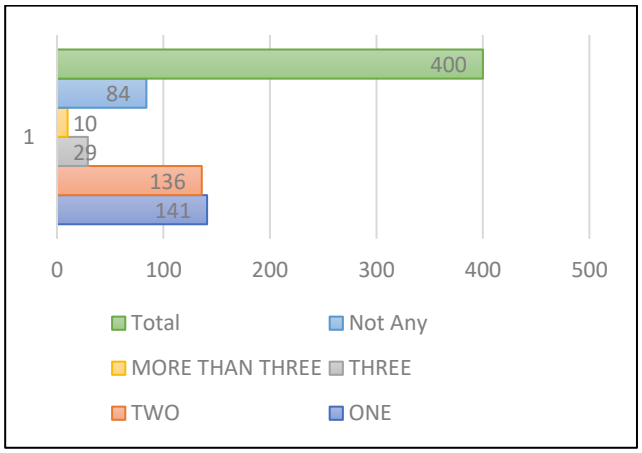

Fig. 10. Change Of Modes To Reach The Destination

Fig. 11 shows that Commuters might travel from suburban or rural areas. Users responded that they travel approximately 5 kilometres to reach public transport.

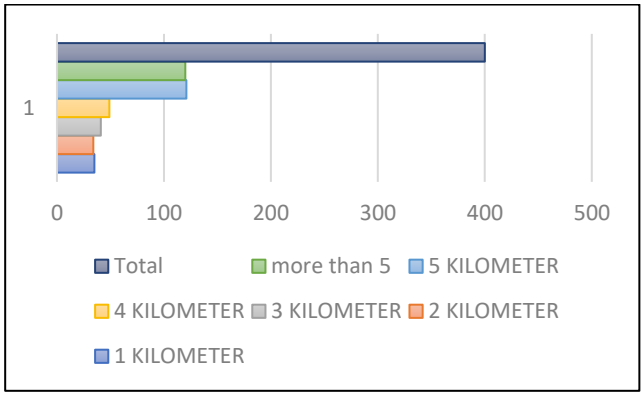

Fig. 11. Distance Covered To Reach The Destination

Various factors influence transportation systems and the choices individuals make regarding transport. Higher population density often leads to better public transport services due to higher demand. The

affordability of different transport modes is the main factor influencing public transportation, like public transport fares vs. fuel costs for private vehicles.

3.2 Cross-tabulation and Chi-square of Different Variables

3.2.1 Cross-tabulation and Chi-square test for monthly income and Traveling info during a week

Table 04 summarizes the frequency of travel within a week across different income groups.75 individuals travel every day and have 10,000 incomes in a month.

Table 4

Crosstabulation of monthly income and Travel info during a week

Sno	Monthly income	Every day	Several times a week	From time to time	Never	Total
1	Up to 10,000	75	37	30	7	149
2	10,001 to 15,000	21	14	15	3	53
3	15,001 to 20,000	23	102	5	4	44
4	20,001 to 25,000	30	28	10	0	68
5	25001-50000	18	11	11	4	44
6	50,001-100000	10	7	6	2	25
7	More than 100000	7	3	3	4	17
	Total	184	112	80	24	400

In Table 05, the p-value for the Pearson Chi-Square test is 0.068. Since this value is slightly above the common significance level of 0.05, it fails to reject the null hypothesis. This means there isn't strong evidence to suggest a significant association between monthly income and travel frequency within a week.

Table 5

Chi-square tests of monthly income and traveling info during a week

Sno	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	27.638[a]	18	.068
Likelihood Ratio	27.551	18	.069
Linear-by-Linear Association	2.277	1	.131
N of Valid Cases	400		

3.2.2 Cross Tabulation and Chi-Square Tests for Monthly Income and Reason for Using Transportation Mode

This dataset includes monthly income categories and their preferences for different aspects of travel: safety, comfort, accessibility, being the only alternative, and cost. Table 06 shows that most users stated that existing public transportation is the cheapest.

Table 6

Crosstabulation Monthly Income and Reason for Using the Transportation Mode

Sno	Monthly income	Safety	Most comfortable	Most Accessible	The only alternate	The cheapest	Total
1	Up to 10,000	20	39	27	22	41	149
2	10,001 to 15,000	8	12	12	11	10	53
3	15,001 to 20,000	5	7	10	4	18	44
4	20,001 to 25,000	2	9	23	20	14	68
5	25001-50000	4	14	13	8	5	44
6	50,001-100000	0	12	3	4	6	25
7	More than 100000	2	7	3	5	0	17
	Total	41	100	91	74	94	400

In Table 07, the p-value for the Pearson Chi-Square test is 0.001, which is less than the common significance level of 0.05. This indicates a statistically significant association between monthly income and travel preferences. The most common preference is the

cheapest option, followed by the 10,000-income group.

Table 7 Chi-Square Test of Monthly Income and Reason for Using the Transportation Mode

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	52.780a	24	.001
Likelihood Ratio	59.141	24	.000
Linear-by-Linear Association	.315	1	.575
N of Valid Cases	400		

3.2.3 Cross-tabulation and chi-square tests of age group and reason for using transportation mode

Table 08 displays that younger age groups, 15-25 and 26-35, have higher counts and show a strong preference for comfort, accessibility, and cost-effectiveness, whereas older age groups, 46-55 and 56-65, have fewer responses and show a more even distribution of reasons for using transportation.

Table 8

Crosstabulation of Age Group and Reason for Using Transportation Mode.

no	age group	safety	most comfortable	most accessible	The only alternate	the cheapest	total
1	56-65	0	2	3	1	3	9
2	46-55	1	2	3	6	4	16
3	36-45	2	3	7	6	8	26
4	26-35	2	10	20	16	12	60
5	15-25	36	83	57	45	67	288
6	33	0	0	1	0	0	1
	Total	41	100	91	74	94	400

In Table 09, the p-value is 0.099, which is greater than the common alpha level of 0.05, indicating that we failed to reject the null hypothesis. This suggests there is no significant association between age group and reason for using transportation. This means that the reasons for choosing transportation do not significantly differ across different age groups in this dataset.

Table 9

Chi-Square Tests of Age Group Reason for Using the Mode of Transportation

Sno	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	28.455a	20	.099
Likelihood Ratio	29.409	20	.080
Linear-by-Linear Association	2.686	1	.101
N of Valid Cases	400		

3.2.4 Cross-tabulation changing the mode of transport and distance covered

Table 10 shows that the most common distances covered are 5 KM and more than 5 KM. Commuters who change their mode of transport once or twice tend to cover longer distances (5 KM and more than 5 KM) more frequently than shorter distances.

Table 10

Crosstabulation Changing the mode of transport and Distance covered

Sno	Changing the mode	1 KM	2 KM	3 KM	4 KM	5 KM	more than 5KM	Total
1	ONE	16	11	13	16	43	42	141
2	TWO	10	12	13	24	35	42	136
3	THREE	0	4	3	5	10	7	29
4	MORE THAN THREE	0	1	3	0	3	3	10
5	Not Any	9	6	9	4	30	26	84
	Total	35	34	41	49	121	120	400

The p-value is 0.353, which is greater than the common alpha level of 0.05, indicating that we failed to reject the null hypothesis. This suggests there is no

significant association between changing the mode of transport and the distance covered.

Table 11

Chi-Square Tests Changing the mode of transport and Distance covered.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	21.771a	20	.353
Likelihood Ratio	25.599	20	.179
Linear-by-Linear Association	.174	1	.677
N of Valid Cases	400		

3.3 Analysis Of Commuter Satisfaction With Different Variables By Using The Likert Scale With ANOVA Test

A Likert Scale is a psychometric tool commonly used to measure respondents' attitudes, feelings, or satisfaction across a range of values. An ANOVA test was performed in SPSS for three major groups of data. These three groups belong to different locations in the studied area, such as Hyderabad City, Hyderabad Rural, Latifabad, and Qasimabad. The analysis found that there is no difference among Hyderabad respondents regarding their perception of the quality of transportation in Hyderabad, as the significance value is higher than 0.005, as shown in Table 12. It suggests that almost every group has similar perceptions about Comfort level, Conditions, Frequency, and Satisfaction.

Table 12

Anova value of each variable in the Likert scale

Variables		Sum of Squares	df	Mean Square	F	Sig.
comfortable	Between Groups	9.212	4	2.303	1.459	.214
	Within Groups	623.485	395	1.578		
	Total	632.698	399			
Conditions	Between Groups	7.943	4	1.986	1.236	.295
	Within Groups	634.447	395	1.606		
	Total	642.390	399			
Frequency	Between Groups	12.274	4	3.068	2.073	.084
	Within Groups	584.604	395	1.480		
	Total	596.877	399			
Satisfaction	Between Groups	6.941	4	1.735	1.384	.239
	Within Groups	495.357	395	1.254		
	Total	502.298	399			

A Radar chart is developed to represent Likert scale data of variables such as Comfortable level, Conditions, Frequency, and Satisfaction. It is used to display multivariate data on a two-dimensional plot. It's often used to visualize Likert scale data across multiple variables or categories, especially when comparing them. In this context, each axis of the radar chart represents a different variable (or survey question), and the values on those axes represent the level of agreement or satisfaction on a Likert scale.

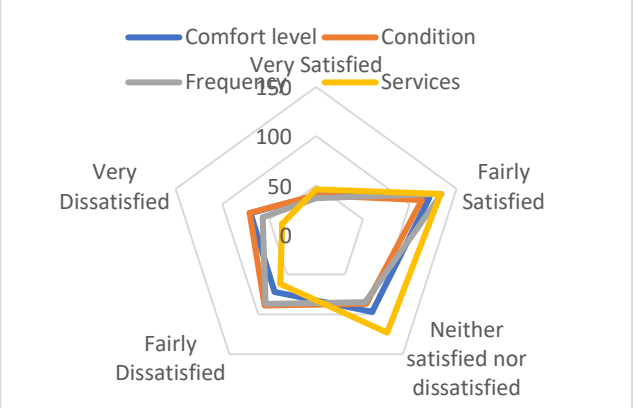

Fig. 12. Radar Fig. Of Likert Scale Variables

3.4 Analysis of Correlations for Different Variables

Correlation is a statistical measure that describes the strength and direction of the relationship between two continuous variables.

3.4.1 Correlation between monthly income and Transportation Mode

Table 13 shows a correlation between variables, showing that respondents have lower monthly income, which is why they select to travel in public transport.

Table 13

Correlation between monthly income and Mode of Transport

		Monthly income	Mode of Transportation
Monthly income	Correlation Coefficient	1.000	0.781
	Sig. (2-tailed)	.	0.001
	N	400	400

Transportation mode used to travel	Correlation Coefficient	0.781	1.000
	Sig. (2-tailed)	0.001	.
	N	400	400

3.4.2 Correlation between distance and mode of transport

In Table 14, a correlation coefficient of 0.652 between distance covered and transport mode indicates a moderate to strong positive relationship between these two variables. It might imply that longer distances are associated with the selection of public transport modes that can cover greater distances more comfortably and quickly.

Table 14

Correlation between distance and mode of transport

		Distance covered (Approx.)	Transport mode used for travel
Distance covered (Approx.)	Correlation Coefficient	1.000	0.652
	Sig. (2-tailed)	.	0.001
	N	400	400
Transportation mode	Correlation Coefficient	0.652	1.000
	Sig. (2-tailed)	0.001	.
	N	400	400

3.4.3 Correlation between residence location and transportation mode

Table 15 shows a correlation coefficient of 0.632 between residence location and mode of transport, suggesting a moderate positive relationship. This indicates that the location of a person's residence significantly impacts their choice of transport mode.

Table 15

Correlation between Residence location and transportation mode

		Residence location	Transport mode used for travel
Residence	Correlation Coefficient	1.000	0.632
	Sig. (2-tailed)	.	0.001
	N	400	400
	Correlation Coefficient	0.632	1.000
Transport mode used for travel	Sig. (2-tailed)	0.001	.
	N	400	400

3.5 Analysis of Existing and Catchments Routes of Public Transportation by GIS

There are multiple processes involved in creating an entire route map that defines the current public transit routes. Since Geographic Information System (GIS) data offers detailed spatial information that is included with route information. The different forms of public transportation, their routes, stops, and important areas of interest should all be represented on the map, as shown in Fig. 13.

Route Information data is obtained from public transportation authorities (RTA Department) and on-site surveys regarding all available routes for public transportation, types of transportation, and their schedule timing.

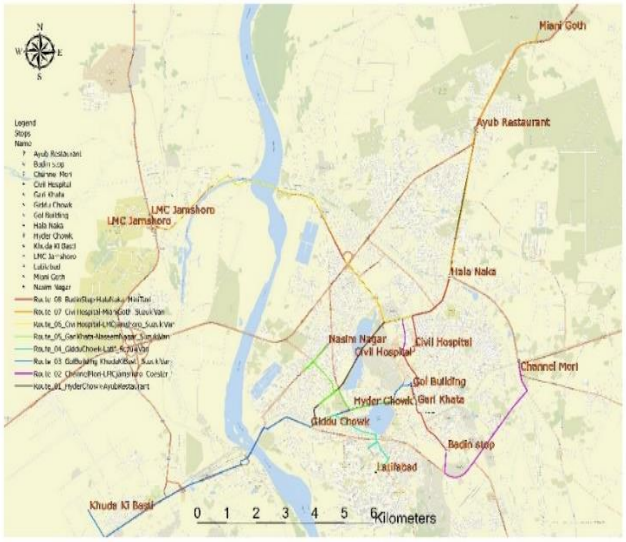

Fig. 13. Existing Routes of Public Transport by Using GIS

In GIS, open data portals such as OpenStreetMap are used, which have existing route data. The Map Digitizes the Routes (land uses), and Routes are drawn with the help of a polyline tool to draw each transportation route on the map, following the exact path from the collected data. Each route is labelled with its name or number for easy identification. Points are used as markers to indicate each stop or station along the routes.

After that, the Network Dataset in ArcGIS is built by a network analyst tool. Select the road network and public transportation routes as sources for the network dataset. Analyze the output, which includes optimal paths, service coverage areas, or facility locations.

Hyderabad City uses GIS to create a comprehensive network dataset for public transportation routes, permitting detailed analysis and improved decision-making for transportation planning and management.

Fig. 14 shows the catchment areas for existing public transportation routes in Hyderabad. It involves the areas from which passengers can easily access these routes. So, the map is useful for understanding the service coverage and identifying gaps in the public transport network. It generated service area polygons to see the coverage of each public transportation stop.

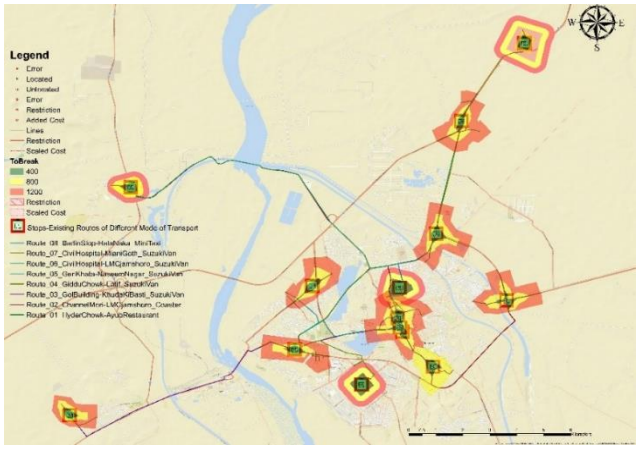

Fig. 14. Catchment Areas Of Existing Public Transport Routes In Hyderabad City

The map illustrates the service area coverage of the existing public Transit route network based on walkable distances converted to travel times. The service areas are categorized as follows:

- 400 meters (5-minute walk): This zone represents areas within a 5-minute walking distance from public Transit. It highlights the immediate accessibility of the public transport system for nearby residents and commuters.
- 800 meters (10-minute walk): The second zone extends to areas within a 10-minute walking distance, capturing neighborhoods and facilities slightly farther from the stops but still accessible on foot.
- 1200 meters (15-minute walk): This outermost zone depicts areas within a 15-minute walking distance from the public transport stops, providing insight into the broader reach of the network.

Each zone is represented with distinct colour gradients to differentiate between the levels of service coverage. The analysis aims to identify the extent of accessibility provided by the existing Transit system and highlight potential gaps in coverage that may require intervention to improve urban mobility.

3.6 Research Contribution

This research contributes to the field of Transit-Oriented Development (TOD) by shifting the focus from established urban centres in developed countries to emerging cities in developing regions. It provides a comprehensive analysis of TOD for underdeveloped cities, addressing the unique challenges posed by rapid urbanization and underdeveloped infrastructure. The study's findings are particularly related to reviewing the flow of traffic, travel patterns, peak hours, and public transportation schedules.

4. Conclusion

Public transportation in Hyderabad is relatively affordable compared to private vehicles, helping residents save on daily commuting costs. It improves access to business districts and markets, enhancing economic activities and job opportunities. The usage of GIS (Geographical Information Systems) aids in the visualization of all data on maps and the easy identification of elements through geo referencing. The study's findings led to a reduction in traffic congestion and the optimal pattern for transit services in Hyderabad City, Pakistan. Residents in areas near public transport can easily access essential services, including education, healthcare, and employment opportunities. Promoting TOD policies can further enhance the benefits of areas near public transport by encouraging mixed-use developments and higher density around transit hubs. Increased foot traffic and activity around public transportation hubs can lead to improved public safety and reduced crime rates. The more people are walking, the more they will have chances to slip, fall, and pickpocket.

This study introduces a GIS-based TOD framework for addressing travel and transportation issues in Hyderabad, Sindh. Future research can expand on this approach by incorporating real-time mobility data, multimodal transport integration, and socio-economic factors.

5. Statements and Declarations

5.1 Funding

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5.2 Competing Interests

The authors declare no competing interests.

5.3 Author Contributions

Sania Rehman memon was solely responsible for the conceptualization, methodology, investigation, data curation, formal analysis, writing (original draft and revisions), visualization, and project administration under the supervision of Mir Aftab Talpur, Imtiaz Chandio, and Ali Raza Khoso.

6. References

[1] F. Shatu, L. Aston, L. B. Patel, and M. Kamruzzaman, "Transit-oriented development:

A bibliometric analysis of research", Advances in Transport Policy and Planning, 1st ed., vol. 9. Elsevier Inc., 2022.

[2] F. Baig, S. Shaikh, and M. A. H. Talpur, "Motorization and under-reported road accidents: Spatial evidence from Pakistan", Mehran University Research Journal of Engineering & Technology, vol. 40, no. 3, pp. 482–495, 2021. [Online].

[3] O. S. Azeez, H. Z. Shafri, A. H. Alias, and N. A. Haron, "Integration of object-based image analysis and convolutional neural network for the classification of high-resolution satellite image: A comparative assessment", Applied Sciences, vol. 12, no. 21, p. 10890, 2022.

[4] K. Kepaptsoglou, C. Milioti, D. Spyropoulou, F. Haider, and A. G. Karlaftis, "Comparing traveler preferences for BRT and LRT systems in developing countries: Evidence from Multan, Pakistan", Journal of Traffic and Transportation Engineering (English Edition), vol. 7, no. 3, pp. 384–393, 2020.

[5] J. Monteiro, N. Sousa, J. Coutinho-Rodrigues, and E. Natividade-Jesus, "Challenges ahead for sustainable cities: An urban form and transport system review", Energies, vol. 17, p. 409, 2024.

[6] P. Ricardianto, A. Suryobuwono, E. Liana, and E. Endri, "Implementation strategy of transit-oriented development based on the bus rapid transit system in Indonesia", Decision Science Letters, vol. 12, no. 3, pp. 551–560, 2023.

[7] M. H. Abdi, "What the newcomers to transit-oriented development are confronted with? Evidence from Iranian policy and planning", Journal of Transport Geography, vol. 92, p. 103005, 2021.

[8] M. A. H. Talpur, T. H. Ali, I. A. Chandio, and F. A. Shaikh, "Transportation planning studies for socio-economic development of depressed sub-regions: A review", Mehran University Research Journal of Engineering & Technology, vol. 37, no. 3, pp. 603–614, 2018.

[9] S. Qureshi, I. A. Memon, and M. A. H. Talpur, "Association between objectively measured neighborhood built environment and walkability", Mehran University Research Journal of Engineering & Technology, vol. 41, no. 1, pp. 157–168, 2022.

[10] J. P. Rodrigue, "Transportation and the geographical and functional integration of global production networks", Growth and Change, vol. 37, no. 4, pp. 510–525, 2006.

[11] N. J. A. Van Exel and P. Rietveld, "Could you also have made this trip in another mode? An investigation of perceived travel possibilities of car and train travelers on the main travel corridors to the city of Amsterdam, The Netherlands", Transportation Research Part A: Policy and Practice, vol. 43, no. 4, pp. 374–385, 2009.

[12] J. Riaz and F. Naz, "Socio-political impacts and challenges of urbanization on Pakistan", Pakistan Journal of International Affairs, vol. 7, no. 2, 2024.

[13] P. R. Bipin, A Comprehensive Study on Footpath Encroachment and Governance Interventions – A Case of Ahmedabad, Doctoral dissertation, The Maharaja Sayajirao University of Baroda, 2024.

[14] A. M. Espitia, Transforming Urban Mobility: A Multidimensional Analysis of the Bus Rapid Transit System of Mexico City, 2010.

[15] M. M. Aboulnaga, M. F. Badran, and M. M. Barakat, "Global informal settlements and urban slums in cities and the coverage", Resilience of Informal Areas in Megacities – Magnitude, Challenges, and Policies: Strategic Environmental Assessment and Upgrading Guidelines to Attain Sustainable Development Goals, pp. 1–51, 2021.

[16] J. Stehlin, "'Freeways without futures': Urban highway removal in the United States and Spain as socio-ecological fix?", Environment and Planning E: Nature and Space, vol. 7, no. 3, pp. 1391–1417, 2024.

[17] N. A. Unar, N. H. Mirjat, B. Aslam, M. A. Qasmi, M. Ansari, and K. Lohana, "Modeling and analysis of load growth expected for electric vehicles in Pakistan (2021–2030)", Energies, vol. 15, p. 5426, 2022.

[18] J. N. O'Sullivan, "Demographic delusions: World population growth is exceeding most projections and jeopardizing scenarios for sustainable futures", World, vol. 4, no. 3, pp. 545–568, 2023.

[19] H. Yaqoob et al.., "Current status and potential of tire pyrolysis oil production as an alternative fuel in developing countries", Sustainability, vol. 13, no. 6, p. 3214, 2021.

[20] F. Baig, I. A. Rana, and M. A. H. Talpur, “Determining factors influencing residents’ satisfaction regarding urban livability in Pakistan”, International Journal of Community Well-being, vol. 2, pp. 91–110, 2019.

[21] R. Jiang, P. Wu, and C. Wu, “Driving factors behind energy-related carbon emissions in the US road transport sector: A decomposition analysis”, International Journal of Environmental Research and Public Health, vol. 19, no. 4, p. 2321, 2022.

[22] R. Cervero, B. Caldwell, and J. Cuellar, “Bike-and-ride: Build it and they will come”, Journal of Public Transportation, vol. 16, no. 4, pp. 83–105, 2013.

[23] M. H. Abdi and P. J. Lamíquiz-Daudén, “Transit-oriented development in developing countries: A qualitative meta-synthesis of its policy, planning and implementation challenges”, International Journal of Sustainable Transportation, vol. 16, no. 3, pp. 195–221, 2022.

[24] A. Terpo, Metamorphosis through Transition: The Application of TOD as Mobility/Land-Use Model and Its Applicability in the Case of Tirana, 2022.

[25] H. Shawly, “Evaluating compact city model implementation as a sustainable urban development tool to control urban sprawl in the city of Jeddah”, Sustainability, vol. 14, no. 20, p. 13218, 2022.

[26] F. Filippi, “A paradigm shift for a transition to sustainable urban transport”, Sustainability, vol. 14, no. 5, p. 2853, 2022.

[27] Y. Yang, Z. Dong, B. B. Zhou, and Y. Liu, “Smart growth and smart shrinkage: A comparative review for advancing urban sustainability”, Land, vol. 13, no. 5, p. 660, 2024.

[28] J. B. H. Yap, C. Y. Chua, and M. Skitmore, “Towards sustainable mobility with transit-oriented development (TOD): Understanding greater Kuala Lumpur”, Planning Practice & Research, vol. 36, no. 3, pp. 314–336, 2021.

[29] D. Akin and D. Kara, “Multicriteria analysis of planned intercity bus terminals in the metropolitan city of Istanbul, Turkey”, Transportation Research Part A: Policy and Practice, vol. 132, pp. 465–489, 2020.

[30] A. Ceder, “Urban mobility and public transport: Future perspectives and review”, International Journal of Urban Sciences, vol. 25, no. 4, pp. 455–479, 2021.

[31] M. Gallo and M. Marinelli, “Sustainable mobility: A review of possible actions and policies”, Sustainability, vol. 12, no. 18, p. 7499, 2020.

[32] M. Sohaib et al., “Improving urban road infrastructure analysis and design using an integrated BIM-GIS and traffic microsimulation framework”, Innovative Infrastructure Solutions, vol. 9, no. 7, p. 285, 2024.

[33] Y. H. Kuo, J. M. Leung, and Y. Yan, “Public transport for smart cities: Recent innovations and future challenges”, European Journal of Operational Research, vol. 306, no. 3, pp. 1001–1026, 2023.

[34] A. Baobeid, M. Koç, and S. G. Al-Ghamdi, “Walkability and its relationships with health, sustainability, and livability: Elements of the physical environment and evaluation frameworks”, Frontiers in Built Environment, vol. 7, p. 721218, 2021. [35] M. A. H. Talpur, S. H. Khahro, S. Abro, and H. Shaikh, “Measuring GIS-based pedestrian accessibility to bus stops: A sustainable approach to easing urban traffic problems at Hyderabad, Pakistan”, Discover Cities, vol. 1, no. 1, p. 28, 2024.

[36] S. Gopal, “Interplay of smuggling of foreign currencies and illegal import of gold through passengers at international airports: An analysis”, International Journal of Law, Management & Humanities, vol. 5, no. 6, p. 38, 2022.

[37] F. Baig, I. A. Rana, and M. A. H. Talpur, “Determining factors influencing residents’ satisfaction regarding urban livability in Pakistan”, International Journal of Community Well-being, vol. 2, pp. 91–110, 2019.

[38] A. Talpur, F. Baig, A. Pervez, and J. J. Lee, “Analysis of travel decision behaviour during extreme floods in Pakistan”, Transportation Safety and Environment, vol. 2025,

[39] S. R. Memon, M. A. H. Talpur, and F. J. Arain, “Site suitability for intercity bus terminal at Hyderabad, Pakistan: A citizen's perception”, Mehran University Research Journal of Engineering & Technology, vol. 42, no. 4, pp. 93–108, 2023.

[40] S. H. Khahro, M. A. H. Talpur, M. G. Bhellar, G. Das, H. Shaikh, and B. Sultan, “GIS-based sustainable accessibility mapping of urban parks: Evidence from the second largest settlement of Sindh, Pakistan”, Sustainability, vol. 15, no. 7, p. 6228, 2023.