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Spatio-Temporal Variation in Bus Service Satisfaction and Policy Implications: A Case-Based Study in an Emerging Urban Area

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Abstract

This study investigates the spatio-temporal variation in bus service satisfaction in a rapidly urbanizing city in Southeast Asia. The research addresses a critical gap in urban transit studies, where passenger satisfaction is often treated as a static construct, overlooking how satisfaction may fluctuate across different geographic areas and time periods. By applying a spatio-temporal analytical framework, this study aims to provide a more dynamic and localized understanding of transit service perceptions. The research builds upon existing approaches by integrating a structured survey based on the Customer Satisfaction Survey (CSS) method with Best–Worst Scaling (BWS) to prioritize service attributes. A stratified sampling technique was employed across multiple wards in the study area, with 612 valid responses collected during both peak and off-peak hours. The survey captured data on passenger experiences and preferences, disaggregated by time of day, location, and demographic characteristics. Multinomial Logit (MNL) modeling was used to estimate the relative importance of key service dimensions, such as punctuality, comfort, frequency, and accessibility. The analysis revealed significant spatial and temporal heterogeneity in satisfaction levels. For instance, passengers in peripheral wards rated reliability and onboard conditions more negatively compared to those in central areas. Similarly, satisfaction levels were lower during evening hours, particularly concerning bus overcrowding and wait times. The findings suggest that transit policy must adopt a more flexible and localized strategy, rather than uniform service standards, to address distinct user expectations. Targeted improvements in underperforming routes and time slots could enhance overall user experience and promote public transport usage. This study contributes new insights to the evaluation of urban bus services in emerging cities and underscores the value of incorporating spatio-temporal dynamics into transit planning and customer satisfaction research.

Keywords: Passenger Experience, Perceived Transit Quality, Urban Bus Systems, Best-Worst Analysis, Spatial and Temporal Dynamics

1. Introduction

Passenger satisfaction is considered a fundamental measure for evaluating the effectiveness of public transportation systems [1], as it affects both continued ridership and the system's long-term viability. Prior research has highlighted the importance of service quality in encouraging greater transit use and supporting sustainable urban goals by mitigating traffic congestion, reducing environmental impacts, and promoting social inclusion [2], [3]. Among the most widely adopted methods for evaluating user experience, the CSS remains a widely used tool in transit research for measuring user experience (e.g., see literature review).

Traditional approaches, however, tend to treat satisfaction as a static construct. Several studies have adopted this approach by analyzing cross-sectional data without accounting for spatial or temporal variation (e.g., [4], [5]). Such models typically measure satisfaction at a single point in time and generalize the findings across entire systems or cities, overlooking potential spatio-temporal variation where satisfaction may differ by route, time of day, or demographic group. Recent efforts have begun to address this gap. For instance, [6] examined spatial satisfaction differences across urban zones, while [7] incorporated temporal dynamics in evaluating passenger perceptions. Nevertheless, few studies have attempted to combine spatial and temporal perspectives in a unified framework, leaving a significant research gap. The present study extends this line of inquiry by examining bus service satisfaction in Thu

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Duc City, Vietnam, using a combination of Best–Worst Scaling and logit regression. This methodological framework allows for the assessment of both perceived importance and variability in satisfaction levels across time slots and routes, contributing new empirical insights into user experience in a rapidly developing urban context.

The article is structured into six main sections. Sections 1 and 2 provide the research background and a review of the relevant literature. Section 3 outlines the dataset and methodological framework, including the design of the questionnaire, the fieldwork procedures, and data processing techniques. Section 4 presents the analytical approach, with a focus on estimating the relative contribution of service attributes and examining spatial and temporal variations in satisfaction. Section 5 reports the empirical findings, highlighting key patterns and differences in user perceptions. Finally, Section 6 offers concluding remarks and proposes practical policy recommendations based on the study's outcomes.

2. Literature Review

Efforts to improve public transit systems have been widely acknowledged for their broader social benefits, such as alleviating road congestion [8], [9], [10] mitigating environmental impacts through emission reductions [2] and promoting social equity by enhancing mobility for marginalized populations [3], [11], [12]. The CSS [1] remains one of the most robust and widely adopted tools for measuring passenger satisfaction. It allows for the assessment of both general satisfaction levels and user-specific perceptions of transit service components, which in turn supports the identification of critical areas for targeted improvements [13]. Typically, service quality indicators are categorized into three dimensions: service provision (e.g., accessibility, timetable frequency), operational performance (e.g., reliability, safety, travel time), and environmental quality (e.g., cleanliness, comfort) [14]. Scholars have also differentiated between core factors—those that directly influence travel decisions—and peripheral ones, which impact satisfaction but do not significantly affect mode choice behavior [15].

Despite these advances, a common limitation in the literature is the static nature of satisfaction assessment, with limited attention paid to its variation over time or across geographic space. For instance, [6] revealed differences in satisfaction levels among districts within a single metropolitan area, and [7] explored variations across metro lines in Santiago de Chile. Longitudinal studies such as those by [1], [2] tracked satisfaction trends over time in Sweden, yet few have investigated how satisfaction fluctuates by bus route or time of day—factors that may substantially influence the passenger experience in dynamic urban environments.

Expanding upon previous research, this study investigates the spatial and temporal variation of passenger satisfaction within the bus network of Thu Duc City. Rather than aiming to estimate absolute causal effects, the analysis adopts a relative approach, emphasizing the comparative significance and statistical differentiation of factors such as waiting duration, onboard crowding, travel timing, and route-specific characteristics. By applying the CSS framework alongside robust analytical methods, the study identifies which service attributes are most valued by users, thereby offering a practical evidence base to inform policy interventions aimed at enhancing the quality of urban public transportation.

Research on transit satisfaction is frequently anchored in Random Utility Theory (RUT), which posits that passenger evaluations and choices reflect attempts to maximize individual utility. Within this paradigm, satisfaction is shaped by the perceived performance of a range of service features—from foundational elements like reliability and frequency to supplementary aspects such as comfort and access to information [1], [15]. This study adopts RUT as a conceptual foundation for modeling passenger choice behavior. RUT assumes that individuals choose the option with the highest perceived utility, which consists of observable and unobservable components [16], [17]. These foundational works have been widely applied in transport modeling, providing a rigorous basis for understanding how individuals prioritize different service attributes under uncertainty. The adoption of BWS and MNL regression is grounded in the RUT framework. BWS elicits implicit utility trade-offs between service attributes, aligning with the RUT assumption that individuals choose alternatives that maximize their perceived utility. Similarly, MNL regression operationalizes these preferences by estimating the probability of selecting one attribute over others, providing empirical structure to utility-based decision making [17], [18]. Discrete choice theory suggests that passengers implicitly make trade-offs between service attributes. For example, some may tolerate longer waiting times if onboard conditions are comfortable, while others prioritize punctuality over seating availability. The BWS design captures these latent trade-offs by requiring respondents to identify both the most and least important attributes in context, revealing underlying utility hierarchies.

Importantly, satisfaction is neither fixed nor uniform; it fluctuates across both space and time. Prior studies on transit service satisfaction have typically examined either spatial or temporal dimensions of variation, but seldom both in an integrated manner. Spatial variation studies have investigated how user satisfaction differs across geographic areas, such as urban centers versus suburban zones, or between specific transit routes and districts. For instance, [6] explored satisfaction patterns in Spanish cities and identified that passengers in peripheral areas reported lower satisfaction with service frequency and accessibility compared to those in central areas. Similarly, [19] showed that satisfaction levels are often linked to build environment characteristics, including population density, land use, and station spacing.

In contrast, temporal variation studies have focused on how satisfaction fluctuates across time, such as during peak and off-peak hours, weekdays versus weekends, or across different seasons. employed a longitudinal design to capture shifts in satisfaction throughout the day, finding notable declines in passenger satisfaction during evening rush hours [4]. Also reported that perceptions of crowding and wait times are significantly worse during late-day periods, particularly for female and elderly passengers [5].

While both spatial and temporal studies provide valuable insights, very few have sought to combine both dimensions within a unified analytical framework. This gap is especially pronounced in research from emerging urban contexts such as Southeast Asia. The current study addresses this limitation by jointly analyzing spatial and temporal patterns in bus service satisfaction in Thu Duc City, Vietnam—an area experiencing rapid urbanization and increased transit demand.

Recently, there has been growing interest in methodological innovations, particularly the use of BWS, which allows for more nuanced analysis of service attribute prioritization [18]. BWS has gained traction in transport research as a robust method for eliciting user preferences and prioritizing service attributes. For instance, [20] employed BWS to evaluate design trade-offs in bus service offerings, while [21] used the method to assess commuter preferences for pedestrian and cycling infrastructure improvements. These studies demonstrate BWS's ability to capture nuanced differences in attribute importance, making it especially useful in complex urban transit settings. However, only a few studies have attempted to simultaneously integrate spatial and temporal perspectives in a unified framework—despite mounting evidence that satisfaction is jointly influenced by both dimensions. This study builds upon these prior theoretical foundations by applying a spatio-temporal analytical framework to evaluate bus service satisfaction in Thu Duc City, Vietnam. In doing so, it contributes new insights into the application of the CSS approach within dynamic, urban transit environments. To better contextualize the evolution of transit satisfaction research, table 1 presents an overview of selected recent studies.

Table 1. Overview of Selected Transit Satisfaction Studies by Region, Method, and Key Findings

Study	Location	Method	Main Finding
[6]	Spain	Spatial clustering	Urban center > Suburban areas
[4]	Netherlands	Longitudinal survey	Satisfaction drops in winter
[5]	Sweden	Time-of-day analysis	Evening rides = lower satisfaction
[23]	Vietnam (Hanoi)	Cross-sectional survey	Poor reliability reduces satisfaction in peri-urban
[26]	China (Beijing)	GWS + Spatial Mapping	Safety and wait time vary strongly by district
[7]	UK	Spatio-temporal regression	Delay perception shifts by both time & location

This table summarizes key characteristics of each study, including geographic scope, methodological approach, and main findings. By consolidating this information, the table highlights both the diversity of research foci and the remaining gaps—particularly in the simultaneous analysis of spatial and temporal variation in passenger satisfaction. In Vietnam, studies by [22], [23] highlight persistent challenges in urban bus service quality, such as long wait times and low comfort. However, few studies in the region employ spatio-temporal analysis or attribute-based modeling, indicating a clear research gap. Demographic factors also appear to shape satisfaction outcomes. For example, younger passengers expressed lower satisfaction with frequency, while older users emphasized comfort. These findings align with previous work (e.g., [15]), and suggest that targeted policies by demographic segment may be more effective. From a sustainability perspective, improving public transit satisfaction can promote modal shifts away from private vehicles, reducing congestion and emissions [24], [25]. However, most studies have focused on operational improvements without linking service satisfaction to broader environmental goals, a gap this study seeks to address.

3. Research Data

3.1.Structure of the CSS Questionnaire

Grounded in internationally established frameworks for assessing public transport quality, was the development of the questionnaire for this study. Incorporated within its design were elements from several prominent sources: the satisfaction indicators developed by [15] specific to bus services, metrics drawn from the European Customer Satisfaction Index (ECSI), the evaluation model introduced by [27], and technical standards outlined in Circular No. 52/2018/TT-BGTVT issued by Vietnam's Ministry of Transport. Tailored and expanded to suit the urban dynamics of Thu Duc City, these service attributes reflected the city's ongoing transition from a motorbike-dependent landscape toward a more public transit-oriented system.

Comprising three main parts was the finalized CSS instrument. The first section collected demographic and behavioral travel data through seven items, addressing variables such as age, gender, employment type, income level, trip purpose, bus usage frequency, and substitute travel modes. In the second section, perceived quality was measured across 24 distinct service attributes using a five-point Likert scale. To mitigate cognitive burden, respondents were randomly assigned a subset of 12 attributes via a clustering strategy. Contained in the final section was a Best–Worst Choice (BWC) task, wherein participants selected the most and least important service features from randomized sets of four, allowing for inference of attribute prioritization. Concise and unambiguous were all survey items, and prior to full-scale deployment, the questionnaire underwent pilot testing with 20 individuals to ensure clarity and consistency in interpretation.

3.2.Survey Implementation

This study was conducted in Thu Duc City, a major economic and educational hub within Ho Chi Minh City, with a population of approximately 1.28 million. Private transportation remains the dominant mode of travel, with motorcycles accounting for 70% and automobiles 12%, while public transportation—primarily buses—accounts for only 6%. Research data were collected through a CSS conducted between October and November 2024 via direct, face-to-face interviews. The survey was implemented on four major bus routes operated by the Ho Chi Minh City Public Transport Management Center: Route 8, Route 19, Route 56, and Route 76. These routes were selected due to their high passenger volumes and their role in connecting Thu Duc with central urban areas.

3.3.Data Processing Methods

Key factors considered in the regression model include variables such as passenger waiting duration, onboard crowding, time-of-day effects, and specific route characteristics. Additionally, the BWS method was employed to evaluate how passengers prioritize different aspects of service quality. This approach enables the identification of which attributes are viewed as more or less important from the user's standpoint.

3.4.Survey Design

The survey collected data from 738 bus passengers, with the sample distributed across different times of day and bus routes. The number of responses was stratified by time slots from 6:30 AM to 7:00 PM, with a higher concentration of surveys conducted during peak hours compared to off-peak periods. The distribution of survey responses by route (routes 8, 19, 56, and 76) and time slot is presented in table 2.

Table 2. Respondent Count and Allocation by Time Slot

Time Period	Number of Valid Responses				
	Route 8	Route 19	Route 56	Route 76	Total
≤ 6:30	11	10	15	12	48
6:30–7:30	16	15	17	16	64

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7:30–8:30	18	17	18	17	70
8:30–9:30	13	14	12	8	47
9:30–10:30	14	11	13	14	52
10:30–11:30	16	14	16	15	61
11:30–12:30	17	12	11	11	51
12:30–13:30	10	11	8	9	38
13:30–14:30	12	14	16	13	55
14:30–15:30	16	18	15	16	65
15:30–16:30	13	12	8	12	45
16:30-17:30	17	17	15	18	67
17:30-18:30	13	14	12	13	52
< 19:30	7	**7**	5	4	23
Total	193	186	181	178	738

Figure 1, derived from table 3, provides key insights into the characteristics of bus users in Thu Duc City, facilitating the identification of main passenger groups and their mobility needs. Differences across bus routes are largely attributable to the demographic profiles and travel behaviors of specific passenger segments. Additionally, while many respondents reported having access to private cars as alternatives, the limited use of bicycles or motorcycles suggests a need to improve transport infrastructure to promote more sustainable modes of travel. Finally, the high proportion of passengers who declined to disclose their income highlights the importance of designing more effective survey instruments to collect comprehensive and reliable socioeconomic data.

Table 3. Socio-Economic Attributes Considered in the Survey

Attribute	Level	Route 08	Route 19	Route 56	Route 76	Total
Gender	Male	43.40%	58.33%	50.00%	49.42%	50.14%
	Female	56.60%	41.67%	50.00%	50.58%	49.86%
Age	Under 18	26.42%	22.92%	30.25%	23.26%	25.61%
	Ages 18 to 25	18.87%	19.79%	16.05%	13.95%	17.34%
	Ages 26 to 40	21.70%	24.48%	27.16%	18.60%	22.90%
	Ages 41 to 60	28.30%	26.56%	23.46%	35.47%	28.46%
	Over 60	4.72%	6.25%	3.09%	8.72%	5.69%
Occupation	Homemaker	16.98%	12.50%	19.75%	26.16%	18.56%
	Employed	18.40%	23.96%	11.73%	11.63%	16.80%
	Freelancer	8.02%	13.02%	17.28%	13.95%	12.74%
	Others	17.45%	9.38%	18.52%	10.47%	13.96%
	Student	21.70%	25.52%	7.41%	15.70%	18.16%
	Retired	17.45%	15.63%	25.31%	22.09%	19.78%
Trip Information	Commuting to Work	10.85%	17.19%	11.73%	18.60%	14.50%
	Going to School	14.62%	8.33%	20.37%	14.53%	14.23%
	Medical Appointment	15.09%	13.54%	9.26%	34.88%	18.02%
	Shopping	15.09%	23.96%	22.84%	20.93%	20.46%
	Entertainment	23.11%	16.67%	16.67%	4.65%	15.72%
	Others	21.23%	20.31%	19.14%	6.40%	17.07%
Trip Frequency (trips/week)	<5	28.30%	19.27%	34.57%	36.63%	29.27%
	5-10	21.23%	35.94%	19.75%	20.35%	24.53%
	11-20	22.64%	21.35%	24.07%	26.16%	23.44%
	>20	27.83%	23.44%	21.60%	16.86%	22.76%
Alternative Travel Options	Motorbike	16.04%	21.88%	13.58%	23.26%	18.70%
	GrabBike	25.94%	13.02%	16.05%	13.37%	17.48%
	Walking	19.81%	26.56%	15.43%	9.30%	18.16%
	Taxi	21.23%	15.10%	32.10%	26.16%	23.17%
	None	16.98%	23.44%	22.84%	27.91%	22.49%

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	<5	14.15%	13.54%	3.70%	12.79%	11.38%
	5-10	6.60%	10.94%	8.64%	16.28%	10.43%
Income Level (million VND)	10--15	13.68%	8.85%	12.96%	5.23%	10.30%
	>15	11.79%	13.02%	7.41%	13.37%	11.52%
	No Response	53.77%	53.65%	67.28%	52.33%	56.37%

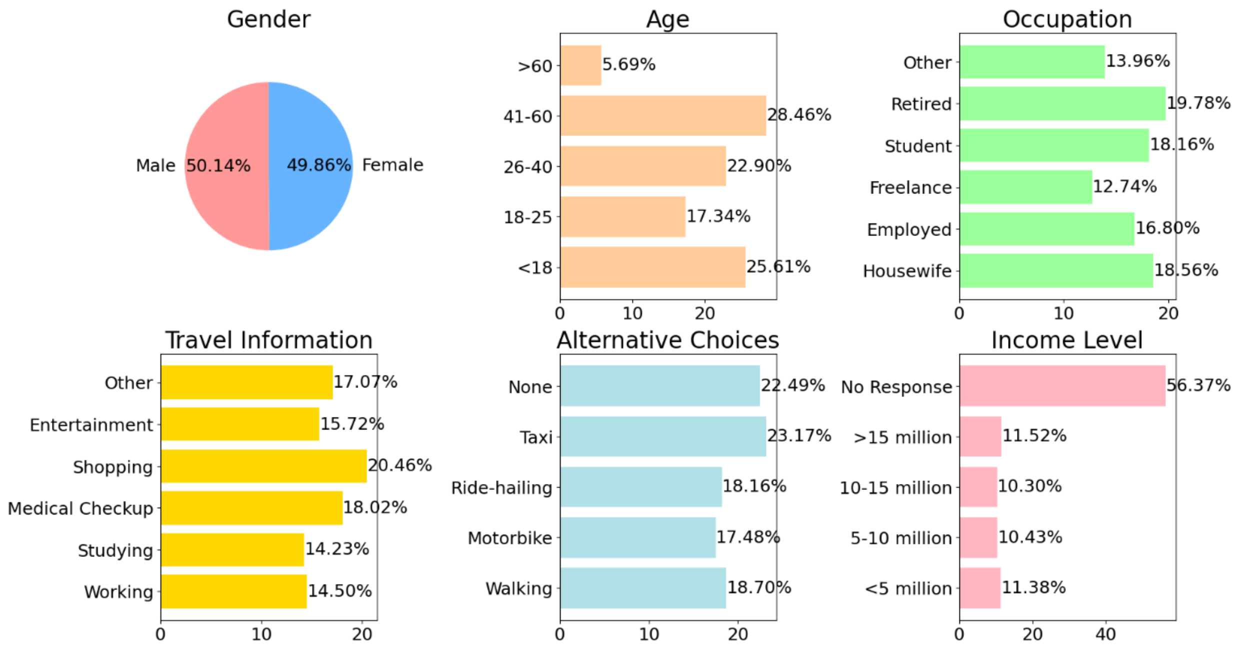

Figure 1. Percentage of Surveyed Attributes by Total Routes

Table 4 illustrates the hierarchy of perceived quality across multiple bus service attributes in Thu Duc City, arranged in descending order. Leading the evaluation is the integration of eco-friendly vehicles—such as electric buses and those operating on clean energy sources—signaling the municipality's increasing prioritization of sustainable transportation strategies. Ranked second is the ease of access to and from bus stops, indicating that the stop network in Thu Duc is reasonably well-designed, offering convenient access for most passengers.

Table 4. User Ratings of Service Dimensions and Overall Satisfaction

Variable Code	Description	Average Score	Standard Error
ENV	Adoption of eco-friendly buses (hybrid/electric models)	8.11	1.89
ACC	Proximity to boarding points	7.43	2.23
TFD	Duration from bus stop to final destination	7.19	2.12
BCL	Cleanliness of bus interior	7.02	1.65
TR	Convenience of Transfers	6.96	2.24
IS	Information at Bus Stops	6.90	2.43
IB	Onboard Display Information	6.83	2.24
CM	Bus Display Information	6.77	1.86
SR	Comfort of Bus Use	6.75	2.16
SAF	Courtesy and helpfulness of bus drivers	6.53	2.11
FAC	Condition of stop infrastructure	6.54	2.02
APP	Availability of real-time data via mobile apps	6.53	3.14
COV	Extent of route network coverage	6.49	2.01
WEB	Accuracy of online system information	6.41	2.32
ACCX	Accessibility for individuals with disabilities	6.25	2.18
WST	Passenger waiting duration at stops	6.21	2.22

CRW	Perceived crowding inside the vehicle	6.24	2.15
MAP	Ease of interpreting the route diagram	6.24	2.36
DUR	Total journey duration	6.14	2.09
FRQ	Regularity and scheduling of service	6.09	2.22
DRV	Driving style of the operator	5.88	2.13
PR	Bus Fare	5.78	2.22
CA	Air Conditioning System on the Bus	5.72	2.48
NO	Noise Level on the Bus	5.68	2.02
OS	Overall Satisfaction with the Bus System	6.70	2.01

In contrast, service-related attributes such as service frequency and fare pricing received lower ratings. This may be due to the bus system's inability to meet desired frequency levels—especially during peak hours—as well as fare structures that are not sufficiently competitive with private modes of transport. Environmental comfort factors, including onboard air conditioning and noise levels during transit, also received relatively low scores, highlighting the need for vehicle quality improvements. Some attributes, such as bus cleanliness and onboard comfort, were rated with a high level of consensus among respondents. However, there was significant variation in perceived quality across other attributes—particularly those related to passenger information systems, including mobile app information, route map clarity, and information availability at bus stops. This underscores the need to improve information accessibility in Standard Deviation order to enhance the overall user experience.

4. Methodology

This study defines a spatio-temporal integration as the concurrent measurement and modeling of passenger satisfaction across both geographic (ward-level) and temporal (peak vs. off-peak) dimensions. By embedding spatial and time-specific identifiers into the BWS questionnaire and modeling interaction effects in the MNL regression, the study offers a novel empirical framework for capturing dynamic variation in transit service perceptions. To assess passenger satisfaction with the bus system, this study employs two primary approaches: the Overall Satisfaction (OS) method and the BW model. The OS method is used to analyze variations in satisfaction across bus routes and time slots throughout the day, thereby identifying specific locations and periods with lower satisfaction levels. In contrast, the BW model focuses on evaluating the relative importance of individual service attributes, allowing for the identification of both the most and least influential factors affecting the passenger experience.

The combination of these two methods provides a comprehensive understanding of satisfaction levels while enabling the prioritization of key service factors. Moreover, the study offers empirical evidence on the spatio-temporal variation in user satisfaction, serving as a foundation for proposing targeted solutions to improve the quality of bus services.

4.1. Calculation of Overall Satisfaction

To calculate overall satisfaction levels, each bus route was divided into segments based on passengers' boarding and alighting points. Survey data were assigned to the corresponding segments used by each respondent. Data from passengers traveling on the same segment were then aggregated and averaged to accurately reflect satisfaction levels for that specific portion of the route. To improve interpretability, the original 0–4 scale was rescaled to a 1–10 scale. In order to analyze satisfaction by time of day, satisfaction values for each segment were grouped according to defined time slots. This spatio-temporal aggregation of data provides a comprehensive view of passenger experience and supports efforts to improve bus services by optimizing frequency, adjusting routing, and enhancing service quality in areas and periods with the lowest satisfaction levels.

4.2. Evaluation of the Most Important Factors

To determine which service features are perceived as most and least influential in shaping passenger experience, this study utilizes the BWS method [18]. In each task, respondents are shown a randomly selected subset of four service attributes and asked to identify the one they value the most and the one they consider least important. To ensure unbiased responses, participants are restricted from selecting the same attribute as both best and worst within a single scenario. To quantify these judgments, a multinomial logit model is employed, allowing the estimation of the likelihood

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of each Best–Worst choice. This modeling approach facilitates the computation of the relative importance of individual service attributes and enables comparison of their significance across different time intervals. Compared to traditional rating methods such as Likert scales, the BWS framework enhances the precision of attribute prioritization and supports subgroup analysis based on demographic and contextual factors—such as age, gender, route, or time of day.

Table 5. Best–Worst Choice Scenarios for Evaluating Passenger Satisfaction

Most important attribute to	Passengers evaluate the importance of each factor in Group	Least important
○	Waiting Time	○
○	Service Provision	○
○	Route Coverage	○
○	Onboard Information	○

Note: The circles (○) indicate selectable options in the survey design, where respondents were asked to choose: One "Most important" attribute (left side), and One "Least important" attribute (right side) from each set of four attributes.

5. Results and Discussion

5.1. Spatial Variation in Satisfaction Levels

Figure 2, constructed from table 6, illustrates the spatial distribution of satisfaction across the four surveyed bus lines, with route segments delineated by stop intervals. For each segment, satisfaction scores were computed based on the procedure outlined in Section 3.1. Overall, satisfaction differences along individual routes were relatively minor. Likewise, satisfaction levels across the four bus lines showed a general consistency within the network, with the overall level of satisfaction assessed as moderate.

Table 6. Satisfaction Levels Across Four Bus Routes

	Level	Route 08	Route 19	Route 56	Route 76	Total
Satisfaction Level	Very Dissatisfied	13.68%	24.48%	25.31%	21.51%	20.87%
	Dissatisfied	27.36%	20.83%	6.79%	17.44%	18.83%
	Neutral	26.42%	22.40%	26.54%	29.07%	26.02%
	Satisfied	20.75%	8.85%	16.67%	13.95%	15.18%
	Very Satisfied	11.79%	23.44%	24.69%	18.02%	19.11%

Analysis of spatial satisfaction patterns reveals considerable variability along different segments of the surveyed bus routes in Thu Duc City. Route 8 shows pronounced disparities at both termini, especially in locations with limited access to supplementary transit services. In the northeastern zone, passenger feedback is mixed—while some respondents express approval, others report dissatisfaction, likely stemming from infrequent bus arrivals that fall short of demand. The western end of the route similarly records lower satisfaction, potentially linked to infrastructure constraints or inadequate vehicle capacity during peak usage periods.

In contrast, Route 19 achieves relatively higher satisfaction ratings, likely attributable to its service coverage of high-demand destinations such as the High-Tech Park, Linh Trung Export Processing Zone, and Vietnam National University. Nonetheless, declines in satisfaction are observed in segments within the central and western portions of the route, possibly due to chronic congestion and extended wait times. Notably, satisfaction differs by direction of travel, with more favorable ratings associated with trips heading toward the city center—presumably due to more efficient intermodal connections.

Route 56 tends to display moderate satisfaction overall, although notable variations exist. Certain sections perform poorly, while one eastern segment—serving university areas and operating at higher frequency during specific hours—achieves above-average ratings. Directional effects are again evident, with higher satisfaction reported for trips toward the university corridor. This may reflect the limited presence of alternative transit options along the route, reinforcing its value for students.

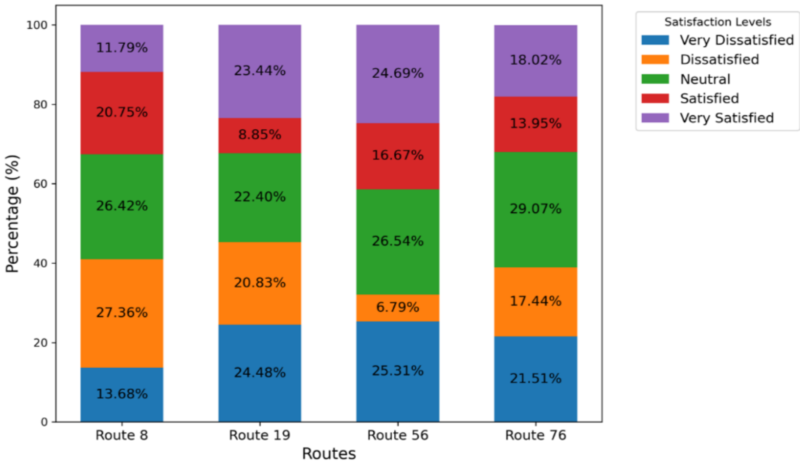

Figure 2. Distribution of Passenger Satisfaction Across Bus Routes

As for Route 76, the northeastern segment—particularly northbound—shows stronger performance. Other sections yield average satisfaction, apart from the western zone where ratings decline sharply. This area coincides with lower vehicle deployment, which may constrain accessibility and reduce service appeal.

Taken together, the findings demonstrate that satisfaction levels are not consistent along entire routes. Areas lacking alternative transport or characterized by sparse route coverage tend to underperform. Moreover, directionality plays a role in shaping user perceptions, especially for Routes 19 and 56. These insights emphasize the importance of targeted service adjustments in low-performing segments to improve passenger experience and enhance the efficiency of the bus network in Thu Duc City.

5.2. Temporal Variation in Satisfaction Levels

Passenger satisfaction was analyzed across two-hour intervals between 6:00 a.m. and 7:00 p.m. using survey responses. The results indicate that satisfaction tends to decline during peak periods—most notably around midday—while off-peak hours, particularly in the afternoon, are associated with more favorable evaluations. Satisfaction levels also differed across routes. Services with higher frequency, such as Routes 8 and 19, showed greater consistency in user evaluations, while lower-frequency routes exhibited more pronounced temporal fluctuations. Route 76 demonstrated a distinct pattern, with the lowest satisfaction recorded during morning off-peak hours—potentially linked to a larger proportion of elderly passengers with specific travel needs. To assess whether satisfaction and perceived service quality varied significantly by time period or route, ANOVA was employed. This analysis examined three key dimensions: (1) temporal variation in satisfaction, suggesting time-specific service adjustments where necessary; (2) differences across routes, indicating a need for route-specific improvements; and (3) the relative influence of individual service attributes, highlighting priorities for targeted enhancements. Table 7 summarizes the results, with statistically significant attributes indicated in bold.

Table 7. ANOVA Test for Differences by Time Period and Bus Route

ANOVA Results	Hourly Interval		Broad Time Window		By Bus Route	
	F-statistic	p-value	F-statistic	p-value	F-statistic	p-value
OS	0.553	0.684	0.523	0.550	4.145	0.002*
ACC	0.886	0.259	1.339	0.127	1.762	0.126
WST	1.236	0.231	0.257	0.485	0.746	0.225
DUR	1.353	0.211	2.023	0.020*	1.319	0.211
TFD	1.314	0.212	0.342	0.230	1.234	0.218
PR	2.940	0.001*	2.783	0.017*	0.975	0.404
TR	0.840	0.600	1.192	0.313	0.540	0.655
FRQ	1.046	0.405	1.455	0.204	10.128	0.000
SR	0.650	0.785	0.649	0.662	2.448	0.023*

COV	2.679	0.003*	3.464	0.004*	1.718	0.163
IS	1.219	0.324	1.323	0.321	1.326	0.104
WEB	1.506	0.301	1.342	0.323	0.543	0.405
IB	1.323	0.432	1.212	0.319	2.233	0.003*
CRW	1.655	0.002*	2.154	0.000*	5.317	0.001*
CA	1.287	0.229	2.310	0.000*	5.662	0.001*
ACCX	0.877	0.447	1.325	0.322	0.453	0.532
CM	1.341	0.105	2.122	0.015*	2.139	0.103
BCL	1.142	0.440	1.352	0.369	0.524	0.438
DRV	0.696	0.440	0.793	0.422	1.759	0.222
SAF	1.564	0.144	2.795	0.015*	1.302	0.333
ENV	1.236	0.404	0.394	0.871	0.562	0.676
NO	1.675	0.003*	1.351	0.223	3.292	0.001*
APP	1.347	0.225	1.879	0.034*	4.441	0.000*
FAC	0.681	0.671	0.892	0.470	1.416	0.220
MAP	1.112	0.327	1.291	0.006*	1.178	0.120

Although no substantial changes in perceived service quality are detected when analyzing at the hourly level, broader temporal segments reveal clearer distinctions. Service characteristics such as ticket cost (PR), network span (COV), passenger density (OC), and acoustic environment (NO) exhibit significant shifts throughout the day. Even greater temporal deviations are found in aspects such as temperature regulation (CA), seating comfort (CM), and operator demeanor (SAF). Meanwhile, trip duration (DUR), real-time mobile information (IM), and route guide interpretability (MAP) show moderate levels of variation across different time blocks. In contrast, overall satisfaction varies more distinctly across bus routes. Corresponding differences are also evident in perceptions of service frequency (FRQ) and reliability (SR). Additional route-dependent variations appear in onboard information (IB), crowding levels (CRW), air conditioning (CA), noise (NO), and mobile-based service information (APP).

5.3. Best–Worst Logit Modeling Results

Table 8 presents the regression outcomes derived from a discrete choice modeling approach, which evaluates the prioritization of different transit service dimensions across five defined temporal categories. These intervals—early morning rush (6:30–8:30), post-peak morning (8:30–11:30), midday congestion (11:30–13:30), early afternoon lull (13:30–16:30 and post-19:30), and evening rush (16:30–19:30)—were delineated in accordance with observed commuting behaviors in Thu Duc City, ensuring an even distribution of observations for robust model calibration.

Table 8. MNL Model Based on Best–Worst Analysis Examining Temporal Variation

Variable Code	Attribute in the Model	Coefficient	p - value
ACC	Proximity to boarding points	1.517	12.13
WST	Passenger waiting duration at stops	2.042	15.96
DUR	Total journey duration	2.296	17.50
TFD	Duration from bus stop to final destination	1.478	2.29
PR	Fare Price	1.412	3.24
TR	Ease of Transfer	1.193	6.48
H1TR	Ease of Transfer × Morning Peak Hours	-0.345	-1.97
H3TR	Ease of Transfer × Afternoon Peak Hours	0.480	2.21
FRQ	Regularity and scheduling of service	2.243	9.32
SR	Service Reliability	1.301	14.54
COV	Extent of route network coverage	1.437	13.24

H1LC	Extent of route network coverage × Morning Peak Hours	0.221	1.86
IS	Information at Bus Stops	1.320	9.20
H1IS	Information at Bus Stops × Morning Peak Hours	0.447	1.49
H2IS	Information at Bus Stops × Midday Peak Hours	-0.435	-1.58
H3IS	Information at Bus Stops × Afternoon Peak Hours	0.438	1.92
H1WEB	Accuracy of online system information × Morning Peak Hours	-0.436	-2.17
IB	Onboard Information	0.199	1.48
CRW	Perceived crowding inside the vehicle	1.203	9.23
H1CRW	Perceived crowding inside the vehicle × Morning Peak Hours	-0.203	-1.67
CA	Air Conditioning System	0.367	2.74
ACCX	Accessibility for individuals with disabilities	1.469	9.78
CM	Bus Display Information	1.138	6.26
H3CM	Bus Display Information × Afternoon Peak Hours	-0.225	-1.21
BCL	Cleanliness of bus interior	0.742	5.67
DRV	Driving style of the operator	13514	8.53
SAF	Courtesy and helpfulness of bus drivers	0.337	3.31
H2SAF	Courtesy and helpfulness of bus drivers × Midday Peak Hours	-0.234	-1.79
H4SAF	Courtesy and helpfulness of bus drivers × Morning Off-Peak Hours	0.343	2.82
ENV	Adoption of eco-friendly buses (hybrid/electric models)	1.121	7.34
NO	Noise Level	0.406	3.09
APP	Availability of real-time data via mobile apps	1.011	6.74
FAC	Condition of stop infrastructure	0.330	3.57
MAP	Ease of interpreting the route diagram	1.117	7.56
H4MAP	Ease of interpreting the route diagram × Morning Off-Peak Hours	-0.501	-2.05
Log-likelihood		-5234.2	
Pseudo R2		0.17	

The parameter estimates represent the perceived importance of each attribute, with higher values indicating stronger user preference. The model achieved a log-likelihood of –5234.2 and a McFadden's R^2 of 0.17, demonstrating a meaningful improvement over the null model as confirmed by the likelihood ratio test. These results allow for time-specific identification of priority service attributes across the daily schedule.

Table 9 presents standardized importance indices alongside the mean evaluations of perceived service quality corresponding to each attribute over distinct time periods. Values range from 0 (least important) to 10 (most important), with intermediate scores scaled proportionally. Route coverage, service reliability, and service provision (frequency and scheduling) consistently emerge as top priorities, showing stable importance throughout the day. In contrast, attributes such as website information, onboard information, air conditioning, and noise level are rated lowest in importance and display greater temporal fluctuation, though they never attain high overall relevance.

Table 9. Attribute Importance and Perceived Quality Across Time Periods

Var. Code	Morning Peak Hours		Morning Off-Peak Hours		Midday Peak Hours		Afternoon Peak Hours		Afternoon Off-Peak Hours	
	Imp.	Per. Quality	Imp.	Per. Quality	Imp.	Per. Quality	Imp.	Per. Quality	Imp.	Per. Quality
AT	5.43	6.39	5.32	6.67	5.32	6.21	5.32	5.98	4.47	6.37

WST	7.22	5.08	7.35	5.23	7.43	5.20	7.61	5.54	7.12	5.34
DUR	7.72	4.92	8.45	5.04	8.34	5.45	8.26	5.82	8.07	5.05
TFD	5.87	6.34	5.99	6.36	5.99	5.82	5.89	6.40	5.56	6.52
PR	6.61	4.62	6.86	4.74	6.86	6.06	6.86	4.64	6.67	5.25
TR	2.57	6.62	2.97	6.02	2.97	5.94	5.45	5.54	2.32	5.71
FRQ	7.88	4.55	7.64	4.59	7.44	4.58	7.34	4.41	7.52	4.42
SR	8.22	5.34	8.51	5.94	8.34	5.55	8.15	5.81	8.12	5.44
COV	8.01	4.69	7.35	5.88	7.65	5.25	7.45	5.27	8.23	5.34
IS	7.89	5.49	3.61	4.53	4.92	5.50	7.32	5.50	1.45	5.46
WEB	0	4.36	0	5.66	0	5.75	0	5.67	1.13	5.85
IB	1.63	6.13	1.24	5.85	1.24	6.15	1.24	5.33	0	5.75
CRW	4.57	5.12	4.27	4.28	4.34	3.83	4.26	3.74	5.17	4.62
CA	2.36	6.07	1.94	4.52	1.84	5.07	1.83	4.21	0.80	5.23
ACCX	5.46	5.55	5.55	5.36	5.76	5.37	5.72	5.18	5.42	4.64
CM	3.54	6.20	3.82	5.73	3.82	5.33	2.47	5.60	4.63	5.79
BCL	2.66	6.41	2.92	5.09	2.92	5.32	2.85	5.54	2.07	6.02
DRV	5.23	5.25	5.64	5.22	5.31	4.85	4.31	4.83	4.67	5.12
SAF	2.34	5.23	0.38	5.54	3.62	5.79	1.42	5.21	0.57	5.34
ENV	4.23	7.08	3.37	7.01	3.47	6.48	3.57	7.12	2.82	7.17
NO	2.27	4.34	1.11	4.34	1.11	4.43	1.11	5.16	0.67	4.43
APP	2.57	4.90	2.21	4.14	2.11	4.5	2.21	5.67	1.43	4.17
FAC	2.77	5.20	1.45	5.52	1.62	5.67	1.54	5.42	1.45	5.65
MAP	4.58	5.41	4.37	5.48	3.19	5.47	4.27	5.11	5.78	4.48

Of particular salience during peak hours are information accessibility at stops (IS) and the driver's interpersonal conduct, both of which gain heightened significance as travel intensity increases. These factors become more important during peak hours, as higher travel demand increases passengers' need for clear information and supportive service interactions.

5.4. Spatio-Temporal Variation in Satisfaction

Integrating temporal and spatial dimensions reveals how satisfaction levels shift across both time and location within the bus network. While the same analysis was applied to all routes and service attributes, only key patterns are highlighted to avoid redundancy. Findings indicate that satisfaction varies jointly by time of day and position along the route. During Early Morning Rush (6:30–8:30 a.m.), a directional pattern emerges: satisfaction is lower for passengers commuting from northern residential areas to western job centers, and higher in the reverse direction. This trend reverses in the off-peak morning period (8:30–11:30 a.m.), with reduced satisfaction eastbound and improved satisfaction westbound. Both endpoints consistently show lower ratings.

Midday peak hours follow a similar trend to the morning, with overall satisfaction declining—particularly at the northeastern terminus. The lowest levels are observed around 3:00 p.m., marking the transition between midday peak and afternoon off-peak. In early afternoon (1:30–4:30 p.m.), satisfaction improves in central segments, while peripheral areas continue to lag. By late afternoon (4:30–7:30 p.m.), satisfaction again drops sharply at both ends of the route, likely due to rush-hour congestion. From 7:30 p.m. onward, low satisfaction persists across the network.

Overall, satisfaction is typically lower at route extremities and varies by direction and time. This may reflect the nature of trips, with obligatory travel (e.g., commuting) linked to lower satisfaction than discretionary journeys such as leisure or shopping.

6. Conclusion and Recommendations

This study contributes a novel perspective by examining how passenger satisfaction with bus services varies both spatially and temporally within an urban context—an area often overlooked in previous research. While earlier studies commonly compare satisfaction across routes or regions, limited attention has been given to variations occurring within a city and across different times of day. The results demonstrate that satisfaction is influenced by both location and time, emphasizing the interplay of spatial and temporal dynamics in service evaluation. Spatially, satisfaction levels differ across the network, with peripheral zones—typically characterized by lower service density—reporting lower ratings than central areas with more route options. This aligns with prior findings (e.g., [28]) and highlights the value of localized analysis for policy design.

Temporally, peak hours—particularly midday—are associated with decreased satisfaction, diverging from studies such as [7] that identified evening declines. Service frequency, passenger load, and rider demographics further contribute to temporal variation. For instance, routes serving larger elderly populations tend to exhibit lower satisfaction during morning off-peak hours when demand is concentrated. Moreover, best–Worst Scaling results indicate that the perceived relevance of service attributes changes throughout the day. While core factors like reliability, frequency, and overall service provision consistently hold importance, informational aspects such as announcements or digital content are viewed as less critical—consistent with the work of [5], [29].

Based on these findings, the study proposes several recommendations aimed at improving service quality and attracting more passengers. First, increasing service frequency and reducing waiting times on low-performing routes—especially during peak hours—can help alleviate overcrowding and delays. In addition, optimizing route coordination and adjusting service provision to match dominant travel directions may address imbalances in satisfaction between inbound and outbound flows. It is also essential to prioritize improvements in core service attributes such as network coverage, reliability, and waiting time, as these factors were consistently identified by passengers as the most influential. The study further recommends the implementation of real-time satisfaction monitoring tools, integrated with route maps and operational dashboards, to enable timely interventions where service quality deteriorates. Finally, conducting regular surveys and fostering two-way communication with passengers—particularly those in high-demand areas or belonging to sensitive demographic groups such as students and the elderly—can provide valuable feedback for continuous improvement. This study aims to provide empirical evidence for transport managers and policymakers to guide more flexible, effective, and user-centered service adjustments—thereby promoting the sustainable development of urban public transport systems.

7. Declarations

7.1. Author Contributions

Conceptualization: N.T.N.N., H.N.M.; Methodology: N.T.N.N., H.N.M.; Software: N.T.N.N.; Validation: H.N.M.; Formal Analysis: N.T.N.N.; Investigation: N.T.N.N.; Resources: H.N.M.; Data Curation: N.T.N.N.; Writing – Original Draft Preparation: N.T.N.N.; Writing – Review and Editing: H.N.M.; Visualization: N.T.N.N.; All authors have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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The authors received no financial support for the research, authorship, and/or publication of this article.

7.4. Institutional Review Board Statement

Not applicable.

7.5. Informed Consent Statement

Not applicable.

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7.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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