

Service Quality, Passenger Satisfaction, and Sustainable Urban Mobility: An Economic Study of Chennai Metro Rail

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Abstract

Urban transportation systems play a crucial role in promoting economic development, reducing traffic congestion, and ensuring sustainable urban mobility. Among the various modes of public transportation, metro rail systems have emerged as an efficient, reliable, and environmentally friendly solution to the growing transportation challenges faced by metropolitan cities. Chennai Metro Rail Limited (CMRL) has significantly transformed urban mobility in Chennai by providing safe, comfortable, and time-efficient transportation services to commuters. In this context, passenger satisfaction has become an important indicator for evaluating the effectiveness and quality of metro rail services. The present study examines the impact of service quality dimensions on passenger satisfaction towards Chennai Metro Rail and evaluates its contribution to sustainable urban mobility from an economic perspective. The study is based on primary data collected from 120 Chennai Metro commuters through a structured questionnaire. The analysis focuses on key service quality dimensions such as safety and security, cleanliness and hygiene, infrastructure facilities, service reliability, passenger convenience, and accessibility. Descriptive and inferential statistical tools including percentage analysis, Chi-square test, and multiple regression analysis were employed to analyze the data. The findings reveal that the majority of metro users are young, educated, middle-income, and professionally employed individuals who frequently utilize metro services for daily travel. The results indicate that infrastructure facilities, safety and security, and service reliability are the most significant determinants of commuter satisfaction. The study further confirms that service quality dimensions have a positive and significant influence on overall passenger satisfaction. Improved service quality not only enhances commuter experiences but also encourages greater usage of public transportation, thereby contributing to reduced congestion, lower environmental pollution, improved accessibility, and sustainable urban development. The study concludes that continuous investment in metro infrastructure and service quality is essential for increasing commuter satisfaction and ensuring the long-term economic sustainability of metro rail operations. The findings provide valuable insights for policymakers, transport planners, and metro authorities in formulating customer-oriented strategies to strengthen urban transportation systems and promote sustainable mobility.

Keywords: Chennai Metro Rail, Passenger Satisfaction, Service Quality, Urban Transport Economics, Sustainable Urban Mobility, Infrastructure Facilities, Public Transportation.

Introduction

Urbanization has become one of the most significant global phenomena of the twenty-first century. Rapid population growth, increasing economic activities, and expanding urban

settlements have generated an unprecedented demand for efficient transportation systems across the world. Transportation is a vital component of economic development, facilitating the movement of people, goods, and services while enhancing productivity and social welfare. However, increasing dependence on private vehicles has resulted in severe traffic congestion, environmental pollution, energy consumption, and loss of productive time in major cities. Consequently, urban planners and policymakers have increasingly focused on developing sustainable public transportation systems capable of addressing these challenges.

Metro rail systems have emerged as one of the most efficient and sustainable modes of urban transportation worldwide. The first metro railway system was introduced in London in 1863, and since then metro networks have expanded across Europe, North America, Asia, and the Middle East. Cities such as London, Moscow, Shanghai, Tokyo, and Dubai have developed extensive metro rail networks that serve millions of passengers daily. These systems are recognized for their high carrying capacity, reliability, safety, punctuality, energy efficiency, and environmental sustainability. Metro rail projects have significantly reduced traffic congestion, improved urban mobility, and contributed to economic growth in metropolitan regions. Furthermore, metro systems support sustainable development goals by reducing greenhouse gas emissions and promoting environmentally friendly transportation.

In India, rapid urban growth and increasing population density have intensified transportation challenges in metropolitan cities. Traditional modes of public transport such as buses and suburban railways have often struggled to meet the growing travel demand. Recognizing the need for modern mass transit systems, India introduced metro rail services as an effective solution for urban transportation problems. The first metro rail system in India, Kolkata Metro, commenced operations in 1984 and marked the beginning of a new era in urban public transport. Since then, metro rail networks have been established in several cities, including Delhi, Bengaluru, Hyderabad, Mumbai, Kochi, and Chennai. These metro systems have transformed urban mobility by providing safe, reliable, affordable, and environmentally sustainable transportation alternatives. Metro rail projects have also generated substantial economic benefits through reduced travel time, lower fuel consumption, increased labor productivity, enhanced accessibility, and improved quality of life.

Among the metropolitan cities of India, Chennai has experienced rapid urbanization, industrialization, and population growth over the past few decades. As one of India's major economic, educational, and industrial hubs, Chennai attracts a large number of daily commuters from surrounding regions. The city's growing population and expanding economic activities have placed significant pressure on its transportation infrastructure. Increasing vehicle ownership, traffic congestion, air pollution, and longer travel times have highlighted the need for an efficient mass rapid transit system capable of meeting the mobility requirements of its residents.

To address these challenges, the Government of Tamil Nadu and the Government of India jointly established Chennai Metro Rail Limited in 2007 as a Special Purpose Vehicle for implementing the Chennai Metro Rail Project. Chennai Metro commenced commercial operations in 2015 and has since become an integral part of the city's transportation network. The metro system offers modern facilities including air-conditioned coaches, automated

ticketing systems, smart card facilities, advanced signalling technology, security surveillance, escalators, elevators, and accessibility features for differently abled passengers. The network has significantly improved urban connectivity by linking important residential, commercial, educational, and industrial zones across the city.

From an economic perspective, Chennai Metro Rail contributes substantially to urban development and sustainable mobility. It reduces travel time, minimizes vehicle operating costs, lowers fuel consumption, decreases traffic congestion, and reduces environmental pollution. The metro system also enhances labor mobility, increases productivity, supports commercial development, and promotes transit-oriented urban growth. These economic and social benefits justify the substantial public investment made in metro infrastructure.

Despite the significant investments and improvements in transportation services, the long-term success and sustainability of metro rail systems depend largely on passenger satisfaction. Commuter satisfaction serves as an important indicator of service effectiveness, operational efficiency, and customer acceptance. Factors such as service quality, safety, reliability, cleanliness, accessibility, affordability, comfort, and infrastructure facilities influence passengers' perceptions and usage behavior. Satisfied commuters are more likely to continue using metro services, recommend them to others, and contribute to increased ridership and revenue generation.

Therefore, understanding the determinants of commuter satisfaction is essential for enhancing service quality and ensuring the economic sustainability of metro rail operations. Evaluating passenger perceptions provides valuable insights for policymakers, transport planners, and metro authorities in formulating customer-oriented strategies and improving service delivery. In this context, the present study examines the relationship between metro infrastructure investment, service quality dimensions, and passenger satisfaction in Chennai Metro Rail, with a particular focus on its contribution to sustainable urban mobility and urban transport economics.

Review of Literature

The success of any public transportation system depends largely on its ability to meet the expectations of commuters through the provision of high-quality services. Over the years, numerous researchers have examined the relationship between service quality dimensions and commuter satisfaction in metro rail systems across the world. The literature suggests that service quality is a multidimensional concept encompassing reliability, safety, comfort, accessibility, cleanliness, affordability, responsiveness, and infrastructure facilities. Understanding these dimensions is essential for enhancing passenger satisfaction and ensuring the long-term sustainability of metro rail operations. One of the earliest studies in the area of commuter satisfaction was conducted by Som Sankar Sen (2012), who examined commuter fulfillment in the Kolkata Metro Railway system. The study emphasized that customer satisfaction is a critical factor for the success of any transport organization. The author argued that transport service providers must continuously identify the factors influencing passenger satisfaction and implement necessary improvements based on commuter expectations. The study concluded that understanding passenger needs and providing quality services are essential for achieving customer delight and long-term patronage. Sudin Bag (2013)

investigated customer satisfaction in Kolkata Metro Railway and found that commuters primarily use metro services because of their speed, convenience, and reliability. The study highlighted the importance of efficient ticketing systems, timely information regarding train arrivals and departures, and effective security arrangements. The findings suggested that service quality improvements in these areas significantly contribute to enhanced commuter satisfaction and loyalty. Vivek Kumar and Vikas Rastogi (2014) focused on passenger comfort and safety in metro rail services. Their study revealed that commuter satisfaction is strongly associated with physical comfort, cleanliness, seating arrangements, ventilation, and overall travel experience. The authors emphasized that metro authorities should continuously upgrade passenger amenities and infrastructure facilities to improve the quality of service delivered to commuters. Appu and Balaji (2017) conducted an experiential study on contemporary metro rail services in Chennai. Their research highlighted the role of metro rail systems in improving urban mobility and reducing traffic congestion. The study found that Chennai Metro Rail has significantly improved the travel experience of commuters by providing safe, comfortable, and time-efficient transportation. The authors also emphasized the importance of maintaining service quality standards to ensure sustained passenger satisfaction and increased ridership. Kumar and Jeyaprabha (2018) examined commuter satisfaction towards Chennai Metro Rail Limited using a sample of metro users in Chennai. The study identified several factors influencing passenger satisfaction, including air-conditioning facilities, lighting conditions, space allocation, cleanliness of stations, safety measures, and service reliability. The findings revealed that commuters expressed high levels of satisfaction with safety at stations and train coaches, cleanliness of metro premises, and the overall travel environment. The study concluded that service quality dimensions significantly influence commuter satisfaction and recommended continuous improvements in passenger amenities and operational efficiency. Bhagyalakshmi and Vasudevan (2020) conducted a comprehensive study on commuters' satisfaction towards service quality dimensions in Chennai Metro Rail Limited. Using factor analysis, the researchers identified four major service quality dimensions, namely Amenities and Hygiene Factor, Service Establishment Factor, Service Ascent Factor, and Infrastructure Facilities Factor. The study found that infrastructure facilities, service enhancement measures, accessibility features, cleanliness, security arrangements, and information systems positively influence commuter satisfaction. The researchers further observed that service enhancement and infrastructure factors significantly contribute to overall commuter satisfaction and passenger retention. Janarthanan (2024) examined customer satisfaction in Chennai Metro Rail Corporation from the perspective of service quality and transportation efficiency. The study highlighted that metro rail systems have transformed urban mobility by offering reliable, comfortable, environmentally friendly, and cost-effective transportation services. The author emphasized that customer satisfaction is influenced by service reliability, convenience, punctuality, accessibility, safety, and comfort. The study further noted that metro rail systems contribute significantly to sustainable urban development by reducing traffic congestion, pollution, and travel costs while improving the quality of urban life. International studies have also highlighted the importance of service quality in public transportation. Disney (2000) observed that customer expectations in transport services are continuously increasing due to competition and changing travel behavior. The study identified punctuality, cleanliness, comfort, and staff responsiveness as key determinants of customer

satisfaction. Similarly, Pantouvakis and Lymperopoulos (2008) found that both physical infrastructure and service interactions significantly influence passenger perceptions and overall satisfaction levels. Their research demonstrated that well-maintained infrastructure, station facilities, and customer-oriented services enhance passenger loyalty and long-term usage intentions.

The literature also emphasizes the economic significance of passenger satisfaction in public transportation systems. Satisfied commuters are more likely to continue using metro services, thereby increasing ridership, improving operational revenues, and reducing dependence on private vehicles. Higher levels of satisfaction encourage modal shifts from road-based transportation to metro systems, resulting in reduced traffic congestion, lower environmental pollution, decreased fuel consumption, and improved urban productivity. Consequently, investments in service quality not only improve passenger experiences but also generate broader economic and social benefits. Overall, the reviewed studies consistently indicate that service quality is a major determinant of commuter satisfaction in metro rail systems. Safety, cleanliness, comfort, infrastructure facilities, service reliability, accessibility, and information availability emerge as the most influential factors affecting passenger perceptions. While existing studies have extensively examined service quality dimensions and commuter satisfaction, limited attention has been given to understanding how metro infrastructure investment influences passenger satisfaction from an economic perspective. This gap provides the foundation for the present study, which seeks to examine the relationship between metro infrastructure investment, service quality, and passenger satisfaction in Chennai Metro Rail for promoting sustainable urban mobility.

Objectives of the Study

1. To examine the economic significance of Chennai Metro Rail services.
2. To identify the major service quality dimensions affecting passenger satisfaction.
3. To analyze the relationship between service quality and commuter satisfaction.
4. To provide policy suggestions for improving sustainable urban mobility.

Methodology

The present study adopts a descriptive and analytical research design to examine the influence of service quality dimensions on passenger satisfaction in Chennai Metro Rail. The study seeks to understand commuters' perceptions regarding various service attributes and identify the factors that significantly affect their overall satisfaction. Since passenger satisfaction plays a crucial role in determining the success and sustainability of urban transportation systems, the study focuses on evaluating the quality of services provided by Chennai Metro Rail Limited (CMRL).

The study was conducted in Chennai, the capital city of Tamil Nadu and one of India's major metropolitan cities. Chennai has experienced rapid urbanization, industrial growth, and population expansion over the past few decades, leading to increased transportation demand. To address growing traffic congestion and mobility challenges, Chennai Metro Rail Limited was established in 2007 as a joint venture between the Government of India and the Government of Tamil Nadu. Since the commencement of commercial operations in 2015,

Chennai Metro has become an important component of the city's public transportation network. The metro system connects key residential, commercial, educational, industrial, and transportation hubs across the city and provides modern facilities such as air-conditioned coaches, automated ticketing systems, smart card facilities, escalators, elevators, CCTV surveillance, passenger information systems, and accessibility features for differently abled passengers.

The study is based on both primary and secondary data sources. Primary data were collected directly from metro rail passengers through a structured questionnaire. The questionnaire was designed to obtain information regarding demographic characteristics, travel behavior, frequency of metro usage, perceptions of safety and security, cleanliness and hygiene standards, infrastructure facilities, service reliability, passenger convenience, accessibility, and overall satisfaction. Secondary data were collected from research journals, books, published articles, Chennai Metro Rail Limited reports, government publications, and other relevant academic sources to provide theoretical support and background information for the study.

A sample of 120 Chennai Metro Rail passengers was selected for the study using a convenience sampling technique. Respondents were approached at major metro stations across Chennai and included passengers from different age groups, genders, educational backgrounds, occupations, and income categories. The sample was chosen to ensure adequate representation of diverse metro users and to obtain meaningful insights into their satisfaction levels and service expectations.

The study focuses on several important service quality dimensions that are considered critical in determining commuter satisfaction. These dimensions include safety and security, cleanliness and hygiene, infrastructure facilities, service reliability and punctuality, passenger convenience and comfort, and accessibility and inclusiveness. Passenger satisfaction is treated as the dependent variable, while the various service quality dimensions are considered independent variables influencing overall satisfaction levels.

The collected data were coded, classified, tabulated, and analyzed using the Statistical Package for Social Sciences (SPSS). Both descriptive and inferential statistical techniques were employed for data analysis. Descriptive statistics such as percentage analysis, frequency distribution, mean, and standard deviation were used to summarize respondent characteristics and satisfaction levels. Inferential statistical tools including Chi-square test, Independent Sample t-test, One-Way Analysis of Variance (ANOVA), Correlation Analysis, and Multiple Regression Analysis were utilized to examine relationships between variables, identify significant differences among respondent groups, and determine the impact of service quality dimensions on overall passenger satisfaction.

The analytical framework of the study is based on the assumption that improved service quality leads to higher passenger satisfaction. It is expected that better safety measures, enhanced cleanliness, modern infrastructure, reliable services, greater convenience, and improved accessibility positively influence commuter perceptions and encourage continued usage of metro services. The findings of the study are intended to provide valuable insights for policymakers, transport planners, and Chennai Metro authorities in developing customer-oriented strategies and improving service delivery. Furthermore, the study contributes to the

understanding of how service quality influences commuter satisfaction and supports the broader objective of promoting sustainable urban mobility in Chennai.

Data Analysis

Table 1: Socio-Economic Profile of Chennai Metro Commuters

Variables	Category	Frequency	Percentage
Gender	Male	72	60.0
	Female	48	40.0
Age	Below 20 Years	12	10.0
	21–30 Years	42	35.0
	31–40 Years	36	30.0
	41–50 Years	18	15.0
	Above 50 Years	12	10.0
Educational Qualification	School Level	15	12.5
	Undergraduate	42	35.0
	Postgraduate	51	42.5
	Professional Degree	12	10.0
Occupation	Student	24	20.0
	Government Employee	21	17.5
	Private Employee	45	37.5
	Business	18	15.0
	Others	12	10.0
Monthly Family Income (₹)	Below 25,000	18	15.0
	25,001–50,000	39	32.5
	50,001–75,000	33	27.5
	75,001–1,00,000	18	15.0
	Above 1,00,000	12	10.0
Marital Status	Married	66	55.0
	Unmarried	54	45.0
Frequency of Metro Usage	Daily	48	40.0
	Weekly	33	27.5
	Monthly	24	20.0
	Occasionally	15	12.5

Table 1 presents the socio-economic profile of 120 Chennai Metro Rail commuters selected for the study. The gender-wise distribution reveals that the majority of the respondents are male (60.0%), while females constitute 40.0 percent of the sample. This indicates that male commuters use metro services more frequently than female commuters.

With regard to age, the largest proportion of respondents (35.0%) belongs to the 21–30 years age group, followed by 31–40 years (30.0%). This suggests that Chennai Metro is predominantly utilized by young and middle-aged individuals who travel regularly for employment, education, and business activities.

The educational profile shows that 42.5 percent of the respondents possess postgraduate qualifications, while 35.0 percent are undergraduate degree holders. This indicates that a considerable proportion of metro users are well educated and may be more aware of the advantages of modern public transportation systems.

In terms of occupation, private-sector employees account for the largest share (37.5%), followed by students (20.0%) and government employees (17.5%). This finding highlights the importance of Chennai Metro as a preferred mode of transport among working professionals and students due to its convenience and time-saving features.

The income distribution reveals that 32.5 percent of respondents belong to the monthly family income group of ₹25,001–₹50,000, while 27.5 percent earn between ₹50,001 and ₹75,000. This indicates that Chennai Metro is widely used by middle-income households who seek affordable, safe, and efficient transportation services.

Regarding marital status, 55.0 percent of respondents are married and 45.0 percent are unmarried. This suggests that metro services cater to a diverse group of commuters irrespective of family status.

The frequency of metro usage indicates that 40.0 percent of respondents use Chennai Metro daily, followed by 27.5 percent who use it weekly. This demonstrates that Chennai Metro has become an integral part of the daily travel routine of a significant proportion of commuters in Chennai city.

Overall, the socio-economic analysis reveals that Chennai Metro Rail is primarily used by young, educated, middle-income, and professionally employed individuals. The high proportion of daily users further reflects the growing importance of metro rail services in enhancing urban mobility and supporting sustainable transportation in Chennai.

Hypothesis Testing

Hypothesis 1

H₀: There is no significant association between the socio-economic characteristics of commuters and their level of satisfaction towards Chennai Metro Rail services.

H₁: There is a significant association between the socio-economic characteristics of commuters and their level of satisfaction towards Chennai Metro Rail services.

Table 2: Chi-Square Test between Age Group and Level of Satisfaction

Particulars	Chi-Square Value	df	p-value	Result
Age Group and Satisfaction Level	12.846	4	0.012	Significant

The Chi-Square test was performed to examine the association between the age group of commuters and their satisfaction level towards Chennai Metro Rail services. The calculated Chi-Square value is 12.846 with a p-value of 0.012, which is less than the 5 percent level of significance ($p < 0.05$). Therefore, the null hypothesis is rejected and the alternative hypothesis is accepted. This indicates that there is a significant association between the age of commuters and their level of satisfaction. The findings suggest that satisfaction levels vary across different age groups, and age plays an important role in shaping commuter perceptions regarding metro services.

Hypothesis 2

H₀: Service quality dimensions do not significantly influence commuter satisfaction towards Chennai Metro Rail services.

H₁: Service quality dimensions significantly influence commuter satisfaction towards Chennai Metro Rail services.

Table 3: Multiple Regression Analysis of Service Quality Dimensions on Commuter Satisfaction

Variables	Beta Coefficient	t-value	p-value
Safety and Security	0.324	4.287	0.000
Cleanliness and Hygiene	0.218	3.146	0.002
Infrastructure Facilities	0.356	5.018	0.000
Service Reliability	0.271	3.875	0.001
Passenger Convenience	0.194	2.769	0.007
Accessibility and Inclusiveness	0.163	2.354	0.021

Model Summary

R	R ²	Adjusted R ²	F Value	p-value
0.781	0.610	0.589	29.847	0.000

Multiple regression analysis was employed to determine the influence of various service quality dimensions on overall commuter satisfaction. The model summary indicates an R² value of 0.610, implying that 61.0 percent of the variation in commuter satisfaction is explained by the selected service quality variables. The F-value of 29.847 with a significance value of 0.000 confirms that the regression model is statistically significant.

Among the independent variables, infrastructure facilities ($\beta = 0.356$), safety and security ($\beta = 0.324$), and service reliability ($\beta = 0.271$) emerged as the strongest predictors of commuter satisfaction. Cleanliness and hygiene, passenger convenience, and accessibility also showed significant positive effects on satisfaction levels. Since all p-values are less than 0.05, the null hypothesis is rejected. Therefore, it can be concluded that service quality dimensions significantly influence commuter satisfaction towards Chennai Metro Rail services.

Suggestions

1. Strengthen digital ticketing and smart card services.
2. Enhance Wi-Fi and mobile connectivity across stations.
3. Expand parking facilities and integrated transport services.
4. Maintain high standards of cleanliness and safety.
5. Increase accessibility features for elderly and differently abled passengers.
6. Conduct regular passenger satisfaction surveys for continuous improvement.

Conclusion

Urban transportation plays a crucial role in supporting economic development, improving accessibility, and enhancing the quality of life of urban residents. Chennai Metro Rail has emerged as a modern, efficient, and sustainable mode of public transportation that addresses the growing mobility needs of Chennai city. The metro system has significantly contributed to reducing traffic congestion, travel time, fuel consumption, and environmental pollution while providing a safe, comfortable, and reliable travel experience for commuters. The findings of the study reveal that the majority of metro users are young, educated, middle-income, and professionally employed individuals who rely on Chennai Metro for their daily travel needs.

The socio-economic analysis indicates that metro services are widely utilized by working professionals and students, highlighting the growing importance of metro rail in urban transportation. The high proportion of daily commuters further demonstrates the increasing acceptance and dependence on Chennai Metro as an effective mode of public transport.

The study also examined the influence of various service quality dimensions on commuter satisfaction. The results indicate that safety and security, cleanliness and hygiene, infrastructure facilities, service reliability, passenger convenience, and accessibility significantly affect passenger satisfaction. Among these factors, infrastructure facilities, safety and security, and service reliability emerged as the most influential determinants of commuter satisfaction. The hypothesis testing results further confirmed that service quality dimensions have a significant positive impact on overall commuter satisfaction. From an economic perspective, improved passenger satisfaction contributes to increased ridership, higher operational efficiency, and greater public acceptance of metro services. Satisfied commuters are more likely to continue using metro services, thereby encouraging a shift from private vehicles to public transportation. This modal shift generates broader economic and environmental benefits, including reduced congestion costs, lower carbon emissions, improved productivity, and enhanced urban sustainability.

The study concludes that Chennai Metro Rail has successfully established itself as a vital component of Chennai's urban transport system. However, continuous efforts are required to further improve service quality through enhanced infrastructure, better passenger amenities, improved connectivity, advanced digital services, and efficient customer support mechanisms. Regular assessment of commuter satisfaction and service performance will help Chennai Metro Rail Limited identify areas for improvement and maintain high service standards. Overall, the study highlights that investment in metro infrastructure and service quality is not merely a transportation initiative but also a strategic economic investment that promotes sustainable urban mobility, improves commuter welfare, and contributes to the long-term development of Chennai city. Therefore, policymakers, transport planners, and metro authorities should continue to prioritize customer-centric service improvements to maximize the social, economic, and environmental benefits of metro rail transportation.

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