Cross Study on Demand, Satisfaction and Green Travel Incentive of Urban Subway Passengers from Multidimensional Perspective

Yingnan Zhao[1]

[1] *School of Economics and Management, Yanbian University, Hunchun 133399, China*

ABSTRACT

Based on the cross perspective of demand-satisfaction-incentive response, this paper constructs a structural equation model and discusses the interaction among them. Through the empirical analysis of 537 valid questionnaires in a big city, it is found that passenger demand is positively correlated with satisfaction (r=0.48), and satisfaction is positively correlated with green travel incentive response (r=0.52); Satisfaction plays a partial intermediary role between demand and incentive response, and the intermediary effect accounts for 64.2% of the total effect; Potential category analysis identified three types of passenger groups: efficiency priority, comfort concern and environmental experience, and their incentive responses were significantly different (F=68.94, p<0.001). The proportion of environmental experience participating in incentive activities (62.4%) was much higher than that of efficiency priority (18.4%). The results show that improving passenger satisfaction is the key path to activate green travel incentive response, and the design of differentiated incentive strategy should be based on the structural characteristics of passenger demand. This study provides theoretical reference and practical basis for optimizing subway service quality and enhancing green travel incentive effect.

Keywords: *Urban subway, Passenger demand, Passenger satisfaction, Green travel incentive.*

1. INTRODUCTION

With the deepening of China's "double carbon" strategic goal, green and low-carbon travel has become the core direction of urban transportation transformation. As a public transport mode with large capacity and low energy consumption, urban subway undertakes the important mission of alleviating traffic congestion and reducing carbon emissions. While the passenger flow continues to rise, the problems such as uneven passenger satisfaction and limited incentive effect of green travel are becoming increasingly prominent, which restricts the further play of the subway in the green travel system [1].

From the perspective of passenger demand, there are obvious differences in the expectations of different groups for subway travel [2]. Commuters pay more attention to punctuality rate and transfer convenience, and leisure travelers pay more attention to the comfort of carriages and the environment in the station, while some passengers with environmental awareness show higher attention to green travel incentives [3]. Most of the existing studies analyze passenger demand or satisfaction from a single dimension, and seldom put demand, satisfaction and green travel incentive into the same analysis framework, ignoring the possible cross-interaction among them. From the perspective of satisfaction, passenger satisfaction is a key indicator to measure the quality of subway service, and it is also an important factor affecting the choice of passenger travel mode [4]. From the perspective of green travel incentives, although various incentives such as carbon Pratt & Whitney, point exchange and fare discount have been introduced in various places, the actual effect is not ideal [5]. One of the reasons is that the design of incentive measures often lacks an accurate grasp of the real needs and satisfaction status of passengers, which leads to "mismatch between supply and demand" and greatly reduces the incentive effect.

Based on this, this paper intends to construct an interdisciplinary research framework from three

dimensions: demand, satisfaction and green travel incentive. Through questionnaire survey and empirical analysis, this paper discusses the mutual influence among them, and accordingly puts forward targeted optimization suggestions, with a view to providing reference for improving subway service quality and enhancing green travel incentive effect.

2. RESEARCH DESIGN

2.1 Research Object and Sampling Scheme

Passengers who have traveled by subway at least five times in the past three months among the permanent and floating population in the main city where the subway has been opened in a big city. The method of combining stratified random sampling with convenient sampling is adopted [6-7]. The first floor is divided by line types, including commuter-intensive lines in the city center, suburban connection lines, and hot-spot lines for cultural tourism. The second floor is divided by time periods, including morning peak (7:00-9:00), evening peak (17:00-19:00), flat peak (10:00-16:00) and weekend daytime. At the typical station exit or waiting area of each selected line, the investigator randomly invites passengers to scan the code and fill in the questionnaire.

It is estimated that there are about 30-40 formal questions, so the effective sample size should be no less than 400. Considering the proportion of invalid questionnaires is 20%, it is planned to recycle 500-600.

2.2 Variable Definition and Measurement Tool

Based on the research questions, the three core dimensions are transformed into measurable variables ("Table 1"). In addition, demographic variables and travel habits are collected for group comparison and adjustment effect analysis.

Table 1. Variable definition

Latent variable	Dimension	Observation index (Likert 5 scale)
Passenger demand	Function needs/requirement	Punctuality rate requirements, tolerance of transfer walking time, and shift interval requirements
	Comfort demand	Tolerance of car congestion, number of seats, suitability of air conditioning temperature
	information needs	In-station guidance clarity, arrival forecast accuracy, and sudden information push
	Environmental protection demand	Attention to low-carbon travel signs and expectation of energy consumption information disclosure
Passenger satisfaction	Overall satisfaction	"I am generally satisfied with this/recent subway trip"
	Item satisfaction	Specific scores of service items corresponding to the above requirements
Green travel incentive	Policy awareness	"Do you know that the subway in your city has carbon points/mileage exchange activities?"
	Willingness to participate	"If you can get green points for convertible rights every subway trip, would you like to participate?"
	Actual behavior response	"Have you actively participated in the green travel activities organized by the subway company in the past three months?"
	Incentive preference	"What kind of incentive do you prefer: fare discount, points exchange for goods, charity donation certificate, carbon account ranking"

2.3 Questionnaire Design and Data Collection Process

The questionnaire structure includes introduction, which explains the background, research purpose and anonymity guarantee of "Double Carbon". Travel habits and basic information (5 questions); Demand importance evaluation, which scores each demand index as "very unimportant-very important"; In the current satisfaction evaluation, the same group of indicators are scored as "very dissatisfied-very satisfied"; Perception and preference of green travel incentives (8 questions); Open suggestion (optional). 30 passengers from different backgrounds were invited to try to fill in the questionnaire, and combined with reliability test and wording adjustment, the

items with lower load were deleted, and finally a formal questionnaire was formed.

Push the questionnaire link through the official subway APP and the local lifestyle WeChat official account, supplemented by the 5 yuan travel coupon as an incentive. Investigators hold a two-dimensional code display board in the non-payment area of the selected site to invite passengers waiting for the bus or just leaving the station to scan the code and fill it out. For two consecutive natural weeks (including working days and weekends), it is covered in three periods: morning, noon and evening. SPSS 26.0 and AMOS 24.0 were used for statistical modeling.

2.4 Quality Control and Ethical Considerations

Offline investigators receive unified training to avoid induced questions; Set IP and equipment restrictions for online questionnaires to prevent repeated answers; Exclude samples whose answer time is too short (< 90 seconds) or whose scale options are obviously regular. All respondents were told that the data were only used for academic research, and names and accurate addresses were not collected; Offline research provides small gifts as a thank you, and participation is not mandatory.

3. DATA ANALYSIS AND RESULTS

3.1 Sample Descriptive Statistics

A total of 587 questionnaires were collected in this survey, and 537 valid samples were obtained after excluding invalid questionnaires, with an effective recovery rate of 91.5%. The basic characteristics of the sample are shown in "Table 2". The sample covers passengers of different ages, commuting frequency and living distance, among which commuters account for 74.1%, which conforms to the characteristics of subway core users.

Table 2. Sample demographics and travel characteristics (N=537)

Variable	Category	Frequency	Percentage (%)
Gender	Man	281	52.3
	Woman	256	47.7
Age	18-30 years old	203	37.8
	31-45 years old	268	49.9
	46 years old and above	66	12.3
Weekly average subway times	≤3 times	112	20.9
	4 to 10 times	304	56.6
	≥11 times	121	22.5
Main travel purpose	Commuting (commuting/studying)	398	74.1
	Leisure shopping	89	16.6
	Others (visiting relatives, seeking medical treatment, etc.)	50	9.3
Living distance from subway station	≤10 minutes	341	63.5
	11-20 minutes	156	29.1
	> 20 minutes	40	7.4

3.2 Reliability and Validity Test

Cronbach's α coefficient was used to test the internal consistency of each latent variable. Results As shown in "Table 3", the α values of all latent variables are above 0.78, indicating that the questionnaire has good reliability.

Table 3. Reliability analysis results of each latent variable

Latent variable	Dimension	Number of items	Cronbach's α
Passenger demand	Function needs/requirement	4	0.821
	Comfort demand	3	0.794
	information needs	4	0.805
	Environmental protection demand	3	0.783
Passenger satisfaction	Whole+sub-item	6	0.862
Green travel incentive response	Awareness+Willingness+Behavior+Preference	5	0.847

The results of the confirmatory factor analysis (CFA) showed: $\chi^2/df=2.41$, CFI=0.934, TLI=0.921, RMSEA=0.067, SRMR=0.052. All fit indices met the acceptable standards (CFI>0.90, RMSEA<0.08), indicating that the three-dimensional structure has good construct validity.

3.3 Descriptive Statistics and Correlation Analysis of Variables

The mean, standard deviation and Pearson correlation coefficient of each core variable are shown in "Table 4". The average total score of passenger demand is 3.89 (out of 5), indicating that the overall demand level of passengers is high; the average satisfaction is 3.52, which is above average. The average green travel incentive response is 2.91, which is relatively low, indicating that the current incentive measures have not fully activated passenger participation.

Correlation analysis showed a significant positive correlation between passenger needs and satisfaction (r=0.48, p<0.01), a significant positive correlation between satisfaction and incentive response (r=0.52, p<0.01), and a direct positive correlation between needs and incentive response (r=0.35, p<0.01), which preliminarily supports the subsequent mediation effect hypothesis.

Table 4. Matrix of mean, standard deviation and correlation coefficient of core variables (N=537)

Variable	M	SD	1	2	3
1. Passenger demand	3.89	0.67	1		
2. Passenger satisfaction	3.52	0.71	0.48**	1	
3. Green Travel Incentive Response	2.91	0.82	0.35**	0.52**	1
Note: * * p<0.01 (double tail)					

Further divide the needs into four sub-dimensions and examine their impact on satisfaction. The multiple regression analysis (controlling for age, income, and travel frequency) results show that functional needs (β=0.31, p<0.001), comfort needs (β=0.24, p<0.01), and information needs (β=0.19, p<0.05) significantly and positively affect satisfaction, while the direct effect of environmental needs on satisfaction is not significant (β=0.08, p>0.05). This finding suggests that environmental needs mainly influence green travel motivation through other pathways.

3.4 Intermediary Effect in Structural Equation Model

A structural equation model (SEM) is established with passenger demand as exogenous latent variable, passenger satisfaction as intermediary variable and green travel incentive response as endogenous latent variable. The model fits well: $\chi^2/df=2.28$, CFI=0.941, RMSEA=0.062. The standardized path coefficients are shown in "Table 5".

Table 5. Standardized path coefficient and significance of structural equation model

Path	Normalization coefficient (β)	S.E.	C.R.	p value
Demand → satisfaction	0.56	0.059	9.49	<0.001
Satisfaction → Incentive response	0.48	0.061	7.87	<0.001
Demand → Incentive Response (Direct)	0.15	0.058	2.59	0.010

The mediation effect of satisfaction was tested using the bias-corrected bootstrap method. The results are shown in Table 6. The indirect effect of demand on incentive response through satisfaction was 0.269 (95% CI: [0.189, 0.357]), the direct effect was 0.150 (95% CI: [0.036, 0.264]), and the total effect was 0.419 (95% CI: [0.323, 0.515]). Mediating effect accounts for 64.2% of the total effect, indicating that satisfaction plays a partial mediating role between demand and incentive response.

Table 6. Bootstrap analysis results of intermediary effect

Effect type	Effect value	Boot standard error	95% confidence interval (lower limit, upper limit)	Effect proportion
Direct effect	0.150	0.058	0.036~0.264	35.8%
Indirect effect	0.269	0.043	0.189~0.357	64.2%
Total effect	0.419	0.049	0.323~0.515	100%

3.5 Potential Category Analysis and Group Differences

In order to reveal the heterogeneity of passenger demand structure, latent category analysis (LCA) was conducted on the scores of four demand sub-dimensions: function, comfort, information and environmental protection. According to AIC, BIC and entropy index, the optimal number of categories is determined to be 3. The naming and demand characteristics of each category are shown in "Figure 1" below.

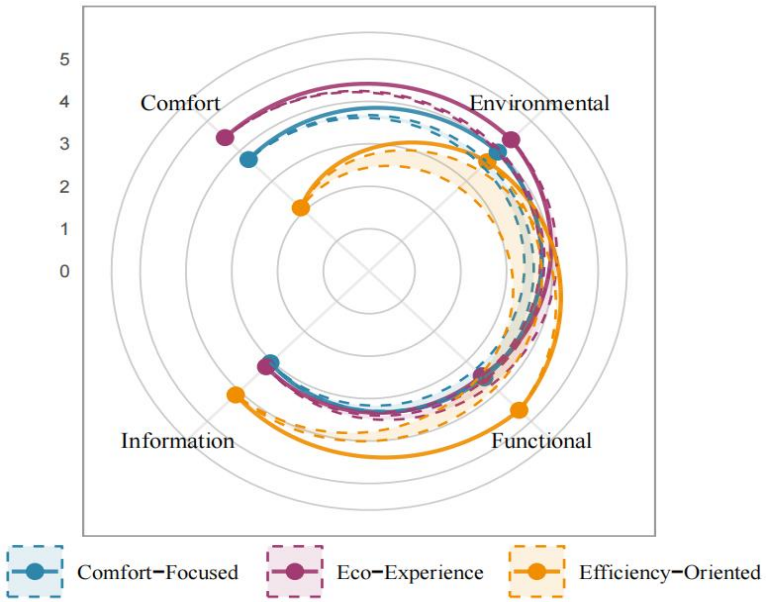


Figure 1 Radar chart of demand characteristics of three types of passengers.

The score of functional requirements is the highest (M=4.63), comfort and information requirements are moderate, and environmental protection requirements are the lowest (M=2.11). The main features are high commuting frequency and time sensitivity. Comfort demand (M=4.45) and information demand (M=4.12) are prominent, followed by functional demand and environmental protection demand (M=3.05). Most of them are leisure travelers or long-distance commuters. The demand for environmental protection is significantly higher than the other two categories (M=4.38), and the demand for information is also higher (M=3.97). These passengers are young, with high academic qualifications, and their awareness of incentives such as carbon Pratt & Whitney is significantly higher than that of the first two categories. See Table 7 for the differences in satisfaction and incentive response of different potential categories.

Table 7. Differences in satisfaction and incentive response of different potential categories (one-way ANOVA)

Category	Satisfaction (M ± SD)	Incentive response (M ± SD)	Proportion of people who have participated in incentive activities
Efficiency priority type (n=228)	3.24±0.68	2.58±0.79	18.4%
Comfort focused type (n=192)	3.61±0.72	2.97±0.74	31.3%
Environmental experience type (n=117)	3.89±0.65	3.58±0.69	62.4%
F value	39.27***	68.94***	χ^2=74.15***

Note: * * * p < 0.001

Back testing shows that the satisfaction and incentive response of environmental experience type are significantly higher than the other two types ($p<0.01$), while the satisfaction and incentive response of efficiency priority type are the lowest. This suggests that different types of passengers need differentiated incentive strategies.

3.6 Analysis of Incentive Preference for Green Travel

For multiple-choice questions with incentive preference (each person can choose at most two items), the selection frequency of each option is calculated. The results are shown in "Figure 2".

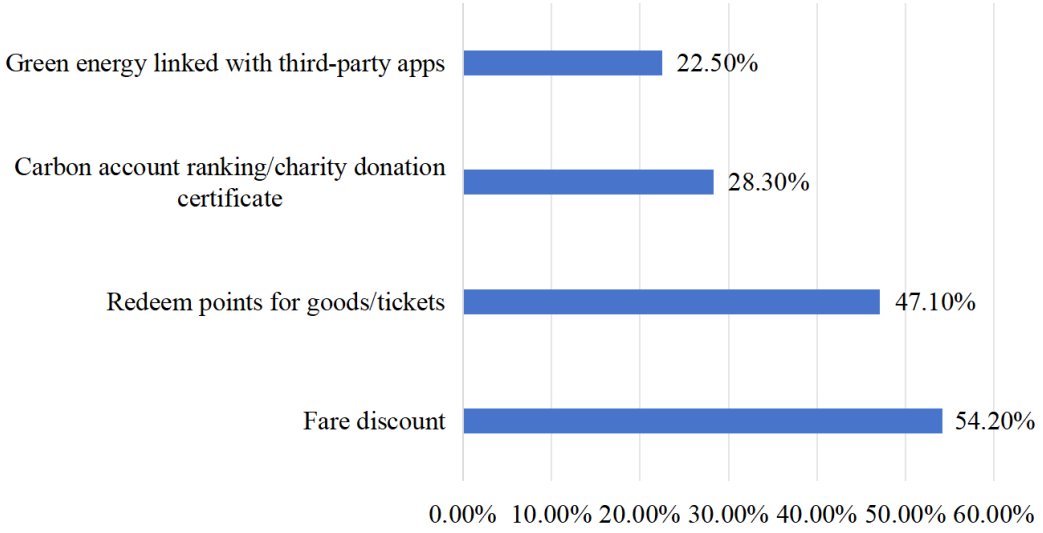


Figure 2 Distribution of passengers' preference for different green travel incentives.

Hierarchical analysis shows that the efficiency-priority type prefers direct fare discount (68.9%), the comfort-concerned type prefers "points for goods" (58.3%), while the environmental experience type has significantly higher selection rates for "carbon account ranking/public welfare certificate" (61.5%) and "third-party energy" (51.3%), which reflects the matching of values and incentive preferences.

4. RESEARCH CONCLUSIONS AND SUGGESTIONS

From a multi-dimensional perspective, this study deeply analyzes the correlation mechanism between urban subway passenger demand, satisfaction and green travel incentive, and draws the following core conclusions:

(1) Passenger demand covers convenience, comfort, economy and other dimensions, and presents hierarchical characteristics due to differences in travel purposes and crowd attributes. The core demand focuses on efficient transfer, on-time guarantee and service experience optimization.

(2) The punctuality rate of subway operation, the perfection of station facilities and the efficiency of service response are the key variables that affect passengers' satisfaction, and the satisfaction level is directly related to passengers' travel preference and green travel willingness.

(3) The existing incentives for green travel are single, the matching degree with the core needs of passengers is low, the closed-loop optimization cannot be effectively formed by satisfaction feedback, and the guiding effect on green travel is limited, and a benign interaction cycle has not yet been formed among them.

The following research suggestions are put forward: accurately meet multiple needs and optimize service supply. Establish a dynamic monitoring mechanism for passenger demand, improve services such as transfer guidance and convenience facilities in different travel scenarios such as commuting and leisure, and launch customized travel plans to effectively meet the needs of stratification. Focus on key shortcomings and improve satisfaction level. Strengthen operation and dispatch management to ensure punctuality, upgrade old site facilities, smooth service feedback channels, establish a quick response mechanism for problems, and lay a solid foundation for green travel by improving service quality. Innovate the incentive system and strengthen synergy. Combined with passenger demand and satisfaction data, we will build a multi-incentive system, such as point redemption, travel concessions, carbon rights and interests incentives, and deeply bind incentive measures with service optimization and demand response to form a benign interactive pattern of demand-satisfaction-incentives, and continuously enhance the attractiveness of green travel.

REFERENCES

[1] Deng F. Research on Metro Passenger Satisfaction Evaluation Based on Multi-Objective Optimization Model[J]. Lecture Notes in Education, Arts, Management and Social Science, 2025,3(9):114-119. DOI:10.18063/LNE.V3I9.968.

[2] Saransi F, Erlinda N. Assessing Service Quality and Passenger Satisfaction: A Quantitative Study of Sea Transportation on the Padang Mentawai[J]. Asian Journal of Economics, Business and Accounting, 2024,24(6):347-355. DOI:10.9734/AJEBA/2024/V24I61366.

[3] Firdaus Y H, Isradi M, Sudrajat M K, et al. Factors Affecting Passenger Satisfaction on the Depok-Bkn Transjakarta Bus[J]. Journal of Engineering Research and Reports, 2025,27(7):373-381. DOI:10.9734/JERR/2025/V27I71579.

[4] Božić D, Hunjak D, Domitrović A, et al. Multicriteria satisfaction analysis to analyse passenger perceptions of air travel service quality in Croatia[J]. Journal of the Operational Research Society, 2024,75(11):2267-2281. DOI:10.1080/01605682.2024.2311323.

[5] Jing L, Dai Z, Yunlong T, et al.Research on the Real-Time Dynamic Evaluation of Public Transport Passenger Service Satisfaction Based on the Internet[J]. Journal of Shanghai Jiaotong University (Science), 2023,28(1):39-51. DOI:10.1007/S12204-023-2568-0.

[6] Alam F, Yang Q, Bandara M Y, et al. The nexus between corporate social responsibility of airports and passenger satisfaction: A cross-country study[J]. Corporate Social Responsibility and Environmental Management, 2023,31(3):2454-2473. DOI:10.1002/CSR.2692.

[7] Rodriguez P J, Muñoz F D. Simulation and Analysis of Line 1 of Mexico City's Metrobus: Evaluating System Performance through Passenger Satisfaction [J]. AppliedMath, 2023,3(3):664-689. DOI:10.3390/APPLIEDMATH3030035.