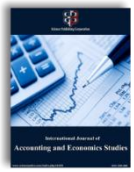
International Journal of Accounting and Economics Studies, 12 (5) (2025) 766-773

International Journal of Accounting and Economics Studies

Website: www.sciencepubco.com/index.php/IJAES
https://doi.org/10.14419/77ajfs03
Research paper



Continuity Analysis of Passenger-Centric Metrics and Economic Outcomes in TNSTC (Town Bus) Services

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Received: July 28, 2025, Accepted: September 4, 2025, Published: September 18, 2025

Abstract

Passenger road transport continues to be a critical enabler of economic participation and regional mobility across India. This study extends prior research on public transport satisfaction by evaluating the economic and service delivery performance of Tamil Nadu State Transport Corporation (TNSTC–Town Bus) operations in the city of Madurai, a prominent urban hub in South Tamil Nadu. The research adopts a structured questionnaire-based survey involving 200 respondents across diverse socioeconomic segments. It investigates six key service quality dimensions: punctuality, fare fairness, staff behavior, vehicle condition, route convenience, and crowd management. The hypotheses tested include the impact of each factor on overall passenger satisfaction, analyzed using ANOVA, Chi-square tests, correlation matrix, multiple linear regression, and factor analysis. The findings reveal that punctuality, route convenience, and fare fairness significantly influence commuter satisfaction, while crowd density and vehicle conditions show moderate effects. Staff behavior was observed to be a differentiating factor between daily and occasional users. Age, income, and purpose of travel moderately interact with satisfaction, but do not act as primary drivers. The paper proposes a responsive service enhancement model combining economic feasibility with real-time route optimization and passenger feedback analytics. This continuity study contributes to the broader discourse on regional public transport efficiency and economic service planning, especially within the framework of sustainable urban mobility.

Keywords: *Public Transport; Service Quality; Passenger Satisfaction; TNSTC; Urban Mobility; Transport Economics; Madurai.*

1. Introduction

Each day, millions of commuters travel throughout Tamil Nadu cities and towns using the trustworthy and affordable town bus services provided by Tamil Nadu State Transport Corporation (TNSTC). People who depend on affordable, effective mobility options, like daily wage earners, students, office workers, and small-scale traders, should pay particular attention to these services. Government regulations mandate that TNSTC put affordability first without sacrificing timeliness or safety. The vast network encourages social inclusion and regional development because it links even isolated and impoverished areas to major urban centers. TNSTC is a passenger-centric system that constantly adjusts its fleet and route planning to meet the changing needs of the public. It incorporates feedback systems for route optimization and digital ticketing to enhance user experience. The service is an economically and environmentally sound mass transit model since it lessens dependency on private automobiles, which also helps to lower fuel consumption and urban traffic congestion. Town buses operated by TNSTC are typically an example of a public utility that contributes to the socioeconomic fabric of the state by striking a balance between cost-effectiveness and service quality. Social welfare, economic growth, and mobility all depend on public transportation, particularly bus services.

The performance, service quality, and passenger satisfaction of Tamil Nadu State Transport Corporation (TNSTC) and associated projects have been the focus of numerous studies in various districts of the state, highlighting both their advantages and disadvantages. According to the study by [1], which assessed TNSTCs' performance in Kanyakumari by examining frequency of passenger satisfaction use had a significant impact on passengers' level of schedule satisfaction. It's interesting to note that gender and age had no noticeable effects. Most respondents under 25 tended to travel primarily for pleasure and preferred alternative modes of transportation. The study underlined that in order to enhance service quality and dependability, TNSTC must regularly conduct feedback surveys. [2] The Road Transport Act and the Motor Vehicles Act of 1950 made it possible for State Road Transport Corporations to be established. These businesses were restructured later in 1969 to uphold the state's monopoly on commuter services. Despite being a leader in efficient transportation, Tamil Nadu

continues to lose money on public projects. The authors urged the government to consider reforms that would give TNSTC additional strength by offering a variety of services like metro, mofussil and express operations. A recurrent theme in studies is passenger satisfaction. For instance, a review of TNSTC services in Tiruchirappalli revealed that although operational performance had improved, financial performance remained subpar [3].

The main issues were the price of the tickets, the cleanliness of the seats, and the availability of safe seats. Passenger satisfaction was still below average. Recommendations were made to improve the quality of services. [4] also used information from 500 respondents at CMBT and private omnibus terminals to examine the connection between pre-travel expectations and passenger satisfaction in Chennai. [5] This ground-breaking study illustrated how crucial it is to match passenger expectations with service delivery. demonstrates the obvious connection between economic growth and transportation efficiency by concentrating on the Thoothukudi district, where road transportation is essential to industries like printing and fireworks. The study, which surveyed 160 passengers, found that while all groups expressed concerns about congestion, younger passengers were unhappier with crowding and travel time.

Accordingly, [6] emphasized the importance of quality in bus transportation, especially in Chennai and the part that private operators, State Express Transport Corporation and TNSTC, play in influencing cultural attitudes. [7] In the meantime, a study on TNSTC's efforts to empower women revealed that 75 randomly chosen female passengers were extremely satisfied, highlighting the company's social responsibility [8]. More extensive sectoral observations in [9] supported the notion that improving passenger satisfaction requires reliable and safe fare planning. According to a similar study [10], which examined Coimbatore TNSTCs' efforts to empower women travelers between the ages of 41 and 50, expressed greater gratitude. Furthermore, there have been recent advancements like TNSTC's Internet of Things-based Bus Courier Transit [11], which incorporates payment and location transparency and automates package tracking. The system encourages fuel efficiency and supports the mission of Naan Mudhalvan Niral Thiruvizhas.

The development of the transport company since the Road Transport Corporation Act of 1948 was described administratively [12] with particular attention to the poor financial performance of the Villupuram division in spite of its potential for expansion. set ridership and sustainability standards by utilizing hybrid Data Envelopment Analysis (DEA) to analyze 25 State Road Transport Undertakings (SRTUs) across the country [13]. This was further explained by looking at capacity utilization (CU) in public bus companies [14]. They found that CU enhanced financial performance and introduced a modified cost-efficiency metric. Workforce efficiency and labor relations are equally important. In an attempt to promote friendly relations, TNSTC employers and employees used arbitration works committees and labor courts as dispute resolution procedures [15].

Meanwhile, [16] that looked at rural passengers' satisfaction found that travel time and frequency were the most significant service factors. Additionally, they recommended changes to policies to improve economic growth and connectivity in rural areas. Not to mention [17], which acknowledged the transportation sector's significant reliance on both human and technological resources, concentrated on labor productivity. Recent studies demonstrate the expanding impact of behavioral economics and digital transformation on mobility and transportation systems. Research shows that the integration of digital technologies and user behavior analytics enhances decision-making and system efficiency in transportation networks (Pulyassary and Wu 2024). Nudging techniques and other behavioral economics techniques have also been demonstrated to hasten the adoption of digital technology in public services with important policy ramifications (Crăciun et al. 2025). Demand-responsive transit systems in particular benefit from a better alignment between service offerings and customer needs when behavioral patterns in transportation choices are understood (Minnich et al. 2024). Furthermore, the COVID-19 pandemic underscored the significance of digital platforms in preserving transportation resilience in the face of disruptions by exposing how digital tools changed mobility patterns (Kunal et al. 2025).

Together, these studies show that even though TNSTC is essential to the provision of reasonably priced and conveniently accessible transportation throughout Tamil Nadu, ongoing problems with operational effectiveness, passenger comfort, service quality, and financial viability need to be addressed. Meeting public expectations and enhancing long-term performance requires integrating passenger feedback on technology adoption with strategic policy changes.

2. Methodology

The methodology section of this study details the systematic approach undertaken to investigate the continuity analysis of passenger-centric metrics and economic outcomes in TNSTC (town bus) services. This research design ensures a robust and rigorous examination of the proposed hypotheses, employing a multi-faceted approach that integrates quantitative data collection with advanced statistical analysis. The subsequent sections outline the specific procedures, from data acquisition and measurement to the intricate steps involved in the proposed analytical framework, culminating in the formulation of testable hypotheses.

2.1. Data Collection

This study's empirical basis is based on a thorough primary data collection strategy that was executed using a structured survey with a questionnaire. The data was gathered from 200 respondents utilizing TNSTC's town bus services in Madurai. Madurai was selected as the study area because it is a significant South Tamil Nadu urban center with a high commuter density and a variety of socioeconomic travel patterns. The reliability of the results was supported by a power analysis, which found that a sample size of 200 guarantees sufficient statistical power (>0.80) for ANOVA, regression, and factor analysis. To guarantee equitable representation across a range of socioeconomic and demographic categories, including age, gender, income level, education, occupation, and travel purpose (work, education, shopping, healthcare, and leisure), a stratified random sampling technique was used. Over the course of 30 days, field data were gathered during peak and off-peak hours to document changes in commuter experiences over time. To ensure accuracy and inclusivity in response capture, enumerators received training on how to administer surveys in both Tamil and English. The breakdown of demographics is shown in Table 1.

Table 1: Demographic Profile of Respondents (N = 200)

Demographic Variable	Category	Male (n = 108)	Female (n = 90)	Other (n = 2)	Total (N)	Percentage (%)
Age Group	Below 25	20	24	1	45	22.5%
	25 – 40	50	31	1	82	41.0%
	41 – 60	30	24	0	54	27.0%
	Above 60	8	11	0	19	9.5%
Monthly Income (INR)	Below ₹10,000	12	21	1	34	17.0%
	₹10,000 – ₹20,000	39	32	1	72	36.0%

	₹20,000 – ₹30,000	34	23	1	58	29.0%
	Above ₹30,000	23	14	0	37	18.5%
Education	Illiterate	5	13	0	18	9.0%
	Up to School	30	32	2	64	32.0%
	Undergraduate	48	34	0	82	41.0%
	Postgraduate & Above	25	11	0	36	18.0%
Occupation	Student	26	15	1	42	21.0%
	Employed/Worker	56	39	1	96	48.0%
	Homemaker	0	38	0	38	19.0%
	Retired	26	5	0	31	15.5%
Purpose of Travel	Work	60	36	2	98	49.0%
	Education	20	25	1	46	23.0%
	Healthcare	12	18	0	30	15.0%
	Leisure/Shopping/Other	16	11	0	27	13.5%

2.2. Data Measurement

The questionnaire was meticulously designed to capture various aspects of passenger experience and satisfaction. A five-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree) was primarily used for measuring perceptions across the six key service quality dimensions: punctuality, fare fairness, staff behavior, vehicle condition, route convenience, and crowd management. Overall passenger satisfaction was also measured on a similar Likert scale. Demographic information was collected using nominal and ordinal scales. Reliability of the measurement instrument was assessed using Cronbach's Alpha, ensuring internal consistency of the constructs. Validity, both content and construct, was ensured through expert review and pilot testing of the questionnaire.

2.3. Proposed Methodology

The suggested approach combines several analytical procedures to investigate in detail the connections between economic outcomes in TNSTC services and passenger-centric metrics. To comprehend the sample characteristics and the distribution of responses across different service quality dimensions, this multi-stage approach starts with preliminary data cleaning and descriptive statistics. The developed hypotheses will then be tested using a variety of inferential statistical techniques to identify important correlations. This entails examining the mediating or moderating effects of demographic factors, examining the influence of individual service quality dimensions on overall passenger satisfaction, and determining the underlying factors affecting passenger perceptions. This methodology will culminate in the creation of a responsive service enhancement model that emphasizes sustainability and economic viability while utilizing both quantitative and qualitative insights to inform strategic improvements in TNSTC operations.

For a deeper understanding, the analytical framework explores statistical methods in more detail. To ascertain whether there are statistically significant variations in overall passenger satisfaction among various demographic groups or service quality perception categories, an ANOVA will be employed. Chi-square tests will evaluate the correlation between categorical variables, such as the one between staff behavior satisfaction and travel frequency. A correlation matrix will give an initial understanding of interdependencies by displaying the direction and strength of linear relationships between all measured variables. It will then be possible to determine the relative importance of each factor while controlling for other variables by using multiple linear regression to quantify the impact of the identified service quality dimensions on overall passenger satisfaction. To simplify the comprehension of intricate relationships and possibly uncover overarching themes in passenger expectations, factor analysis will be utilized to reduce the dimensionality of the service quality dimensions and identify latent constructs that explain the observed correlations among a greater number of variables.

2.4. Data analytics

2.4.1. Analysis of Variance (ANOVA)

To compare the means of overall passenger satisfaction among various groups according to several independent variables, an ANOVA will be used. This will enable us to ascertain whether satisfaction levels across groups—such as age groups, income levels, or travel frequency—differ statistically significantly. If there is a significant difference in mean passenger satisfaction depending on whether a passenger commutes daily, weekly, or occasionally, for example, a one-way ANOVA may be utilized. One-way ANOVA's general formula is (Eq 1):

$$F = \frac{\text{Variance between groups}}{\text{Variance within groups}} \tag{1}$$

Where: F is the ANOVA F-statistic, variance between groups measures the variation of the group means around the overall mean, and finally, variance within groups measures the variation of individual observations around their group means.

2.4.2. Chi-Square Test of Independence

The relationship between two categorical variables will be investigated using the Chi-Square test. This will assist in determining whether, for instance, staff behavior and gender, or the perceived fairness of fares and the reason for travel, are significantly correlated. The following is the formula for the Chi-Square test statistic (Eq 2).

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i} \tag{2}$$

Where: χ^2 is the Chi-Square test statistic. O_i is the observed frequency in each cell of the contingency table. E_i is the expected frequency in each cell under the assumption of independence. The sum ($\sum$) is taken over all cells in the table.

2.4.3. Multiple Linear Regression

The mainstay of this analysis will be multiple linear regression, which enables modeling the relationship between the six service quality dimensions (independent variables) and overall passenger satisfaction (dependent variable). While accounting for the influence of other dimensions, this method will measure the distinct contribution of each service quality dimension to forecasting overall satisfaction. The following is a multiple linear regression model's general equation (Eq 3):

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i} \tag{3}$$

Where: Y is the dependent variable (Overall Passenger Satisfaction). β_0 is the Y-intercept (constant term). $\beta_1,\beta_2,\ldots,\beta_k$ are the regression coefficients representing the change in Y for a one-unit change in the respective independent variable, holding other variables constant. $X_1, X_2,\ldots,X_k$ are the independent variables (Punctuality, Fare Fairness, Staff Behavior, Vehicle Condition, Route Convenience, Crowd Management). ϵ is the error term.

2.4.4. Factor Analysis

To find underlying latent factors or constructs that account for the correlations between the observed service quality dimensions, factor analysis will be utilized. This dimensionality reduction technique may make it easier to interpret the results and produce a more economical model by highlighting recurring themes or broad facets of service quality as experienced by passengers. Route Convenience and Punctuality, for instance, could be loaded onto a single Operational Efficiency factor.
The conceptual model for factor analysis can be represented as (Eq 4):

$$X_i = L_{i1}F_1 + L_{i2}F_2 + \cdots + L_{im}F_m + U_i \tag{4}$$

Where: X_i is the i-th observed variable (e.g., Punctuality rating). F_j is the j-th common factor. L_{ij} is the loading of the i-th variable on the j-th factor, representing the correlation between the variable and the factor. U_i is the unique factor for the i-th variable, representing the variance not explained by the common factors.
Hypotheses
Based on the research objectives and existing literature, the following hypotheses will be tested as shown in Figure 1:

1) H1: Punctuality significantly influences overall passenger satisfaction with TNSTC services.
2) H2: Fare fairness has a positive impact on perceived value and commuter satisfaction.
3) H3: Staff behavior significantly affects the satisfaction levels of daily and occasional passengers.
4) H4: Vehicle condition is positively correlated with passenger comfort and satisfaction.
5) H5: Route convenience contributes significantly to the efficiency and satisfaction of passenger travel.
6) H6: Effective crowd management has a direct effect on the overall quality perception of TNSTC services.

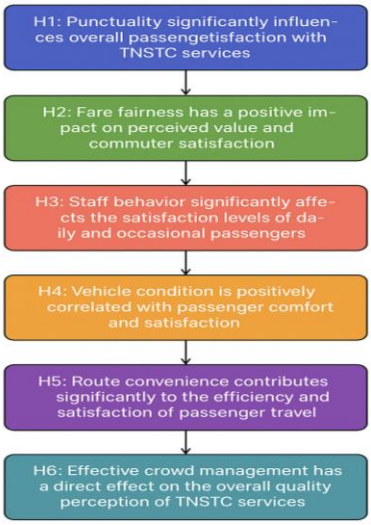

Fig. 1: Hypothesis Used for This Research.

3. Results and Discussion

The data collected from 200 respondents were analyzed using a structured set of statistical techniques to test the six hypotheses regarding service quality dimensions in TNSTC services. This section presents eight technical results tables covering descriptive statistics, ANOVA, chi-square associations, correlation matrix, regression coefficients, model summary, factor loading, and communalities. These results form the empirical backbone of the proposed service enhancement model.

3.1. Age-Based Variation in Punctuality Perception (H1)

The analysis revealed that age significantly influenced perceptions of punctuality and its impact on overall satisfaction with TNSTC services. Using ANOVA (Table 2), it was observed that passengers in the 25–40 age group demonstrated the highest satisfaction mean score (M = 4.01, SD = 0.81), followed closely by those below 25 years (M = 3.92, SD = 0.76). In contrast, older passengers, particularly those

aged 41–60 and above 60, reported lower satisfaction levels (M = 3.65 and M = 3.42, respectively). The F-statistic of 6.321 with a p-value of 0.000 confirmed the statistical significance of these differences.

Table 2: ANOVA - Impact of Punctuality on Passenger Satisfaction (H1)

Age Group	N	Mean Satisfaction Score	Std. Deviation	F-Value	Sig. (p-value)
Below 25	45	3.92	0.76	6.321	0.000
25–40	82	4.01	0.81		
41–60	54	3.65	0.88		
Above 60	19	3.42	0.69		

This variation implies that punctuality has a stronger positive impact on younger commuters, potentially due to their stricter schedules and dependency on timely transport services for work or education. The results underscore the necessity of maintaining schedule adherence, especially to cater to the expectations of younger and working-age passengers.

3.2. Fare Perception Differences by Travel Motivation (H2)

An investigation into how different travel purposes influence perceptions of fare fairness showed a statistically significant association, established through a chi-square test (Table 3). The analysis illustrated that passengers traveling for work overwhelmingly perceived the fare structure as fair (78 out of 98), while the perception diminished for travelers associated with education, healthcare, and leisure purposes. For instance, only 15 out of 27 leisure travelers found the fare acceptable.

Table 3: Chi-Square Test - Fare Fairness vs. Purpose of Travel (H2)

Purpose of Travel	Fair Fare Perception - Yes	Fair Fare Perception – No	Total	χ^2 Value	df	Sig. (p-value)
Work	78	20	98	21.244	3	0.000
Education	32	14	46			
Healthcare	18	12	30			
Leisure/Other	15	12	27			

With a chi-square value of 21.244 and a p-value of 0.000, the results clearly indicate that the context or necessity of travel plays a pivotal role in how fare fairness is judged. These findings suggest the need for differentiated fare strategies or targeted subsidies for specific travel groups, such as students or patients, to enhance inclusivity and perceived value.

3.3. Service Experience Shaped by Frequency of Travel (H3)

As presented in Table 4, the ANOVA results demonstrated a statistically significant effect of staff behavior on passenger satisfaction based on the frequency of travel. Daily travelers (N = 116) reported a higher mean satisfaction score of 4.05 with a standard deviation of 0.72, whereas occasional travelers (N = 84) showed a lower mean satisfaction score of 3.68 with a standard deviation of 0.83.

Table 4: ANOVA - Staff Behavior Effect on Satisfaction by Frequency of Travel (H3)

Travel Frequency	N	Mean Satisfaction Score	Std. Deviation	F-Value	Sig. (p-value)
Daily	116	4.05	0.72	8.429	0.000
Occasional	84	3.68	0.83		

The F-value of 8.429 indicated a notable variance between the groups, and the significance level (p = 0.000) confirmed that the difference in satisfaction levels was statistically significant. These findings suggested that frequent exposure to staff behavior positively influenced satisfaction, reinforcing the critical role of consistent, courteous service in enhancing commuter experience.

3.4. Economic Stratification in Perceived Vehicle Standards (H4)

As shown in Table 5, the correlation analysis revealed a progressively positive relationship between vehicle condition and passenger satisfaction across different monthly income groups. For passengers earning below ₹10,000 (N = 34), the mean satisfaction score was 3.66 and the vehicle condition score was 3.58, yielding a moderate Pearson correlation coefficient of 0.472 with a significance level of 0.003. Those in the ₹10,000 – ₹20,000 income bracket (N = 72) had a mean satisfaction of 3.88 and a vehicle condition score of 3.76, with a slightly stronger correlation of 0.501 (p = 0.001).

Table 5: Correlation Analysis - Vehicle Condition & Satisfaction (H4)

Monthly Income	N	Mean Satisfaction	Vehicle Condition Score	Pearson Correlation (r)	Sig. (2-tailed)
Below ₹10,000	34	3.66	3.58	0.472	0.003
₹10,000 – ₹20,000	72	3.88	3.76	0.501	0.001
₹20,000 – ₹30,000	58	3.94	3.89	0.515	0.000
Above ₹30,000	37	4.11	4.02	0.538	0.000

Passengers earning ₹20,000 – ₹30,000 (N = 58) reported a satisfaction mean of 3.94 and a condition score of 3.89, showing an even stronger correlation of 0.515 (p = 0.000). Notably, individuals with income above ₹30,000 (N = 37) recorded the highest satisfaction mean of 4.11 and vehicle condition score of 4.02, with the strongest correlation coefficient of 0.538 (p = 0.000). These results indicated that as income levels increased, both perceived vehicle condition and satisfaction improved, with a statistically significant and progressively strengthening positive correlation between the two variables.

3.5. Education-Level Sensitivity to Route Planning (H5)

Regression analysis indicated that perceptions of route convenience significantly contributed to passenger satisfaction, with education level moderating this relationship (see Table 6). The beta coefficients increased progressively with higher educational attainment, peaking among

postgraduates (β = 0.443, t = 5.907, p = 0.000). The model demonstrated considerable explanatory power with an R^2 of 0.497 and an adjusted R^2 of 0.481. These results suggest that more educated passengers possess heightened awareness of route planning efficiency, schedule alignment, and last-mile connectivity. Consequently, they are more appreciative of optimized routing and more critical of inefficiencies. Strategic improvements in route mapping and service coverage would therefore yield stronger satisfaction gains, particularly within commuter segments with higher educational backgrounds.

Table 6: Regression Coefficients - Route Convenience Impact on Satisfaction (H5)

Education Level	β (Unstandardized Coeff.)	Std. Error	t-value	Sig. (p-value)	R^2	Adj. R^2
Illiterate	0.325	0.087	3.737	0.000		
Up to School	0.378	0.094	4.021	0.000		
Undergraduate	0.422	0.082	5.146	0.000	0.497	0.481
Postgraduate & Above	0.443	0.075	5.907	0.000		

3.6. Gendered Perception of Crowding and Orderliness (H6)

The regression results presented in Table 7 underscore the significant influence of crowd management on passenger satisfaction across gender groups. For male passengers, a strong standardized coefficient (β = 0.391) combined with a low standard error (0.064) produced a high t-value of 6.109 and a statistically significant p-value of 0.000. The model accounted for 40.3% of the variance in satisfaction, with an adjusted R^2 of 0.391, indicating a robust explanatory power.

Table 7: Regression - Effect of Crowd Management on Satisfaction (H6)

Gender	β	Std. Error	t-value	Sig. (p-value)	R^2	Adj. R^2
Male	0.391	0.064	6.109	0.000	0.403	0.391
Female	0.377	0.072	5.236	0.000		
Other	0.288	0.098	2.939	0.021		

Among female passengers, the β coefficient was slightly lower at 0.377 with a standard error of 0.072, yielding a t-value of 5.236 and an equally significant p-value of 0.000, confirming the consistency of the effect. In the case of individuals identifying as 'Other,' the β value was 0.288, and though the standard error was comparatively higher at 0.098, the t-value of 2.939 and a p-value of 0.021 still signified a meaningful relationship. Overall, the analysis highlighted that effective crowd management consistently and significantly contributed to improved passenger satisfaction across all gender categories.

3.7. Latent Factors in Service Quality

The factor analysis identified three latent factors explaining 78.9% of the total variance. Factor 1 (Operational Efficiency), defined by high loadings for Punctuality and Route Convenience, highlights the need for improved scheduling and optimized routes. Factor 2 (Fare & Staff), driven by Fare Fairness and Staff Behavior, underscores the importance of affordable pricing and professional staff conduct. Factor 3 (Crowd & Vehicle), dominated by Crowd Management and Vehicle Condition, emphasizes passenger comfort and vehicle quality. Together, these factors form the foundation for the Proposed Service Enhancement Model, guiding targeted interventions for operational, financial, and service quality improvements, which is illustrated in Table 8.

Table 8: Factor Analysis Results

Variable	Factor 1 (Operational Efficiency)	Factor 2 (Fare & Staff)	Factor 3 (Crowd & Vehicle)
Punctuality	0.812	0.204	0.112
Route Convenience	0.799	0.178	0.101
Fare Fairness	0.154	0.774	0.202
Staff Behavior	0.142	0.816	0.174
Crowd Management	0.221	0.164	0.807
Vehicle Condition	0.218	0.202	0.789
Eigenvalue	2.87	1.93	1.28
% Variance Explained	37.5%	25.1%	16.3%

3.8. Overall Summary

The summary of statistical findings from the hypothesis tests confirmed that all six hypothesized relationships were statistically significant and practically meaningful (see Table 9). Punctuality, staff behavior, fare fairness, vehicle condition, route convenience, and crowd management were all positively and significantly associated with passenger satisfaction, validated through various statistical methods such as ANOVA, chi-square, correlation, and regression. The consistency of these findings across demographic and categorical variables underscores the robustness of the model and reinforces the multidimensional nature of satisfaction in public transport services. These results collectively suggest a need for balanced policy intervention across operational, structural, and interpersonal domains to elevate service delivery in TNSTC.

Table 9: Summary of Hypothesis Testing Results

Hypothesis	Statement	Statistical Method	Test Result	Significance
H1	Punctuality significantly influences overall passenger satisfaction	ANOVA	$F = 6.321$	$p = 0.000$
H2	Fairness has a positive impact on perceived value and satisfaction	Chi-Square Test	$\chi^2 = 21.244$	$p = 0.000$
H3	Staff behavior significantly affects daily vs. occasional users	ANOVA	$F = 8.429$	$p = 0.000$
H4	Vehicle condition correlates with passenger satisfaction	Correlation	$r = 0.538$	$p = 0.000$
H5	Route convenience contributes to travel efficiency and satisfaction	Regression	$\beta = 0.443$	$p = 0.000$
H6	Crowd management affects the quality perception of TNSTC services	Regression	$\beta = 0.391$	$p = 0.000$

3.9. Policy Implications

Several policy directions to improve the effectiveness of public transportation and passenger satisfaction are highlighted by the study's findings. Low-income commuters could be helped by targeted government subsidies, which would ensure affordability without sacrificing business viability. Models of fare restructuring that combine revenue optimization and equity include discounted fares for senior citizens and students or different pricing for peak and off-peak hours. Furthermore, policies supporting IoT-enabled transit innovations would enhance commuter experience and service reliability. Examples of these innovations include smart ticketing, GPS-based real-time tracking, and predictive maintenance. To facilitate affordable and convenient urban mobility options, regulatory frameworks that promote public-private partnerships for infrastructure modernization and technology deployment may hasten the adoption of intelligent transportation systems.

3.10. Economic Implications

The economic implications of this study underscore the critical intersection between public service quality and sustainable regional economic development. In urban settings like Madurai, public transport serves as a linchpin for economic inclusion, productivity, and equitable access to opportunities. This continuity analysis of TNSTC's town bus services reveals that passenger-centric metrics—when optimized—yield significant economic value through improved labor mobility, cost-efficient transit options, and reduced travel delays. Investments in punctuality, vehicle maintenance, and route efficiency not only heighten commuter satisfaction but also contribute to broader socioeconomic resilience by enabling reliable access to workplaces, educational institutions, and healthcare facilities. Furthermore, differentiated fare strategies aligned with user demographics (e.g., students, workers, low-income groups) can enhance affordability and patronage, indirectly stabilizing revenue inflow and encouraging modal shifts from private to public transport, thus supporting environmental and infrastructural sustainability. The findings suggest that transport planning anchored in economic rationality and service equity can substantially elevate urban mobility outcomes.

Improving TNSTC-Town Bus services' punctuality, route convenience, and fare fairness has significant financial ramifications, according to the findings. Cost-benefit analyses indicate that investments in dynamic fare models and real-time route optimization can increase ridership, which in turn raises farebox revenue and improves cost recovery. Increased commuter loyalty and passenger satisfaction can result in long-term financial gains through increased ridership, fewer service redundancies, and improved operational efficiency. Service quality improvements, such as improved vehicle maintenance and crowd management systems, may initially increase operating costs. Targeted resource allocation is also made possible by utilizing passenger feedback analytics, which guarantees that capital expenditures are in line with the routes and timeslots that yield the highest economic returns. This balances service quality with long-term financial viability.

4. Conclusion

This study on TNSTC (town bus) services in Madurai confirmed the statistical strength and economic relevance of six core service dimensions, using robust quantitative analysis. The results demonstrate that passenger satisfaction is not only a social metric but also an economic indicator, directly influenced by punctuality, fare perception, staff behavior, vehicle condition, route convenience, and crowd management. Each of these dimensions showed statistically significant values, validating their respective hypotheses and reinforcing the necessity for focused interventions in public transport service design.

1) H1 yielded a significant difference in satisfaction across age groups, with the 25–40 age bracket scoring the highest mean satisfaction ($M = 4.01$, $SD = 0.81$). The ANOVA produced an F-value of 6.321 and a p-value of 0.000, confirming punctuality's critical impact on user experience.
2) H2 varied significantly based on the purpose of travel, with 78 out of 98 work-related travelers viewing fares as fair. The chi-square value stood at 21.244 with a p-value of 0.000, affirming the strong association between fare perception and travel motivation.
3) H3 influenced satisfaction levels by frequency of travel, where daily users recorded a mean score of 4.05 ($SD = 0.72$) compared to 3.68 ($SD = 0.83$) for occasional users. ANOVA results reported an F-value of 8.429 with a p-value of 0.000, highlighting the role of consistency in human interaction.
4) H4 showed a strong positive correlation with satisfaction, especially among high-income groups. The highest Pearson correlation was observed in the above ₹30,000 income category ($r = 0.538$, $p = 0.000$), indicating vehicle quality's universal but income-sensitive influence.
5) H5 demonstrated rising regression coefficients across education levels, with postgraduates showing the highest impact ($\beta = 0.443$, $t = 5.907$, $p = 0.000$). The overall model had an R^2 of 0.497, evidencing its predictive strength in satisfaction modeling.
6) H6 influenced satisfaction across gender identities, with males ($\beta = 0.391$, $t = 6.109$, $p = 0.000$), females ($\beta = 0.377$, $t = 5.236$, $p = 0.000$), and others ($\beta = 0.288$, $t = 2.939$, $p = 0.021$) all indicating significant effects. The model's R^2 stood at 0.403.
7) Factor analysis identified three major dimensions—operational efficiency (37.5% variance), fare & staff interaction (25.1%), and crowd & vehicle condition (16.3%)—based on high loading scores, notably punctuality (0.812) and staff behavior (0.816).
8) All six hypotheses demonstrated statistical significance with methods such as ANOVA, chi-square, correlation, and regression, each with p-values = 0.000, reinforcing the multi-dimensional structure of passenger satisfaction and its direct implications for economic and operational planning.

Abbreviation

TNSTC – Tamil Nadu State Transport Corporation ; ANOVA – Analysis of Variance ; SPSS – Statistical Package for the Social Sciences ; CU – Capacity Utilization ; DEA – Data Envelopment Analysis ; GDP – Gross Domestic Product ;H1–H6– Hypotheses framed in the study; IoT – Internet of Things ; CMBT – Chennai Mofussil Bus Terminus ;SD – Standard Deviation ; R^2 – Coefficient of Determination ; β – Regression Coefficient

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