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Analyzing the Socio-Economic Effects of BRT Redline Construction on Local Communities and Transport Patterns: Karachi

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ABSTRACT

The BRT Redline construction initiative, a major infrastructure project, has resulted in a significant transformation within the community transportation system. This study explores the no of impact of this construction on the residents' lives and businesses along its route, focusing on social, economic, and environmental aspects. Utilizing detailed surveys, the research presents a thorough examination of the community's perceptions, concerns, and experiences regarding the ongoing construction. The survey data shows a high level of awareness among respondents and a considerable impact of BRT construction on daily life, including increased traffic congestion, changes in transportation patterns, and challenges for businesses. Additionally, the study also involves the deep analysis of environmental pollutants and microclimatic factors, encompassing CO2, Total Volatile Organic compounds and Formaldehyde emission mapping, noise level evaluations, and assessments of temperature and humidity variations. These environmental metrics corroborate the qualitative feedback, demonstrating tangible alterations in the local environment during the construction phase. The research emphasizes the interconnectedness between perceived socio-economic implications highlighted in the survey responses and the quantifiable environmental changes, advocating for a holistic approach in managing community concerns and environmental impacts associated with large-scale infrastructure projects. The synthesis of qualitative and quantitative data underscores the need for collaborative strategies, aiming to address community apprehensions, enhance socio-economic well-being, and sustain environmental harmony amid infrastructural development.

Key Words: BRT Redline Construction, Infrastructure Development, Community Impact, Survey Data, Environmental Monitoring, Traffic Congestion, Transportation Patterns

INTRODUCTION

The mass urban transit systems play a crucial role in building the socio-economic landscape of a city. In rapidly expanding metropolises like Karachi, where rapidly increasing population intersects with the demand for efficient public transit, the implementation of infrastructural projects such as the Bus Rapid Transit (BRT) Redline Construction stands as a critical intervention. Karachi, being Pakistan's economic hub of the country and one of the most populous cities globally, copping with intricate challenges of mobility, economic development, and societal dynamics. The advent of the BRT Redline Construction project in Karachi heralds an era of significant transformation in the city's transportation network. It aims to reduce traffic congestion, enhance accessibility, and bolster the socio-economic fabric of the region by providing a modern and efficient transit system. Understanding the multifaceted impact of this infrastructural endeavor is crucial to comprehensively assess its implications on both social and economic realms.

Social Dynamics: The socio-cultural dynamics surrounding transportation infrastructures like the BRT Redline Construction route in Karachi extend beyond mere commuting convenience. They encapsulate elements of accessibility, social inclusion, and community integration. The influence of this transit system on the daily lives, social interactions, and well-being of the populace within the vicinity of the route merits close examination. According to Mahmoud and Khan (2019), urban transportation systems significantly shape social interactions, affecting community dynamics and fostering inclusivity. Furthermore, as highlighted by Ahmed et al. (2020), equitable access to transportation has a profound impact on the quality of life, particularly for marginalized communities. Understanding these social dynamics is imperative to gauge the extent of positive societal changes that the BRT Redline Construction might catalyze.

Economic Implications: From an economic perspective, transportation infrastructure projects have far-reaching implications on a city's economic vitality, trade, and employment opportunities. The BRT Redline Construction project is anticipated to not only streamline commuting but also stimulate economic activities along its corridor, potentially revitalizing local businesses and enhancing employment prospects.

Research by Khan and Qureshi (2018) underscores the crucial role of transit infrastructure in fostering economic growth and development. Similarly, studies by Siddiqui et al. (2021) highlight the potential for improved transportation networks to attract investments and enhance productivity within urban centers. Evaluating these economic ramifications is essential to gauge the project's efficacy in fostering sustainable economic growth. The Bus Rapid Transit (BRT) system is a crucial component of urban transportation, designed to enhance efficiency and accessibility in densely populated cities. The proposed Red Line BRT service on University Road in Karachi is a significant development in this regard, connecting Safoora Chorangi to M.A. Jinnah Road. This initiative aims to improve traffic jamming and provide efficient mode of transportation for residents and commuters along this vivacious arterial route. Karachi, as Pakistan's largest city, copes with significant challenges in managing its transportation infrastructure. The origin of this project can be traced back to an all-inclusive urban mobility study, undertaken to address the escalating transportation problems encountered by Karachi. This undertaking aligns pleasantly with the broader aspiration of advancing sustainable and effective public transportation systems in urban environments.

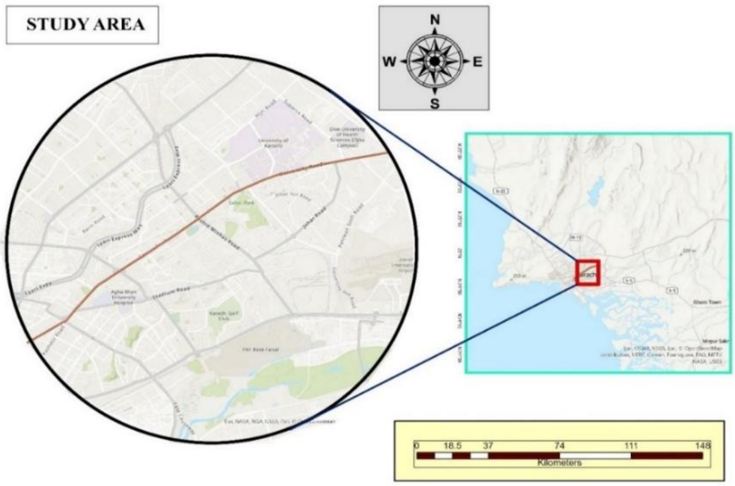

Fig. 1 Shows the BRT redline Construction Route

The proposed BRT route spanning from Safoora to M.A Jinnah Road in Karachi stands as a pivotal endeavor in revolutionizing the city's transportation infrastructure. Its significance emanates from multifaceted advantages that encompass not only the alleviation of traffic congestion but also the augmentation of accessibility for residents relying on public transport. Moreover, the route's integration with existing bus networks promises a seamless transportation experience, fostering an enhanced quality of life by reducing the stress associated with daily commutes. Embracing sustainable transportation practices, this BRT system not only curtails emissions but also stimulates economic activity through improved connectivity, potentially generating increased business opportunities.

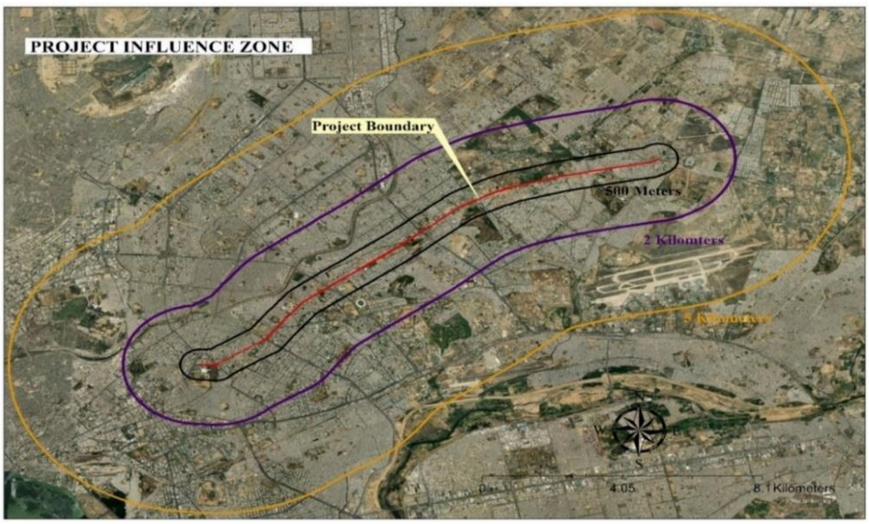

Fig. 2 Shows the BRT Project Influence Zone

Study area: The study area, encompassing the proposed BRT Redline Construction route in Karachi, spans from Safoora to M.A Jinnah Road, as shown on figure3, serving as a critical focal point in the city's transportation infrastructure. Karachi, as Pakistan's largest and most densely populated city, faces profound challenges in managing its urban mobility amidst rapid urbanization. The designated BRT route not only traverses through highly congested areas but also connects vital commercial, residential, and educational hubs, making it a nucleus of socio-economic activities within the metropolis. The area's socio-cultural diversity, comprising varied communities, businesses, and institutions, underscores the route's significance in fostering inclusivity and accessibility. Moreover, its potential impact on local businesses, employment opportunities, and the daily lives of residents necessitates a comprehensive examination of the interplay between the BRT Redline Construction route and the social fabric of Karachi's diverse populace.

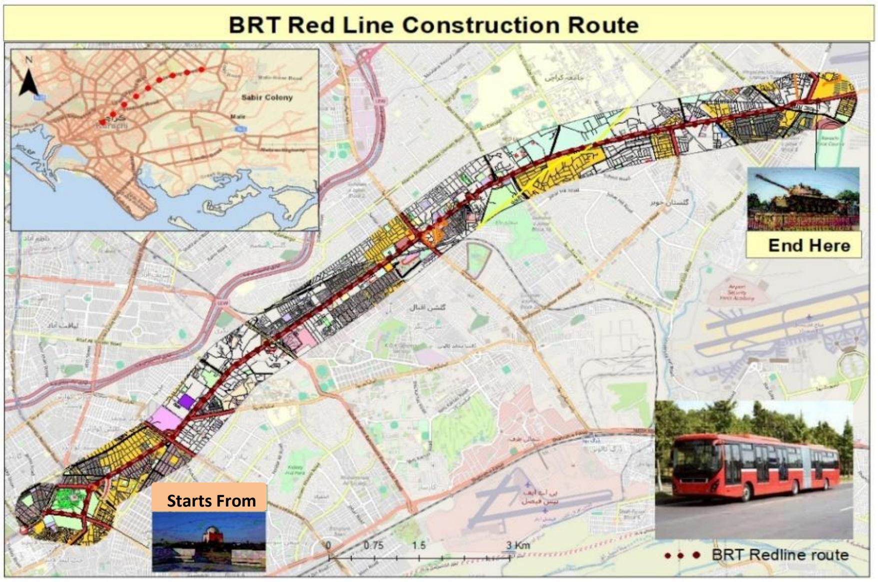

Fig. 3 shows the study area of research

Aims and Objective

Social Objectives:

- Assess the BRT route's impact on community integration and social cohesion along the corridor.
- Analyze changes in daily commuting habits and social interactions resulting from the BRT system.
- Evaluate the accessibility and inclusivity of the BRT for diverse socio-economic groups in Karachi.

Economic Objectives:

- Investigate the route's influence on local business activity and employment opportunities.
- Assess the economic viability of the BRT system, considering its impact on trade and economic growth.
- Analyze the cost-benefit ratio of the BRT implementation concerning its economic impacts in Karachi.

LITERATURE REVIEW

The literature review encompasses a global perspective on the expansion of Bus Rapid Transit (BRT) and Buses of High Level of Service (BHLS) systems, emphasizing their notable growth and success factors, as discussed by Finn (2011), Hensher (1999), (Hidalgo & Gutiérrez, 2013) It delves into the implementation of BRT in Karachi, Pakistan, revealing insights from Khan (2022) regarding its low costs, optimized capacity, and potential for minimizing transport costs. Evaluation of BRT projects in Pakistani cities using IDTP standards is discussed by Haider et al. (2021), emphasizing the need for adherence to standards for future projects (Ferenchak, 2022)) study on the impact of BRT on traffic safety, particularly using the Albuquerque Rapid Transit (ART) system, highlights a significant reduction in collisions and fatalities. (Trubia, et al, 2020)) Underscore the importance of BRT systems in urban transportation, emphasizing their affordability and flexibility, with potential integration with autonomous vehicles (Levinson, 2022)overview provides insights into the popularity of BRT due to its cost-effectiveness and flexibility. (Vecino-Ortiz, et al, 2015) Discussion focuses on the limited and mixed evidence on the safety benefits of BRT systems. (Hoogervorst, 2023)) Study addresses the challenge of balancing BRT investments within budget constraints, exploring trade-offs between passenger attraction and budget limitations. Akbar (2020) sheds light on transportation challenges in Karachi and the potential alleviation through the BRT system. (Huyen T.K. Le et al, 2022)Investigate the impact of BRT systems on property values in the United States, revealing varied effects. The call for more empirical research on the impact of BRT systems on road safety in developing countries is highlighted. (Nadimi, et al, 2023)) Proposed method for BRT route planning considers budget constraints, offering insights into efficient corridor selection. (Vergel-Tovar, et al., 2022). (2022) study the impact of BRT systems on land use in Bogotá and Quito, emphasizing changes in activities and development intensity. (Puspitasari, S. W., et al, 2022)discuss the mode share sensitivity analysis for BRT infrastructure in the new capital city of Indonesia, emphasizing economic benefits. (Liu J, et al, 2022)spatio-temporal analysis of BRT in Shennongjia highlights the importance of balancing economic growth with ecological preservation. (Nazir, H., et al, 2023)Investigation into the impact of the M-9

Motorway on property values in Bahria Town Karachi addresses effects of proximity on property prices. Satrio et al. (2023) assess the positive impact of BRT systems on economic growth and reduced unemployment in Jakarta. Tyndall et al.'s (2022) study in Vancouver, Washington, indicates higher property prices near BRT stations, raising concerns about gentrification. (Mingyu Lu, 2022)discusses the comprehensive benefits of BRT, using Hefei BRT Line 1 as a case study. Finally, Hefei BRT Line 1 explores the impact of BRT systems on ecosystem services value (ESV) in Shennongjia, indicating a significant increase driven by factors like climate regulation and biodiversity (Liu, 2023)

MATERIAL AND MEATHODS

Qualitative and Quantitative Method: Qualitative research is a methodological perspective employed to gain a deep apprehension of social phenomena, often within their natural contexts. Focused on exploring the intricacies of common man reviews, attitudes, and experiences, qualitative research embraces diverse data collection methods, such as interviews, focus groups, observations, and case studies. These techniques facilitate the collection of rich, non-numerical data that captures the complexity and depth of the studied phenomena. Our research methodology involved gathering non-numerical data on the social cohesion and environmental impacts of Bus Rapid Transit (BRT) systems through in-person interviews and questionnaires filling. In participant selection, we intentionally chose a simple random sampling technique, encompassing BRT users, community members, urban planners, environmental experts, and policymakers to ensure a comprehensive range of perspectives.

Unlike the qualitative data, a quantitative analysis related to the collection of calculable data approach to assess various environmental parameters around the Bus Rapid Transit (BRT) system. The statistical data collected in the field included microclimate indicators such as temperature and humidity, as well as concentrations of air pollutants like carbon dioxide,

$$Z(x_0, y_0) = \frac{\sum_{i=1}^{n} \frac{Z_i}{d_i^p}}{\sum_{i=1}^{n} \frac{1}{d_i^p}}$$

Total Volatile Organic Compounds (TVOC), and formaldehyde. To analyze and represent the spatial distribution of these parameters, we use ArcGIS Desktop and ArcGIS Pro.

Spatial Interpolation: We employed the IDW (In ArcGIS, you can find the IDW tool in the "Spatial Analyst" in "Interpolation" in toolbox method in ArcGIS Desktop and ArcGIS Pro to interpolate data points collected on three places (University road, Neepa chorangi and Bagh-e-Jinnah), creating continuous surfaces that represent the spatial distribution of microclimate variables (temperature and humidity) and air pollutants (carbon dioxide, TVOC, formaldehyde).

$Z(x0, y0)$: The interpolated value at the target location

n: The number of sample points (data points with known values).

Zi: The known value at the i-th sample point.

di: The distance between the target location and the i-th sample point.

p: The power parameter, which controls the influence of distance on the weights.

The formula calculates the interpolated value at a target location based on the weighted average of the known values at nearby sample points. The weights are determined by the inverse of the distances raised to the power (p). The numerator sums up the products of each known value and its corresponding weight, while the denominator sums up the weights. The result is a weighted average ArcGIS works on this principle.

Land cover & Land use Analysis: To understand the land-use characteristics around the BRT system, we applied the ArcGIS tool to create a 500-meter buffer around the BRT route. Within this buffer (In ArcGIS, you can find the Buffer tool in the "Proximity Analysis" or "Geoprocessing" in toolbox). We conducted a land-use and land-cover (LULC) analysis using available datasets. The aim was to categorize and quantify the different land uses within the specified distance, providing deep insights of the urban environment surrounding the BRT infrastructure.

Terrain Analysis: In our research methodology, we expanded the analysis to include terrain analysis by extracting data from SRTM 30m by USGS and Google Earth Pro. This integration complements our investigation into the socio-environmental impacts of the Bus Rapid Transit (BRT) system. We acquired high-resolution elevation data from SRTM 30m, known for its detailed digital elevation models, and used Google Earth Pro for initial visualizations. Using GIS tools, particularly in ArcGIS, we processed the elevation data, extracting relevant features along the BRT route and conducting slope, aspect, and visibility analyses. These analyses provided insights into terrain characteristics, including slope inclinations, slope orientations, and visible areas from specific locations. The results were then integrated with environmental data from our quantitative analysis, enhancing our understanding of how terrain features influence the environmental context around the BRT system.

RESULTS AND DISCUSSION

In the pursuit of unraveling the intricacies of our research objectives, we embarked on a comprehensive survey across diverse urban landscapes. Our investigation focused on three distinct survey spots: University Road, Neepa, and M.A Jinnah Road. The utilization of geographic information systems (GIS) allowed us to spatially visualize and analyze the data collected at each spot, enabling a nuanced understanding of the spatial patterns and variations that may influence our findings. In this section, we present the outcomes derived from these survey spots, delving into the unique characteristics of University Road, the intricacies of Neepa, and the distinctive features of M.A Jinnah Road. The juxtaposition of results from these diverse locations offers a holistic perspective on the broader implications of our study, shedding light on the interconnected nature of urban phenomena

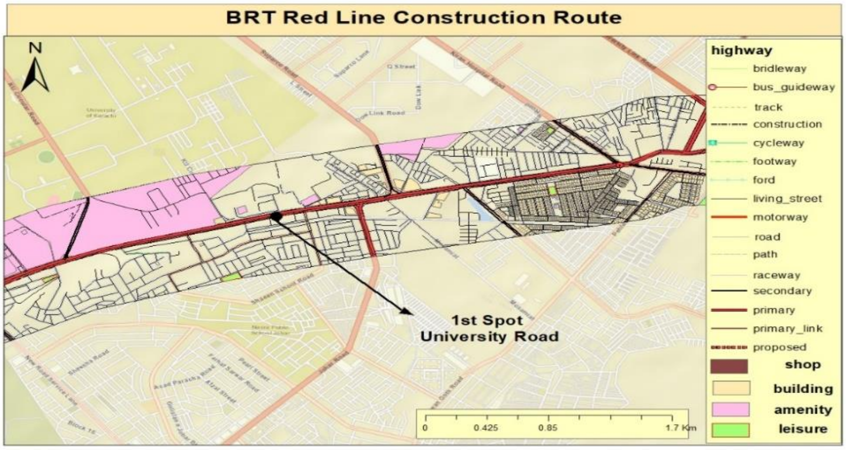

Fig. 4 a shows the survey spot 1

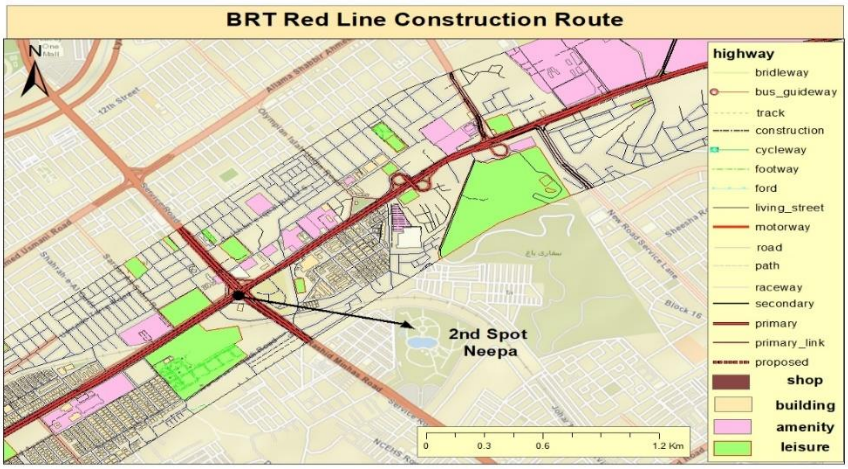

Fig.4 b shows the survey spot 2

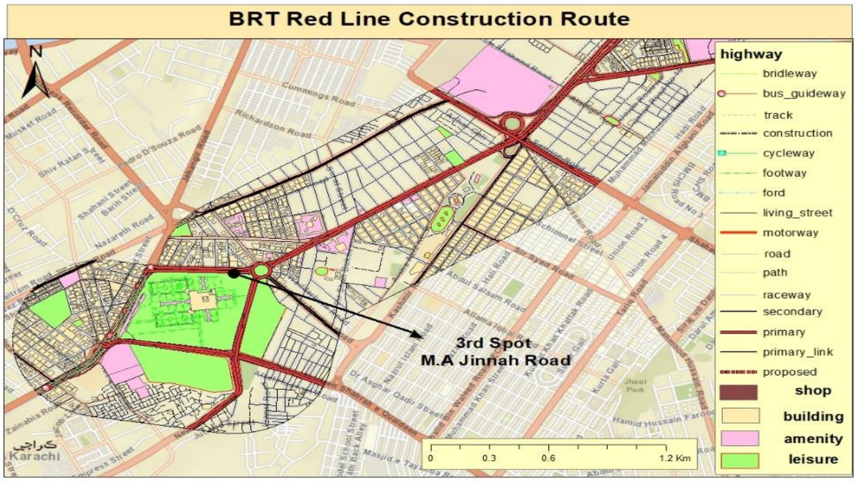

Fig. 4 c shows the survey spots 3

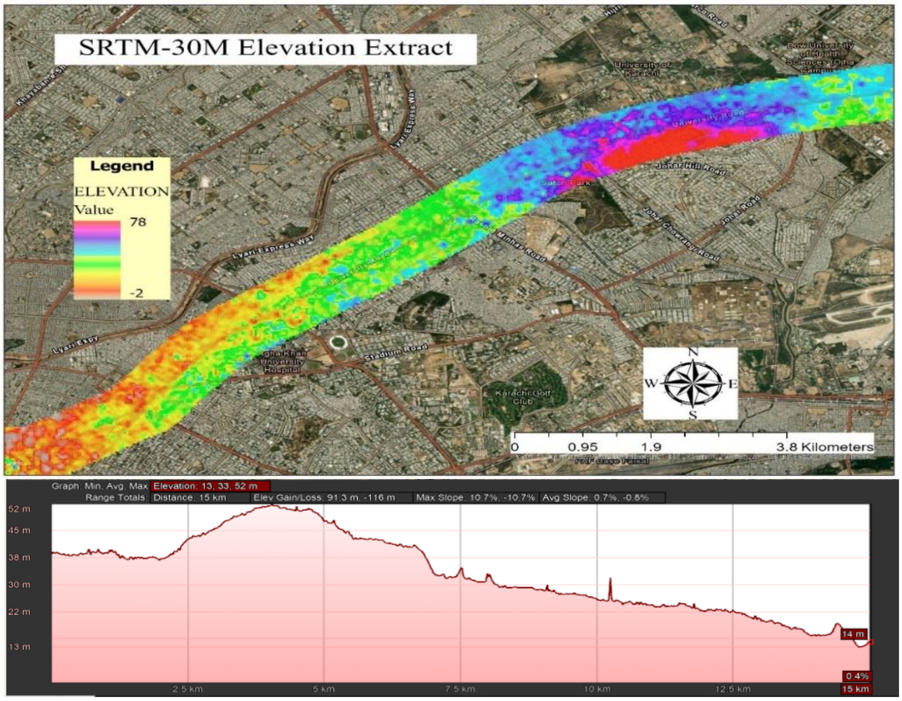

Fig. 5 Elevation Profile along BRT route

Leveraging the SRTM 30-meter extract and Google Earth's elevation profile tool, our study area, encompassing University Road, Neepa, and M.A Jinnah Road, unfolds with unprecedented detail. The high-resolution SRTM map unveils nuanced topographic features, portraying the undulating terrain of our urban landscape. Complemented by dynamic elevation profiles, we gain insights into elevation variations along the surveyed locations.

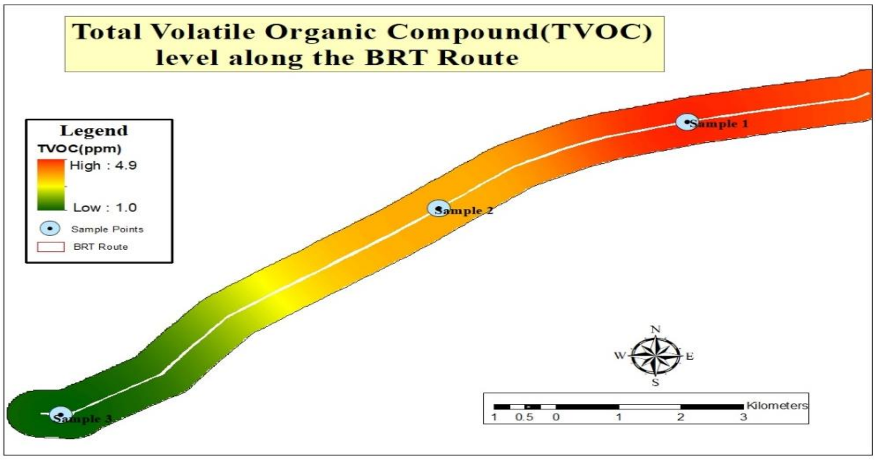

Fig. 6 TVOC Distribution along BRT route

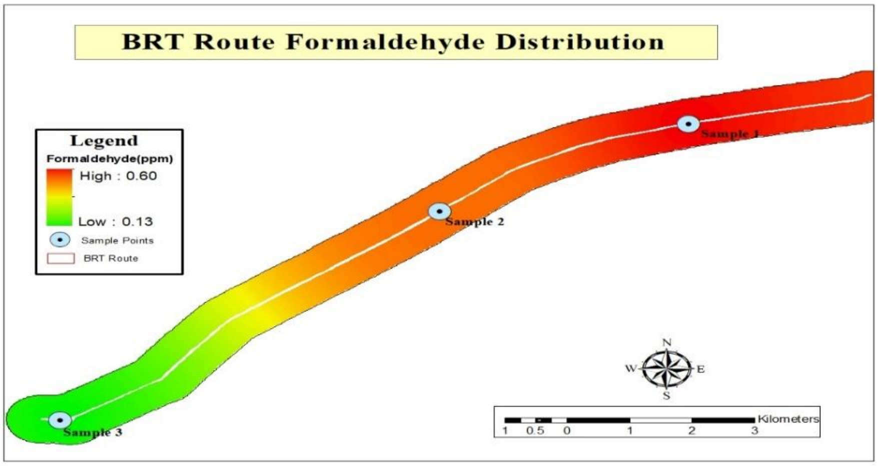

Fig. 7 Formaldehyde Distribution along BRT route

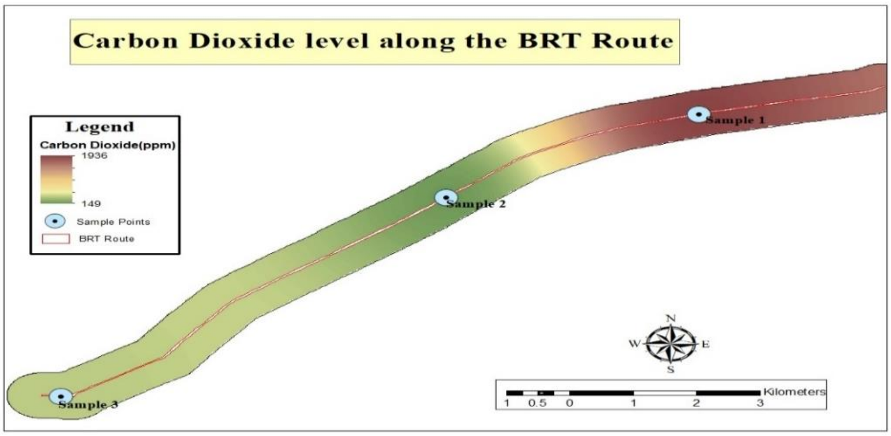

Fig. 8 Carbon Dioxide Distribution along BRT route

The map on figure 8, depicting the distribution of air pollutants—carbon dioxide (CO_2), total volatile organic compounds (TVOC), and formaldehyde—along the bus rapid transit (BRT) route, which is gathered by three distinct regions (i.e. University Road, Neepa Chorangi & Bagh-e-Jinnah), offers a comprehensive snapshot of the air quality dynamics in the urban environment. In areas marked as Sample 1, which is University Road, characterized by higher levels of all three pollutants, there is a clear indication of potential pollution hotspots. This is due to the attributed factors such as heavy traffic congestion, surface drains, or other localized sources emitting significant quantities of CO_2, TVOC, and formaldehyde. Residents and commuters traversing these zones may face heightened health risks due to increased exposure to multiple air pollutants, warranting urgent attention to identify and mitigate the sources contributing to the elevated pollution levels. On Neepa collected our sample 2, where medium levels of CO_2, TVOC, and formaldehyde are observed, and the maps 8, 12,13 suggests a moderate degree of pollution along specific segments of the BRT route. This is the result of a combination of residential, commercial, and traffic-related sources contributing to air quality degradation. Implementing comprehensive monitoring and regulatory measures in these areas becomes crucial to strike a balance between urban development and the preservation of air quality standards. Conversely, Sample 3 i.e Bagh-e-Jinnah represents areas with lower levels of all three pollutants, indicating regions along the BRT route with relatively cleaner air. These areas encompass larger green spaces and zones with limited industrial activities. Residents and commuters in these locales may benefit from better air quality, contributing to overall well-being and potentially reducing health risks associated with air pollution.

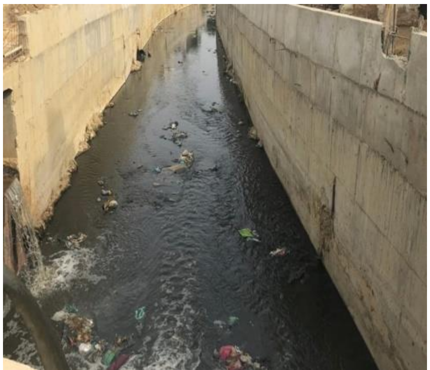

Fig. 9 Surface drains observed on University road

Fig. 10 Construction condition along the route

Fig. 11 Traffic congestion along the route observed

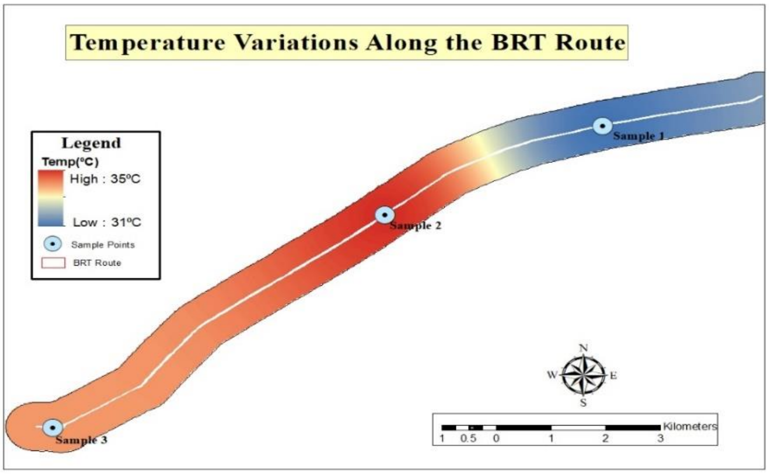

Fig. 12 Shows Temperature variability along BRT route

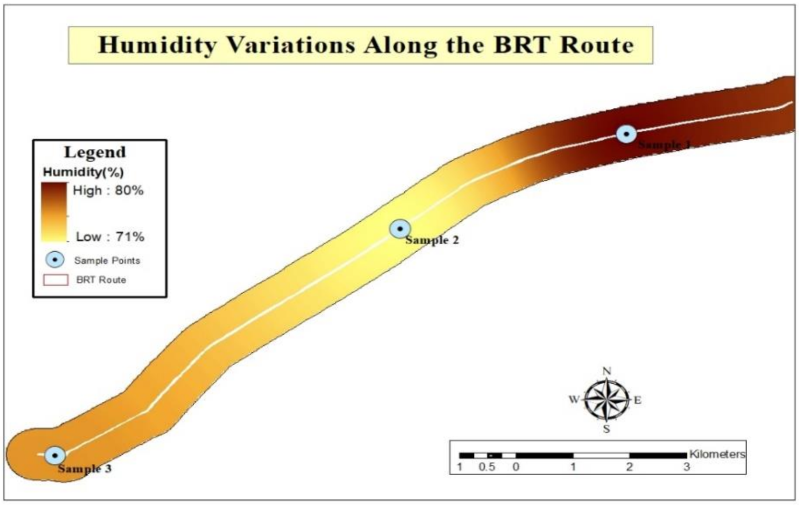

Fig. 13 Shows Relative Humidity variability along BRT route

The map on fig. 12, illustrating temperature variability along the bus rapid transit (BRT) route at three distinct spots provides valuable insights into the local microclimates and factors influencing temperature differences. In the first spot that is University of Karachi Road, where lower temperatures are observed, it suggests due to the presence of factors that contribute to a cooler environment. This is due to the presence of vegetation and shade that allows for better heat dissipation contrastingly, at the second spot (Neepa Chorangi) where higher temperatures of 35°C are noted, it is the consequence of traffic congestion and reduced vegetation that is contributing to elevated temperatures. The heat generated by vehicles, combined with the lack of greenery to provide shade and absorb sunlight, could be causing localized warming. This highlights the impact of urban heat island effects, where human activities and the built environment led to increased temperatures in urban areas. In the third spot, Bagh-e-Jinnah, where temperatures of 34°C are observed, the presence of a park or green space is playing a mitigating role. The vegetation in the area may be providing shade, cooling the surroundings, and contributing to a more pleasant microclimate. Parks and green spaces are known for their cooling effects as they absorb sunlight and release moisture through a process known as evapotranspiration.

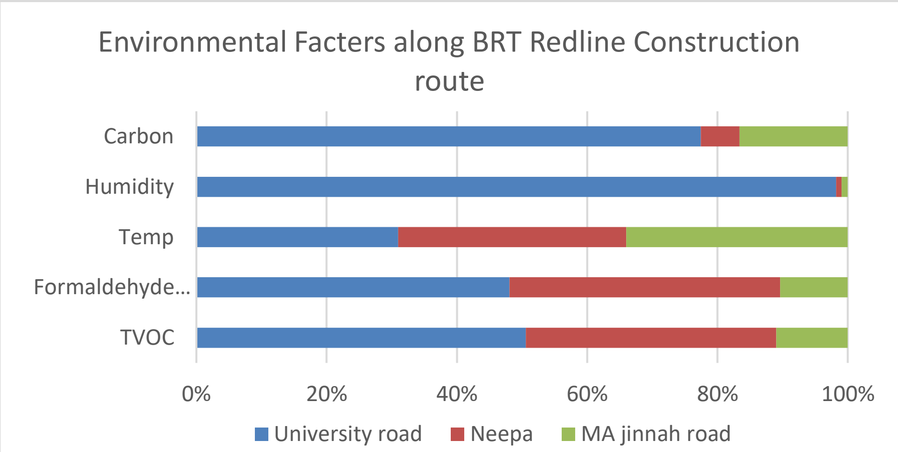

Fig. 14 Environmental Factors along BRT Redline Construction route

The map on Fig. 13 shows relative humidity level on the bus rapid transit (BRT) route at three distinct regions revealing significant differences in local microclimates. In the first spot, where a higher humidity level of 80% is observed, it indicates a more moisture-containing atmosphere. This is influenced by factors such as vegetation, or climatic conditions that promote moisture retention. The elevated humidity level might contribute to a more humid and potentially milder climate in this area. In contrast, the second sample was collected from Neepa Chorangi, showing a lower humidity level of 71%. This could be attributed to various factors such as urbanization, reduced greenery, or local weather patterns that result in a drier environment. The lower humidity level might lead to a drier and potentially warmer microclimate, impacting the local comfort and atmospheric conditions. The third spot, Bagh-e-Jinnah, exhibits a moderate humidity level of 76%. This suggests a balanced moisture content in the air, possibly influenced by the presence of green spaces like parks or gardens. Such areas often contribute to a more pleasant microclimate, as vegetation releases moisture through transpiration, which can help maintain a comfortable level of humidity.

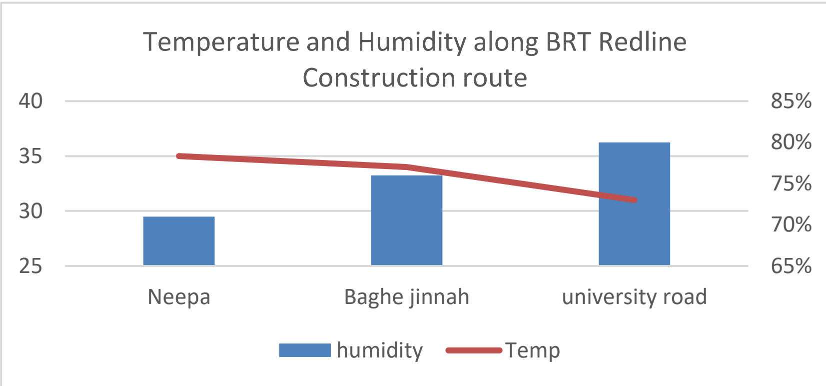

Fig. 15 Temperature and Humidity along BRT Redline Construction route

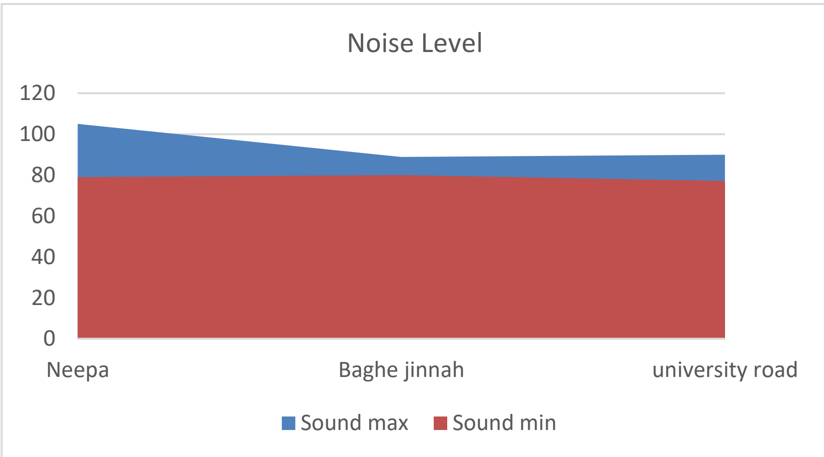

Fig. 16 Noise level along BRT Redline Construction route

Questionnaire Responses

Demographic Distribution of Respondents

The survey involved a diverse group of respondents residing or owning businesses along the BRT Redline construction route. The age distribution among the participants varied, with the majority falling within the 18-24 and 25-34 age brackets, comprising approximately 45% and 35% of the total respondents, respectively. Additionally, regarding gender representation, the survey captured responses from both males and females, with males constituting around 80% of the total respondents.

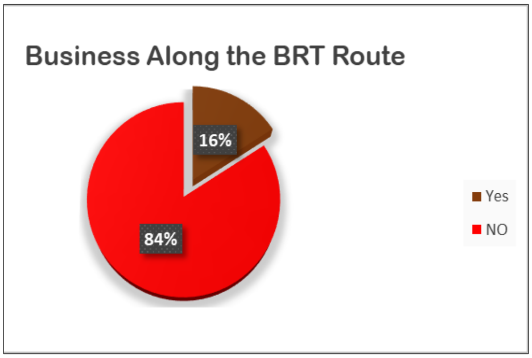

Fig. 17 Business along BRT Redline Construction route

Awareness and Perception of the BRT Redline Construction

When questioned about their awareness of the BRT Redline construction, an overwhelming majority, approximately 95% of the respondents, confirmed their awareness of the ongoing project. Additionally, inquiring about their familiarity with the construction's impact on their daily lives or businesses, roughly 80% acknowledged experiencing notable effects due to the construction activities. Among these effects, concerns regarding increased traffic congestion and alterations in transportation routes were frequently highlighted, accounting for nearly 70% and 60% of the responses, respectively.

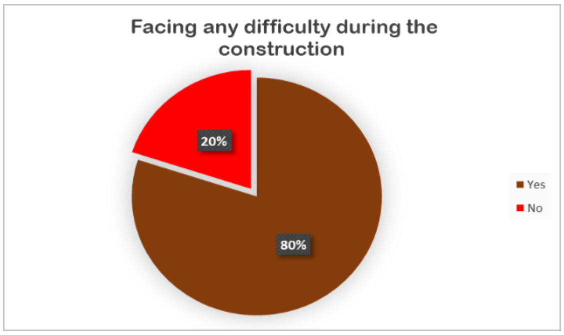

Fig. 18 BRT construction affected the daily life

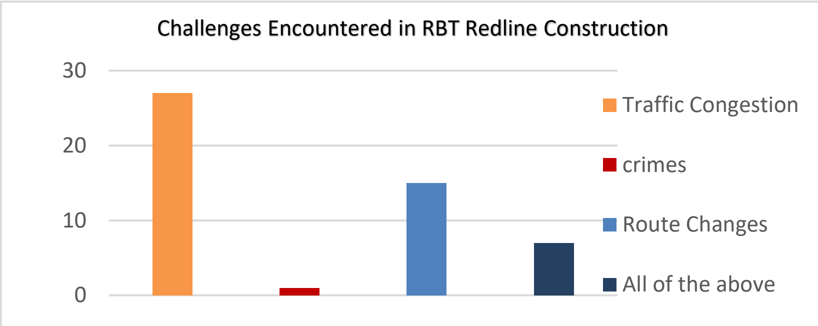

Fig. 19 BRT Challenges encountered along BRT Redline Construction route

Impact on Daily Life, Businesses, and Community Well-being

Regarding the impact of the construction on daily life and businesses, a significant percentage, around 75% of the respondents, reported facing difficulties during the construction phase. Factors contributing to these challenges included overcrowding, timing troubles, and route changes, comprising approximately 80%, 70%, and 50% of the respondents' concerns, respectively. Moreover, in terms of safety and consultation with authorities, a considerable proportion of respondents, approximately 60% and 65%, respectively, expressed their dissatisfaction, citing a lack of engagement from authorities and safety concerns during the construction phase.

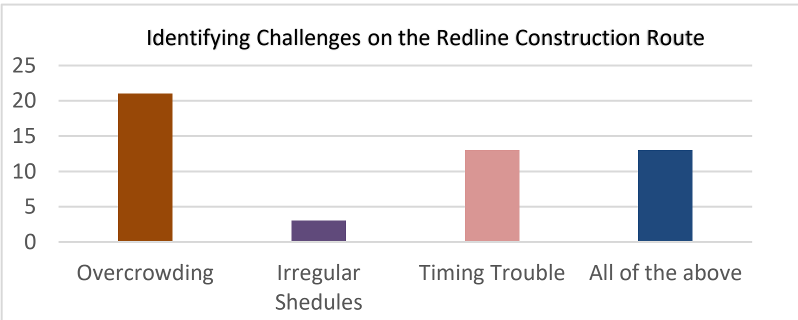

Fig. 19 Challenges on the Redline Construction Route: Insights and Perspectives

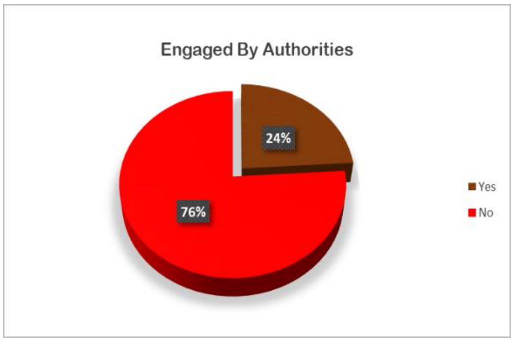

Fig. 20 Authority engagement

Property Values and Environmental Impact

When questioned about the potential impact on property values due to the BRT Redline construction, approximately 60% of the respondents perceived either a significant increase or decrease in property values, while 40% reported no significant change. Furthermore, about 70% of the respondents believed that the construction had resulted in changes in air quality, green spaces, and water bodies, indicating heightened awareness regarding environmental impacts.

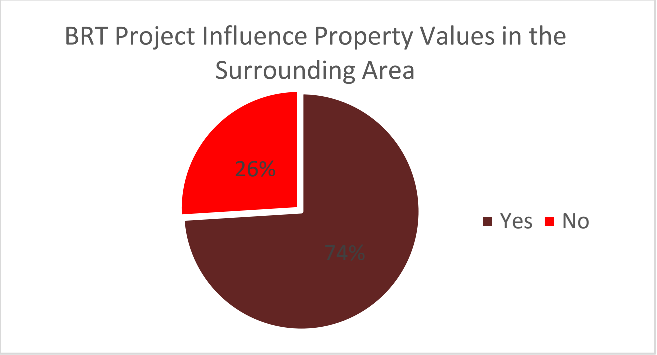

Fig. 20 BRT project influence property values in the surrounding Area

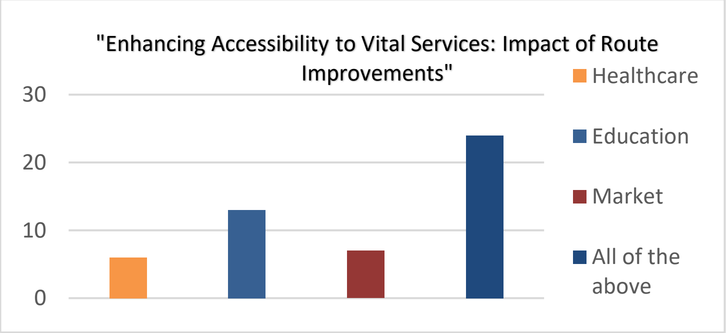

Fig. 21 Enhancing Accessibility to Vital Services: Impact of Route Improvements

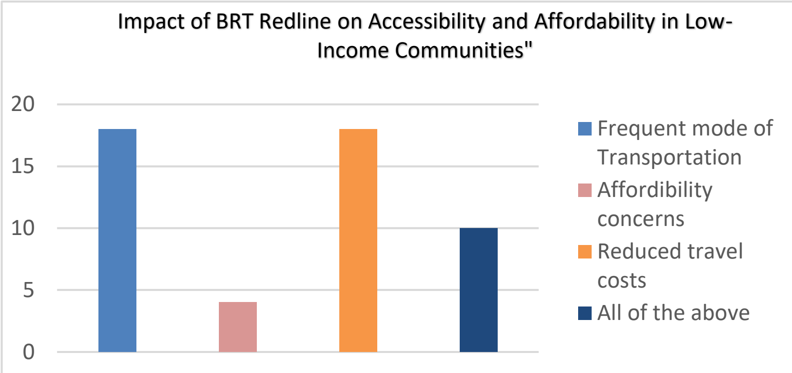

Fig. 22 Impact of BRT on Accessibility and Affordability in Low-Income Communities

CONCLUSION

In conclusion, our interdisciplinary study of the BRT Redline construction route in Karachi has provided a comprehensive understanding of its multifaceted impacts on the urban environment, social dynamics, and economic landscape. Through spatial analysis, environmental assessments, and a thorough questionnaire survey, we have identified significant changes in commuting habits, social interactions, and business activities, alongside environmental consequences such as alterations in air quality, green spaces, and temperature variations. While the BRT system holds promise in enhancing community integration, promoting economic growth, and reducing emissions through improved public transportation, challenges such as traffic congestion, disruptions to businesses, and environmental pollution must be carefully addressed. By incorporating these findings into future planning and implementation processes, policymakers can ensure a more inclusive, sustainable, and resilient urban development trajectory for Karachi, fostering well-being and prosperity for its diverse population.

RECOMMANDATION

1. Engagement with Authorities: Recommend increased engagement and communication between authorities and residents/business owners to address safety concerns and offer support during construction phases.
2. Environmental Impact Mitigation: Suggest methods to mitigate the environmental impact of construction, such as incorporating green spaces, enhancing waste management, or implementing air quality improvement measures.

3. Community Engagement: Advocate for increased community involvement and awareness-building programs to address concerns and enhance cooperation between stakeholders.

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