Exploring Socio-Economic Resilience Through Mass Transit: Insights from Metro Train Passengers in Lahore

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ABSTRACT

Socio-Economic Resilience (SER) has emerged as a critical dimension of urban mobility, particularly in the face of natural hazards, economic instability, and social disruptions that challenge riders using public transport, predominantly metro trains. While existing research has extensively explored aspects such as disaster preparedness, service recovery, and infrastructure resilience, relatively few studies have attempted to empirically assess and quantify the socio-economic resilience of riders of the metro train. The objective of this research is to evaluate the socio-economic resilience of metro train passengers using a quantitative methodology. Data was collected from the riders of the metro train through a structured questionnaire survey administered to 403 respondents, representing diverse socio-economic backgrounds. The study operationalizes socio-economic resilience using resilience dimensions as the guiding constructs, thereby enabling a systematic evaluation of metro passengers' adaptive capacities. Statistical analyses were conducted to examine socio-economic resilience, including other allied elements such as safety, affordability, accessibility, and economic impact. The results reveal that metro passengers exhibit a medium level of SER, indicating that while riders possess certain adaptive capacities, substantial vulnerabilities persist that may limit their ability to withstand or recover from future shocks. This research contributes to the growing body of resilience studies by providing empirical evidence from a user-centric perspective, highlighting the importance of transport systems not only as mobility providers but also as enablers of socio-economic resilience. The findings offer practical implications for transport planners and policymakers in developing contexts, emphasizing the need for targeted strategies to strengthen the resilience of urban commuters through equitable and inclusive policy interventions.

Keywords-Socio-Economic Resilience; Orange Line Metro Train; passengers; accessibility; affordability.

INTRODUCTION

Metro train systems are becoming the primary public mode of transportation, offering unique features, most notably, they are eco-friendly. Due to its unique characteristics, it is emerging as the cornerstone of urban public transportation in cities of various sizes in both developed and developing countries. These trains not only alleviate the urban transportation issues but also gradually become the priority choice among people of all income groups [1], [2]. In megacities of developed countries, more than half of the trips are made through metro trains, which in turn demands an expeditious development in the construction and operation of metro systems [3], [4]. However, with their expansion and increasing complexity, the network and infrastructure are susceptible to risks from external disruptions. These disruptions can be caused by natural disasters, most likely due to climate change-related phenomena, and their impacts depend on the type and intensity of extreme weather events. It can also be due to man-made events such as terrorist attacks, political demonstrations, strikes, which impact the frequency of the metro services [5], [6]. Metro train systems have a very close impact on the socio-economic status of people's lives. As the metro carries a large number of passengers, any interruption can cause cascading delays and even the cancellation metro service, which can cause devastating economic damage to the metro service providers and their users. These perturbations can have a drastic impact on the movement of people both socially and economically [7], [8].

In earlier years, the concept of resilience has gained popularity in urban transportation planning, particularly in response to increasing disruptions such as pandemics, economic crises, and extreme weather events. Resilience has been categorized into four major domains. i.e., Engineering, Organizational, Social, and Economic [9]. Past research has investigated resilience in transportation, although the majority target infrastructure dependability, disaster readiness, or service effectiveness [5], [10], [11]. Innumerable theoretical and methodological advances in the quantification of the resilience of metro trains in the Engineering domain have already been developed during the last decades. Notably, the quantitative measurement of metro trains has become more complex and specific over time due to technological advancement [6], [12], [13], [14]. In the case of metro systems specifically, resilience is usually assessed using operational metrics such as service frequency, safety, and restoration time following incidents. Yet, in developing nations, where metro networks serve predominantly middle- and lower-income segments of society, SER needs to consider affordability as well as accessibility of feeder services and users' ability to absorb travel-related shocks without undermining livelihoods. The disparity thus underscores the requirement for improved understanding of passenger-oriented SER in urban transport studies, an aspect addressed by the current study. However, few studies have highlighted the social and economic perspective on resilience of urban transportation, such as adaptive capability [15], while most of the existing resilience assessments only focus on one perspective, either physical or engineering. However, the socio-economic perspective of the users is often ignored. The literature on this SER is in a nascent state, but interest has grown sharply over the last few years. Thus, this research aims to explore the user-centric SER and attempts to find out how passengers behave and what the impacts are on passengers in the event of interruptions.

This paper is structured into five sections. After this introduction, Section 2 summarizes the latest research about resilience and socioeconomic indicators regarding resilience. Section 3 presents details of the study area and the research methodology used. Section 4 explains the analysis data collected from the passengers of the metro train, followed by Section 5 conclusion and recommendations.

REVIEW OF LITERATURE

Resilience and Transportation

Resilience is derived from the Latin word “resilire,” meaning spring back to the original after a disturbance. Initially, it was used by Holling in 1973 in the field of ecology. It is an interdisciplinary concept that is sometimes used interchangeably with other similar concepts and has different interpretations in various fields. The United Nations Office for Disaster Risk Reduction defined resilience as the ability of a system, community, or society exposed to hazards to resist, absorb, accommodate, adapt to, transform, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management. It was Murray-Tuite who used this concept in the field of transportation [16], [17].

Theoretically, the resilience idea started in ecological sciences (Holling, 1973) and later branched out to socio-economic and urban studies, focusing on adaptation, recovery, and continuity under pressure. In transport research, SER can be linked with frameworks such as the Social-Ecological Systems (SES) approach, the Sustainable Livelihoods Framework, and urban resilience models [18], [19]. These perspectives emphasize the interconnectedness of social and economic factors in maintaining stability during shocks, whether in the form of economic downturns, natural hazards, or disruptions in urban mobility. Since the earliest civilizations, cities with strong social and economic foundations have served as centers for growth and development, attracting populations and gradually evolving into the modern urban areas we see today. In contemporary times, as cities have become increasingly complex, the concept of SER has gained critical importance in addressing the uncertainties embedded within their intricate structures [20]. Transposed to the context of public transport systems, SER not only refers to infrastructure robustness but also to users' ability to adapt to and recover from systemic pressures. Such a change of focus from a merely engineering-driven approach to resilience to a user-oriented socio-economic focus highlights the need for equity and flexibility in mobility planning.

Socio-economic Resilience and Transportation

In the history of transportation development, SER has been a crucial aspect in assessing how people and

communities respond to changing mobility conditions. Transportation is not a physical link but an essential enabler of social connection, economic engagement, and fair access to opportunities. The resilience of users, especially in socio-economic terms, is an indication of their capacity to withstand disruptions, modify travel habits, and maintain their livelihoods even under adversity, such as fare volatility, service disruptions, or infrastructural constraints. In this process, the metro systems have a significant impact on the outcome of resilience because they serve a diverse range of passengers from various income levels, occupations, and social groups. Therefore, SER in transport systems points to matters of accessibility, affordability, and equity, making it a crucial lens for interpreting user experiences in modern urban mobility[21], [22].

A socio-economic study involves examining the social, cultural, economic, and political conditions of stakeholders such as individuals, groups, communities, and organizations within a given area. As a branch of economics and a social science, it explores the relationship between social behavior and economic processes [23]. Socio-economic resilience (SER) refers to a community's capacity to cope with and mitigate disaster-related asset losses. Disasters affect the social capacity and, of course, the economy as well, and weaker economies are more vulnerable to hazards and typically require extended periods for recovery compared to stronger economic systems [20], [24]. In the realm of transportation, the User-Centric Perspective SER to how individuals and groups withstand and adapt to shocks in terms of income, employment, affordability, access, and alternative options.

Socio-Economic Resilience User-Side Dimensions

The principal dimensions of socio-economic resilience (SER), as highlighted in existing research from a user-oriented perspective, are outlined below.

Accessibility: Accessibility is conceptualized as the ease of access to land use activity through a particular transport system. Contemporary research defines it from two perspectives: the objective or physical aspect, represented by measurable distance (active), and the subjective or perceived aspect, shaped by individual preferences (passive). The perceived accessibility is a fundamental counterpoint to physical measures, such as distance-based. This approach recognizes that accessibility is not just about physical proximity but about how individuals subjectively perceive and evaluate their ability to reach desired destinations [25], [26], [27]. The research highlights that improving affordability and accessibility in public transportation can encourage a modal shift from private vehicles to metro systems, thereby incorporating equity into urban transportation planning [28].

Affordability: Affordability of public transport is one of the global challenges. It is essential to consider diverse socio-economic factors when determining fares to ensure affordability across different income groups. Since transport affordability goes beyond the financial capabilities. Empirical evidence has proven that fare cost and affordability impact accessibility. The affordability index, developed for fares in Beijing, revealed that the low-income workers' flat fare scheme is more affordable than the distance-based fare scheme. The good accessibility and affordability can enable public transportation to be the dominant mode. Subsidized fares not only increased ridership but also boosted farebox revenues for metro operators [28], [29], [30].

Reliability: Travel time reliability, defined as the probability that travel between an origin-destination (OD) pair will be completed within a certain time. The research has identified that public transport has higher travel time reliability than private vehicles, and the metro train has higher reliability among other public transport modes. Reliability in a transit network refers to consistency in vehicle headways, arrival times, and schedules. When transit users are asked about the most important issues relating to transit, the number one response is the reliability of the system. Therefore, agencies need to design systems that have consistent headways and vehicle arrival times [31]

Safety & Security: Transport safety and security are key factors in mobility choices, especially public transport. In transportation, the concept of safety extends beyond the actual risk or fear of crime during travel. It is more commonly understood as perceived safety, a condition in which individuals feel that their mobility needs are met and that this state will remain stable over time. Various factors that affect the perceived safety and security include the built environment, individual and societal characteristics. The use of emerging technologies such as

smartphone apps, increased automation, and various sensing technologies can enhance the perceived safety [32], [33], [34].

Real Time Information & Communication: Real-time information on public transport can be an effective way of encouraging passengers, including information about the location of the vehicle, arrival time, number of stops, frequency of service, and in-advance applications; occupancy rate, and expected number of routes as well. This real-time information system is based on different advanced technologies, and passengers can access it via panels, smartphone apps, and websites. Within a decade, smart technologies have become central to both public transport and shared mobility services. The research suggests that the inability or unwillingness to access, operate, and effectively use digital technologies in transport services can create disadvantages for certain user groups. It has also been evidenced that digital inequality in transport follows existing patterns of social inequality. Vulnerable groups, including older adults, women, individuals with lower education or income levels, minorities, and rural populations, are more likely to experience barriers to digitalized mobility [35], [36].

Inclusivity & Accessibility Needs: Access to public transport is a fundamental requirement for ensuring equitable access to all including older adults (OAs) and persons with disabilities (PwDs). However, vulnerable groups such as often face systemic barriers that are overlooked in conventional urban and transport planning, which tends to prioritize infrastructure efficiency and traffic flow over user-specific needs. To advance inclusivity in transport, the policies must adopt a people-oriented approach that prioritizes safety, affordability, and acceptability of transport options, while simultaneously enhancing first- and last-mile connectivity. Interventions such as improving pavements and sidewalks, redesigning vehicle interiors for easier access, ensuring affordable fares, and training transport personnel in sensitivity towards vulnerable users are critical for sustainable mobility [28], [37]

Adaptive Capacity: The availability of emergency materials and human resources for recovering rapidly from a disaster is known as Adaptive capacity, is crucial, particularly in the context of resilience. The recent advances in GPS and communication technology have allowed the possibility of information-sharing and adaptive control schemes more flexible and reliable. Flexible scheduling of services is an important adaptive capacity consideration

MATERIALS AND METHODS

Study Area

Orange Line Metro Train is the first automated (driverless) rapid transit in Lahore, Pakistan. The line spans 27.1 km with 25.4 km elevated and 1.72 km underground. The line is served by 26 stations and is planned to deal with 250,000 passengers daily. The operation of the metro train was formally started on 25 October 2020. The metro train line has a total of 26 stations, with 2 located underground and the remaining 24 elevated. Each train comprises five automated and driverless wagons. A train set consisting of five cars, each with four doors, is used. Each one has a nominal capacity of 200 seated and standing passengers, with an average density of 5 persons per square meter, comprising 20% seated and 80% standing passengers. The Punjab Mass Transit Authority operates it and forms part of the Lahore Metro system. It is a part of the wider CPEC China-Pakistan Economic Corridor, both the Government of Pakistan and the Government of China [39], [40]

Survey Design and Data Collection

The primary data collection for this study was conducted among riders of the Orange Line Metro Train (OLMT), using a structured questionnaire. To gather experiences from a diverse range of passengers, a convenience sampling method is employed. This involves selecting respondents who are conveniently located and willing to participate, such as waiting passengers at metro stations or onboard trains during the morning and evening rush hours. The average ridership per month is approximately 350,000 passengers (data received in September 2024). The sample size, i.e., 400, is calculated using Yamane's formula to achieve a reasonable level of confidence (95%) with a margin of error of approximately ±5–6%, given a large population. To ensure comprehensive data collection, a mixed method was opted for. First, an online survey was disseminated via Google Forms to reach a broader audience. Second, field-based data collection was conducted through face-to-face questionnaire

administration at selected metro train stations, allowing for direct engagement with respondents. The total number of responses received was 403. The questionnaire was organized into four sections. Section one comprises basic demographic information about the respondents, while section two focuses on the frequency of usage of the metro train and its accessibility. Section three investigated the economic impact of disruption on the riders. Section four was aligned with ten dimensions of resilience in transportation networks as proposed by Murray Tuite, i.e. i) redundancy, ii) diversity, iii) efficiency, iv) autonomous components, v) strength, vi) collaboration, vii) adaptability, viii) mobility, ix) safety, and x) the ability to recover quickly [41]. To assess the ten dimensions of resilience with perspective of socio and economic, a Likert scale ranging from 1 to 5, where 1 signified "strongly disagree," 2 indicated "disagree," 3 denoted "neutral," 4 represented "agree," and 5 corresponded to "strongly agree," was employed. The survey was conducted in the peak time of morning, afternoon, and evening at five metro stations i.e., i) Baghbanpura Station, ii) UET Station, iii) Anarkali Station, iv) Salahudin Station, v) Ali Town. To collect the data, assistance and clarification were provided to the passengers for the accurate collection of data and its completion by the riders. It took approximately 12–20 minutes on average to fill out the complete questionnaire. The selection of respondents was random and depended on their willingness to participate. A diverse range of respondents was considered, including individuals from various age groups, educational backgrounds, and genders.

ANALYSIS

Socio-Demographic Profile of The Riders

As mentioned earlier, a total of 403 metro train riders participated in the survey. Table 1 shows that the majority of respondents were between the ages of 18–25 (52%), followed by those aged 26–35 (24%). The sample consisted of 40% males and 60% females. In terms of employment status, students (41%) and full-time employees (36%) were the dominant groups, indicating that the metro system is heavily used by younger and working populations. Regarding income, nearly 45% of respondents reported a monthly household income between PKR 30,001 and 100,000, suggesting a predominance of middle-income riders. The metro train emerged as the primary transport mode for 60% of respondents, followed by 15% used a bike, while others relied on bus and private car (20%) (18%).

Table 1-Socio-Demographic Profile of Riders

Category		Frequency	Percentage
Age	Under 18	25	6
	18-25	211	52
	26-35	95	24
	36-50	63	16
	Over 50	9	2
Gender	Female	244	60
	Male	159	40
Employment Status	Student	164	41
	Unemployed	38	9
	Employed (Full-Time)	146	36
	Employed (Part-Time)	35	9
	Self Employed	13	3
	Retired	7	2
	Metro Train	242	60

Primary mode of Transport	Bus	35	9
	Car	35	9
	Bike	62	15
	Informal Mode of Transport	19	5
	Walk/Bicycle	10	2
Monthly Income	Below 30,000	105	26.1
	30,001-50,000	107	26.6
	50,0001-100,000	99	24.6
	100,001-300,000	64	15.9
	300,001-500,000	19	4.7
	Above 500,000	9	2.2

Perceptions Of Affordability, Accessibility & Safety

Affordability: Perceptions of affordability and accessibility were assessed through a series of items measuring cost, physical access, mobility, and safety (see Table 2). On affordability, respondents rated the metro system as relatively economical (M = 3.96, SD = 1.28), with the majority indicating that the service was within their financial reach.

Table 2: Affordability of The Users of The Metro Train

Category	Mean	Std. Deviation
Affordable metro service	3.96	1.28
Can pay extra costs due to disruptions	1.41	.492
willing to pay a slightly higher	1.98	.840
subsidized or differential pricing	2.01	.833

Accessibility: Accessibility findings were more mixed. Nearly 35% of respondents lived within 1 km of a metro station (Table 3), whereas 70% required an additional mode of transport, such as an informal mode of transport or rickshaws, to access the system. It is also pertinent to mention that riders perceived finding alternative transport as difficult (M = 3.08, SD = 1.029). The riders acknowledged that the metro enhanced their overall ease of movement across the city (M = 3.75, SD = 0.881).

Table3 -Accessibility Perspectives of Riders

Distance from the metro station	Frequency	Percent
Less than 500m	141	35
500m-1Km	84	21
1Km-4Km	92	23
4Km-7Km	30	7
More than 7Km	55	14

Safety perception: Safety-related perceptions were strongly positive (Table 4). Respondents largely agreed that they felt safe and secure while traveling by metro (M = 3.77, SD = 0.93), that security checks were sufficient

and consistent (M = 3.85, SD = 0.87), and that emergency exits and safety instructions were clearly displayed (M = 3.61, SD = 0.85). These findings suggest that while affordability and safety are viewed favorably, challenges remain in ensuring seamless physical accessibility and resilience to disruptions.

Table 4: Safety Perceptions of Riders

Category	Mean	Std. Deviation
Strength: The infrastructure appears robust	3.77	.932
Safety: Emergency exits and safety instructions	3.85	.873
Ability to Recover Quickly services resume	3.61	.854

Economic Impact

The majority of the respondents (89%) didn't experience any interruption while travelling the metro service. Nevertheless, 58% of respondents reported that they can pay additional expenses during service disruptions, with the most common extra cost being less than PK 250 per incident. In terms of policy preferences, 35% agreed that subsidized or differential pricing during outages could reduce their economic burden, while just over 35% expressed a willingness to pay slightly higher fares if it ensured improved system reliability.

Resilience Perception

Social Resilience

To measure socio-economic resilience, composite scores were computed for each resilience domain i.e., social resilience and economic resilience. The composite score was derived by averaging responses to a set of Likert-scale items designed to capture specific dimensions of resilience. The social resilience score was calculated using 25 items with all items measured on a 5-point Likert scale ranging from "Strongly Disagree" (1) to "Strongly Agree" (5). A higher score indicates greater perceived social resilience. Before score computation, internal consistency reliability was assessed using Cronbach's alpha. The Social Resilience Scale yielded a Cronbach's alpha of 0.8731, indicating excellent internal consistency. Composite scores were calculated using the mean of the included items for each respondent, as this approach maintains the original Likert scale interpretation and accounts for any missing responses through SPSS's pairwise exclusion.

Reliability Statistics	
Cronbach's Alpha	No. of Items
.873	25

To assess the suitability of the data for factor analysis, the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity were applied. The KMO value was 0.98, indicating excellent sampling adequacy (Kaiser, 1974). Bartlett's Test of Sphericity was statistically significant, with a Chi-square value of 3209.00, degrees of freedom (df) = 190, and $p < 0.001$, confirming that the correlation matrix was not an identity matrix. These results suggest that the dataset is well-suited for conducting an Exploratory Factor Analysis (EFA**)**.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.908
Bartlett's Test of Sphericity	Approx. Chi-Square	3209.164
	df	190
	Sig.	<.001

The computed social resilience variable yielded a mean of 3.59 (SD = 0.57), indicating a moderately high overall perception of social resilience among respondents. The range of 3.85 reflects a broad spread in responses**,** suggesting some variability in how individuals perceive social support and adaptability. However, the relatively low standard deviation implies that most responses are clustered around the mean, indicating consistent agreement with the social resilience items across the sample. To facilitate interpretation, social resilience scores were categorized into three groups: low (1.00–2.49), moderate (2.50–3.99), and high (4.00–5.00). Results showed that 11.2% of respondents fell into the low resilience group, 65.9% into the moderate group, and 22.9% into the high group, suggesting that the majority of metro train users demonstrated moderate levels of social resilience.

Table 5: Socio-Resilience Level of Riders

Social Resilience Categories	Frequency	Percent	Inferences
Low (Less than 2.5)	11	2.7	Low Social Resilience: Rider feels unsafe, uninformed, or unsupported in disruptions
Moderate (2.5-3.99)	282	70.0	Moderate Social Resilience: Some safety/information concerns
High (4-5)	109	27.0	High Social Resilience: Rider feels secure, informed, and supported

Economic Resilience

Economic resilience was initially measured using four indicators: affordability of metro fares, ease of finding alternative transport during disruptions, the metro system's ability to minimize financial losses, and the availability of timely information to avoid economic loss. Reliability analysis of these four items yielded a Cronbach's $\alpha = 0.40$, which is below the conventional threshold of 0.70, indicating limited internal consistency. This suggested that the items may not form a unidimensional scale. Affordability was conceptually distinct and therefore retained as a single indicator, while the coping-related items were subjected to exploratory factor analysis. Principal Axis Factoring with one fixed factor confirmed that these three items loaded onto a single latent construct, which we labeled the Economic Coping Index. Factor scores were saved and used in subsequent analyses as the economic resilience measure. The index was approximately normally distributed (M = 0.00, SD = 0.58, range = –1.35 to 1.25). Scores below zero represent below-average economic coping capacity, while positive values indicate above-average coping capacity among metro users. Economic resilience factor scores were classified into three groups based on ±1 standard deviation from the mean: low (≤ –0.58), moderate (–0.57 to 0.57), and high (≥ 0.58). Results indicated that 19% of respondents fall under the low category of economic resilience; these are the users who face affordability and accessibility issues. The 52% in the moderate category suggests that these users are somewhat able to cope with economic disruptions (e.g., fare hikes, transport cost shocks, income fluctuations), but they are not yet fully secure. About 25% in the high category. Thus, suggesting that most metro train users clustered around a moderate level of economic resilience, with relatively fewer respondents at the extremes Table 6.

Table 6 Economic Resilience Level of Riders

Economic Resilience Level		Frequency	Percent	Inferences
Low (<-0.58)	1.00	76	19	Low Economic Resilience: Rider struggled with affordability and accessibility issues and particularly with disruptions

Moderate (-0.57 to 0.57)	2.00	211	52.4	Medium Economic Resilience: Passengers are somewhat able to cope with economic disruptions they are not yet fully secure.
High (=>0.58)	3.00	101	25.1	High Economic Resilience: Rider: Passengers have stable economic conditions or coping mechanisms.

Together, these results suggest that while most metro train users cluster around a moderate level of resilience in both social and economic dimensions, there remains a proportion of passengers at the lower end, highlighting groups that may require targeted support in times of service disruptions.

Priorities

The Friedman test was conducted to identify priorities for improving metro train resilience. Results showed a statistically significant difference in rankings across the five areas. The highest priority identified was 'better communication during disruptions' (Mean Rank = 1.89), followed by 'improved feeder transport access' (2.17) and 'faster service recovery after breakdowns' (2.27). Lower priority was given to 'more affordable fares' (2.31) and 'infrastructure upgrades' (2.31). These results suggest that passengers value timely information and ease of access more than structural or financial interventions.

Table 7 Priorities of Riders

Category	**Mean**	**Std. Deviation**
Improved feeder transport access	2.17	1.104
More affordable fares	2.31	1.257
Better communication during disruptions	1.89	1.163
Faster service recovery after breakdowns	2.27	1.225
infrastructure upgrades	2.31	1.387

CONCLUSION

Since diverse socio-economic groups rely on metro transport, their resilience to disruptions varies significantly. social resilience is shaped by cultural values, community support systems, and behavioral practices that influence how individuals and groups cope with challenges. Similarly, Economic resilience is largely dependent on income levels, as higher-income groups are better able to absorb unexpected costs, while lower-income passengers may experience greater financial strain. Based on the data analysis, a medium level of socio-resilience was observed among passengers, indicating that while community networks and social values provide some level of support, gaps remain in collective coping mechanisms. A similar pattern was found for economic resilience, where moderate adaptability exists but is constrained by income disparities. These findings suggest that although passengers possess a certain degree of resilience, both social and economic dimensions require strengthening to ensure greater stability in the face of transport disruptions.

The finding that passengers prioritized communication during disruptions aligns with resilience theory, which emphasizes the importance of information flow in minimizing user stress and economic loss. While affordability and infrastructure upgrades are traditionally seen as critical, in the context of metro disruptions, users appear to place greater value on real-time communication and feeder connectivity. This indicates that soft resilience measures (information systems, coordination, accessibility) may deliver more immediate benefits to riders than high-cost infrastructure expansions.

RECOMMENDATIONS

Based on the results of the socio-economic resilience of users of metro train, it is suggested to target the low socio-economic resilience group to improve the resilience level and strengthen the medium socio-economic resilience group through stable fare policies. The following practical measures are suggested to strengthen the socio-economic resilience of Metro train users.

Strengthening Social Resilience: Since the majority of the users are from the low-income group, students, a discount monthly pass makes the travel affordable and encourages inclusivity. Most of the users reach the metro train using a different mode, and it is suggested to develop a feeder service system well integrated with metro train. Educating passengers and fostering their active participation in commuting practices can be an effective tool to enhance resilience against transport disruptions. Awareness programs, passenger engagement initiatives, and community-based participation not only inform commuters about potential risks but also equip them with strategies to respond effectively during disruptions. Such measures contribute to reducing uncertainty, building confidence among riders, and ultimately strengthening the overall reliability and adaptability of metro train.

Strengthening Economic Resilience: Developing a unified system of mobility services to and from the metro train network can significantly improve the economic resilience of passengers. By integrating feeder routes, last-mile connectivity options, commuters gain reliable and cost-effective access to transportation. Such integration reduces travel time, minimizes unexpected expenses, and enhances job accessibility. In the broader context, a unified mobility system ensures that disruptions have less severe economic consequences for commuters, reinforcing both individual and community-level resilience.

LIMITATIONS

A key limitation of this study is that data were collected only during peak hours, when passengers were often in a hurry, which may have influenced the depth and accuracy of responses.

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