ISSN: 1813-4890

Research on the Public Transit Behavior of the Elderly Based on Service Quality

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Abstract

China is a populous country with an increasingly prominent aging population issue, declining birth rates, and increasing average life expectancy. Public transit is currently the main mode of travel for the elderly. To improve the travel conditions of the elderly and enhance their travel happiness, a questionnaire survey was conducted among people over 55 years old in Chongqing. The characteristics of the elderly's travel behavior were studied, and an evaluation index system for public transit service level from the perspective of the elderly was established, which includes four first-level evaluation indicators: convenience, comfort, safety, and efficiency, and nine second-level evaluation indicators such as waiting time, walking time to the station, driver's service attitude, and the cleanliness inside the vehicle. The actual travel behavior of the elderly was analyzed using the Grey Comprehensive Evaluation method. The results show that the elderly are basically satisfied with the service quality of public transit, but there are still issues such as limited comfort and safety risks when getting on and off the bus. Based on the final evaluation results, an improvement plan was designed to increase the satisfaction of the elderly with their travel.

Keywords

Travel behavior, elderly public transit, service quality, Grey Comprehensive Evaluation.

1. Introduction

In recent years, with the rapid development of China's economy and the improvement of urbanization levels, people's travel demands have been increasing, and the frequency of travel per capita has also risen. However, the limited road capacity in cities has led to increasingly severe traffic congestion issues. To alleviate road congestion and environmental pollution, the development of urban public transportation and the implementation of bus priority strategies have become necessary means for sustainable urban traffic development. The current urban public transportation mainly consists of urban rail transit, bus rapid transit, and regular bus services. Due to its wide service range and convenient boarding methods, regular bus services occupy an important position in the urban public transportation system [1]. The "2021 Annual Big Data Analysis Report on Public Transportation in Major Chinese Cities" [2] ranked the happiness index of various cities, as shown in Figure 1.

It can be seen from Figure 1 that the happiness index of ground bus travel in each mega-city in China is 55 % -75 %. Among them, the happiness index of Chongqing is 64.70 %, which is at a medium level and needs to be improved. The travel mode of urban residents is affected by many factors, among which the bus service level gives passengers the most profound subjective feeling in daily travel. In order to develop bus travel and increase the proportion of people traveling by bus, the service level of bus must be improved. At present, most of the research on bus service level is based on the perspective of ordinary passengers. There are few studies on the evaluation of bus service level from the perspective of the elderly. The evaluation of bus

ISSN: 1813-4890

service level from the perspective of the elderly is helpful to increase the happiness of people in an aging society and maintain social harmony and stability. And it can be found that the current bus system has some loopholes in the travel of the elderly, which can promote the overall improvement of bus service level.

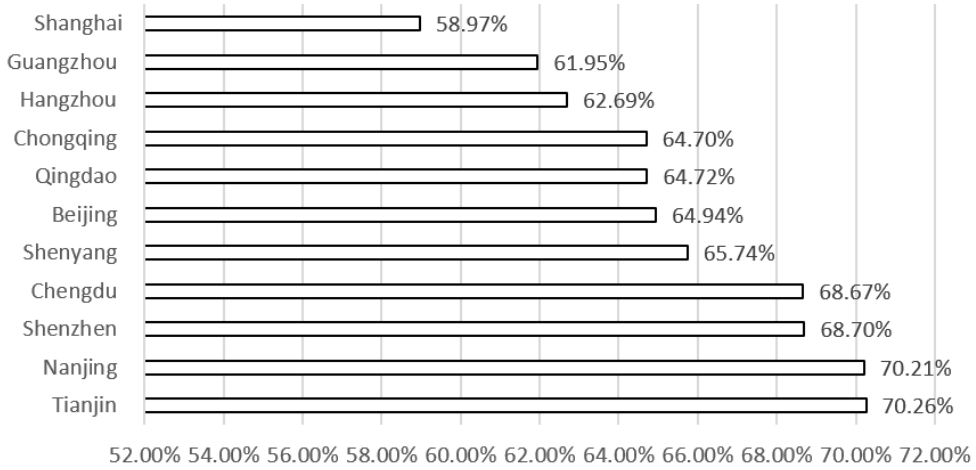

Fig. 1 Happiness index of ground bus travel in major cities across the country

China is a populous country with an increasingly prominent aging issue, declining birth rates, and increasing average life expectancy. According to the "Seventh National Population Census" of China, it is projected that by 2025, the number of people over 60 years old in China will reach 300 million, entering the category of a super-aged country [3]. As shown in Fig.2, the overall aging process is expected to reach a phase peak by 2040[4]. At the same time, due to the issue of aging before becoming wealthy in China, the mobility rate of the elderly is relatively low, and public transportation is currently the main mode of travel for the elderly. The elderly often face greater problems when using public transportation due to the decline in physical function and perceptual information barriers, compared to ordinary passengers. Therefore, to care for the elderly group and improve their travel satisfaction, it is necessary to start from a "people-oriented" perspective, improve the level of public transportation services, and create a better living space and more comfortable travel process for elderly residents. By evaluating the level of public transportation services and proposing improvement and optimization plans, this study provides a basis for improving the level of public transportation services for the elderly.

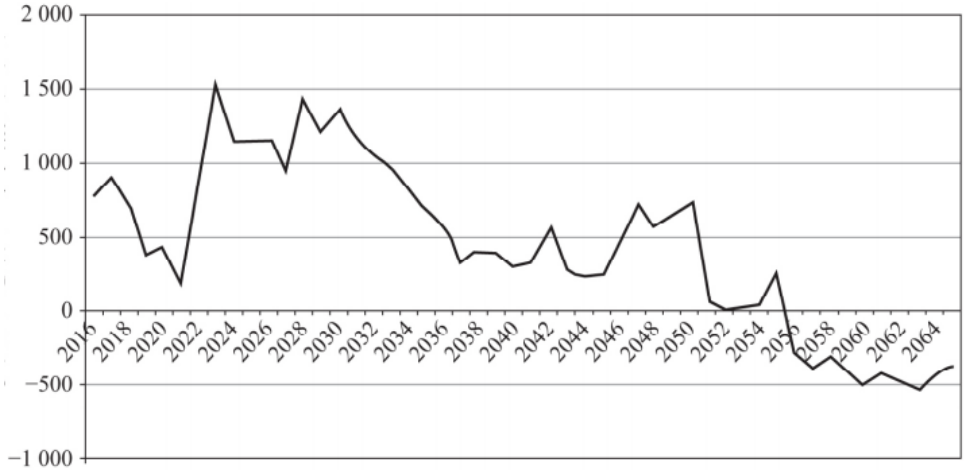

Fig.2 Prediction of the annual net increase of the elderly population in China

ISSN: 1813-4890

2. Research Status

(1) Research Methods on Urban Public Transit Service Level

Butzow[5]conducted a survey on the service quality of the public transportation system in San Francisco, starting from the perspectives of managers and travelers, and constructed a public transportation evaluation index system based on three dimensions: safety, operational speed, and convenience of use, and made a final evaluation.

DuIeba.S[6]conducted a dynamic analysis of the public transit system, used AHP to determine its weights, and prioritized the elements at various levels of the public transit system, proposing measures to improve the quality of the public transit system by comprehensively considering all aspects of public transportation.

Boujelbene Y[7]used the Analytic Hierarchy Process (AHP) to analyze the performance of operators, mainly using AHP and multi-criteria decision-making methods to comprehensively evaluate the performance of operators in Tunisia, Africa, and rank the various public operators to find the best one.

Kuang Xing established a BSCI model and designed a passenger satisfaction survey plan, and after conducting the survey and analyzing the results, used Trans CAD to analyze and evaluate the performance of different urban bus networks [8]. Cheng Jia and Li Yue took Tianfu New Area as the research object, conducted a survey on the layout of the public transit network, and used a decision tree model to analyze the survey results to promote the better and faster development of public transportation in Tianfu New Area [9].

Zhang Peng used the Analytic Hierarchy Process to improve the service quality of urban public transportation, taking the No. 104 bus in Harbin as an example, relying on the weights of four indicators: service interval, travel time, punctuality, and passenger volume, to make a final evaluation of the research object [10].

Xu Bing from Jilin University used the grey relational analysis of the judgment results, took eight bus lines in Shenyang as the survey object for the public transit service level quality survey, and proposed improvement suggestions for Shenyang's public transportation based on the evaluation results [11].

Chen Liu from Chongqing Jiaotong University took the main urban area of Chongqing as the research object to investigate its regular bus service level, used DEA evaluation to study its bus service quality, and proposed an improvement plan for the bus service quality in the main urban area of Chongqing based on the evaluation results [12].

Li Rongrong combined AHP with TOPSIS to evaluate the public transit service level in Pingdingshan, selected nearly 20 secondary indicators to establish a model, and finally obtained the optimal time for the public transit service level, and conducted a cause analysis, which is helpful for improving its service level [13].

(2) Elderly Public Transit Travel

Most of the current domestic expert research mainly focuses on the safety of elderly public transit travel, the convenience of elderly public transit travel, road public transit aging design, and the transformation of the internal space of public transit vehicles.

As age increases, the elderly will undergo physical and psychological changes that affect their daily travel. Chen Xiaoxia conducted a survey on various problems encountered by the elderly in Nanjing when traveling, and the results showed that nearly one-third of the elderly have encountered difficulties in getting on and off the bus, no seats causing easy falls when the bus brakes, and other issues [14]. Ren Futian, after conducting a survey of the elderly in the city, analyzed the travel characteristics of the elderly according to the statistical results, summarized the factors affecting the elderly's travel, and proposed to improve their safety awareness by holding lectures and other means [15]. Liu Jianrong studied the impact of walking time on travel

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behavior, established an evaluation system through the random coefficient Logit model, conducted a survey of respondents to obtain relevant data, and then calculated the final results and analyzed them [16].

3. Method Introduction

3.1. Travel characteristics of the elderly

Public transportation is one of the important modes of travel for the elderly besides walking. Caring for the travel conditions of the elderly and addressing their travel difficulties can make the aging society in China more harmonious and healthy.

In terms of daily travel methods, public transit is greatly influenced by the aging of society. Studying the travel behavior of the elderly on public transportation can improve their satisfaction with public transit, increase their sense of happiness, enhance the level of public transit services, and better serve elderly passengers. It also has reference significance for the improvement of the entire public transit system's service level and the perfection of its system. Due to different national conditions, the elderly population in China faces greater difficulties in travel compared to the elderly population abroad. Moreover, domestic elderly people usually choose public transportation for their travel needs, and the proportion of driving is relatively small. Research and transformation of public transit to suit the elderly are urgently needed. With the increase in life expectancy, the proportion of the elderly population is increasing year by year. According to behavioral cognition, the travel characteristics of the elderly are manifested in the following aspects:

(1) Travel Routes

According to medical research at home and abroad, the elderly will undergo physical and mental changes as they age. Physiologically, this is mainly manifested as the decline of certain body functions, slow movements, and reduced senses and cognition. Psychologically, the psychological needs of the elderly are mainly manifested in five aspects: the sense of family, security, belonging, comfort, and privacy. When traveling by public transit, they are more eager to obtain a better travel environment, smoother speeds, and more convenient boarding facilities. The psychological and physiological characteristics of the elderly determine that the scope of most elderly people's travel is limited. Therefore, within the limited scope, their daily travel routes are relatively fixed, and most of the elderly do not travel very far.

(2) Travel Time

The travel time of the elderly is relatively irregular compared to ordinary passengers. Some of the elderly are retired and do not have fixed times and purposes for going out. When encountering bad weather, if there are no special necessary activities, the elderly usually choose to give up traveling. The purpose of the elderly's travel is usually for leisure and entertainment, shopping, etc. Among these elderly people, some bear the heavy responsibility of taking and picking up their children from school, but overall, their travel time is not fixed.

(3) Purpose of Travel

The purpose of travel for the elderly can be divided into rigid travel purposes and flexible travel purposes. Rigid travel mainly includes commercial activities and medical activities, while flexible travel mainly includes cultural activities and leisure activities. With the decline of physiological functions, when engaging in flexible travel, the elderly usually choose to go to squares or parks near their homes for some leisure and entertainment activities, which are mostly affected by weather conditions.

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3.2. Influencing factors of elderly travel

The factors influencing the travel of the elderly include internal and external factors. Internal factors are divided into psychological and physiological factors, while external factors include family attributes, purpose of activities, etc.

(1) Internal Influencing Factors

a) Physiological Influencing Factors

The physiological impacts on the elderly are mainly in aspects such as vision, hearing, and mobility. As age increases, the elderly's ability to identify space and perceive objects declines. Their sensitivity to colors is also lower compared to young people, which increases the risk of travel for the elderly and may make it difficult for some to discern signs.

In terms of hearing, most elderly people generally have hearing issues, leading to travel difficulties. For instance, in noisy environments, they might miss stop announcements on buses due to not hearing clearly. In daily life, because of hearing problems, information often needs to be repeated multiple times before it is received by the elderly. The elderly are often troubled by chronic diseases such as osteoporosis, coronary heart disease, hypertension, and diabetes. Common changes like the reduction of muscle strength and decrease in height also greatly affect their normal travel.

b) Psychological Influencing Factors

According to Maslow's hierarchy of needs theory, human needs are divided into five levels from high to low. After reaching a certain retirement age, most elderly people's focus in life changes, along with their social networks and social status. Their need for self-actualization also changes, and this change can impact the elderly's psychology, affecting their sense of happiness and security.

In terms of cognition, due to the general decline in attention, memory, and reaction time in the elderly, they face difficulties when traveling alone in recognizing maps, finding the correct path, and choosing transportation. Therefore, compared to young people, the elderly are more prone to psychological states of loneliness and fear. In terms of travel, public transportation should provide more convenient ticket purchasing methods for the elderly, creating a sense of security for their travel. A more comfortable public environment is conducive to increasing the elderly's communication with the outside world.

(2) External Influencing Factors

a) Impact of Family Attributes

The impact of family attributes on the travel of the elderly is primarily in terms of income. Elderly from high-income families often have a more diverse range of travel modes and longer travel distances. Additionally, the level of income affects the daily activities of the elderly. Those from high-income families participate more frequently in various leisure and entertainment activities, whereas elderly from low-income families tend to have relatively fewer recreational activities, with some still continuing to work .

b) Impact of Travel Purpose

The purpose of travel influences the elderly's choice of various modes of transportation. In China, the elderly pay attention not only to the location distribution of bus stops but also to the distance between bus stops and leisure and shopping places such as vegetable markets, parks, and squares . In terms of transportation methods, elderly people abroad tend to prefer traveling by car, while elderly people in China often choose public transportation.

3.3. Grey Comprehensive Evaluation Method

The Grey Comprehensive Evaluation method is an evaluation method based on Grey System Theory. It can extract the required information by analyzing known information, thereby

ISSN: 1813-4890

analyzing complex systems. Grey Comprehensive Evaluation includes the Grey Relational Analysis method and Grey Clustering Analysis method.

Grey Clustering method is divided into two types: one is Grey Relational Clustering, suitable for calculating the relational degree between each sequence; the other is Grey Whitening Weight Clustering, generally used to analyze which category the research object belongs to. Whitening Weight Clustering is to calculate the corresponding values through the Whitening Weight Function, which can determine its grey class. This method has no requirements for the number of samples required and is also suitable for samples with or without regularity.

3.4. Fuzzy Comprehensive Evaluation Method

The Fuzzy Comprehensive Evaluation method is currently used in various aspects, usually for solving problems in the system information that are not quantitative but qualitative and have indeterminate numbers. The essence of Fuzzy Comprehensive Evaluation is to rely on fuzzy mathematics as the basic theory, which is a method of quantifying factors that are not easy to quantify and have unclear extensions, and then calculating the final results through the result matrix. In the evaluation process, the first step is to clarify the influencing factors of the evaluation object and sort them by importance, and then synthesize the evaluation object according to the actual obtained data.

The steps of Fuzzy Comprehensive Evaluation are as follows:

(1) Determine the factor set: The factor set is generally represented by U, U={u1, u2, u3...un}

(2) Determine the weight set W: The weight set is a fuzzy set

(3) Establish the corresponding evaluation set: The evaluation set is generally represented by V, V={v1, v2, v3...vn}

(4) Establish the fuzzy membership matrix R: Establish the score membership function of each factor and the comprehensive evaluation matrix R, and calculate the membership degree and R

(5) Synthesize the result matrix: B=W×R

4. Elderly Public Transit Travel Behavior Research

4.1. Questionnaire Survey

(1) Survey Content

A total of 9 indicators were selected for the survey: walking time to the station, waiting time, vehicle hygiene, bus congestion, driver's service attitude, driving stability, bus station environment, bus punctuality, and vehicle operating speed.

The questions in the designed questionnaire include different aspects. One is the basic situation of the respondents, including the respondent's gender, age, travel frequency, travel purpose, and main mode of travel; the other is the satisfaction degree of the elderly to each indicator, divided into 5 levels; very satisfied, satisfied, general, dissatisfied, very dissatisfied.

(2) Specific Survey Situation

A total of 280 questionnaires were distributed, and 265 valid questionnaires were obtained, with a validity rate of 95.6%.

4.2. Actual Travel Behavior Survey Analysis

(1) Travel Purpose

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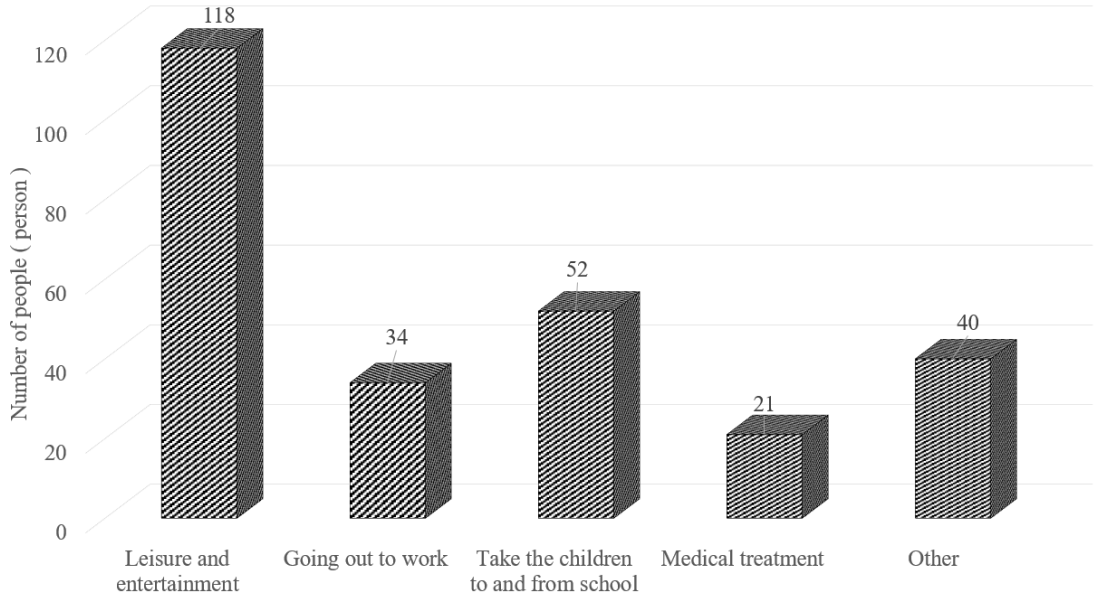

Fig.3 The purpose of the elderly travel

The majority of elderly travelers are engaged in leisure and entertainment, followed by taking children to and from school and other activities. Medical treatment and handling affairs account for 19.6% and 12.8% respectively. Compared to those traveling for leisure and entertainment, this group of elderly people pays more attention to travel efficiency. Overall, the results indicate that most elderly people's travel purposes tend to have a leisurely characteristic, focusing on comfort and safety during the journey.

(2) Elderly Travel Modes

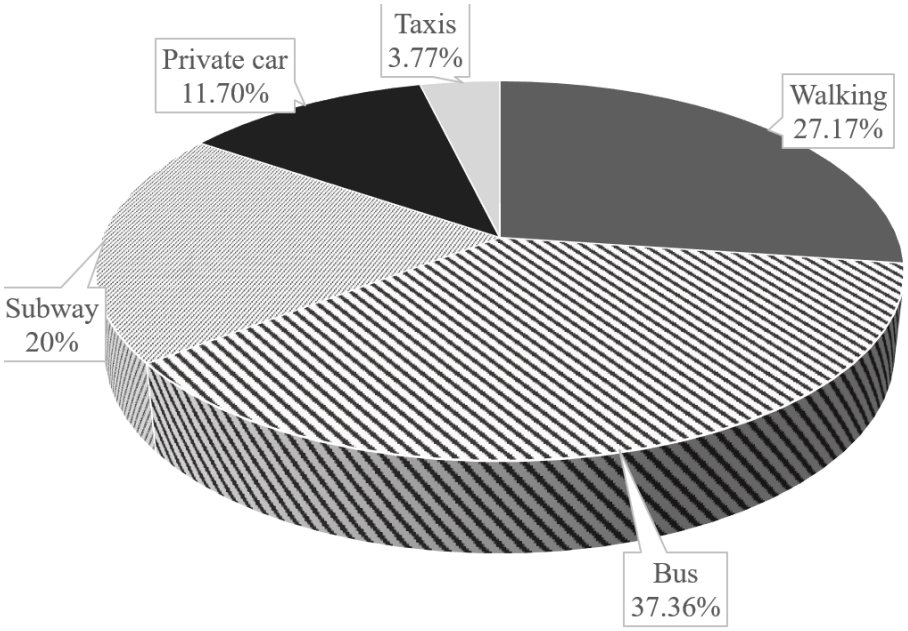

Fig.4 Statistical map of the elderly travel mode

From Figure 4, it can be seen that public transportation and walking are the main modes of travel for the elderly. 37.36% of the elderly choose to travel by bus, 27.17% prefer walking in their daily lives, 20% opt for the subway, and fewer elderly people choose private cars and taxis. There are many factors that affect the choice of travel mode for the elderly. The main reason most elderly people like to travel by bus is that many cities currently offer senior cards, and compared to the subway, buses are more convenient to board and purchase tickets.

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4.3. Grey Comprehensive Evaluation

(1) Determining the Evaluation Grades

Due to the subjective nature of the five evaluation grades in the questionnaire, it is necessary to process the collected data for quantitative analysis. The evaluation grades used in this study are very satisfied, satisfied, general, dissatisfied, and very dissatisfied, scored on a 10-point scale, corresponding to 9 points, 7 points, 5 points, 3 points, and 1 point, respectively. The evaluation set obtained is V=(9,7,5,3,1). By using this method to process the 265 questionnaires, processed data were obtained, and part of the scoring situation is shown in Table 1:

Table 1 Example of Evaluation Values for Each Evaluation Indicator

index	B1		B2			B3		B4	
	C1	C2	C3	C4	C5	C6	C7	C8	C9
evaluation number	9	9	7	7	7	7	5	7	5
	7	7	5	7	9	5	7	7	3
	5	7	7	9	9	9	7	7	7
	5	7	7	7	7	7	7	7	9
	9	7	7	7	5	5	5	7	9
	1	3	5	5	7	7	7	7	5
	7	7	7	7	5	5	3	5	7

(2) Determining the Evaluation Matrix

Based on the survey form and the evaluation values of the evaluation indicators, the evaluation matrix can be listed. Here, i ranges from 1 to 9, representing the number of second-level evaluation indicators in the AHP model; *n*n ranges from 1 to 275, indicating the number of samples to be analyzed; *din*din represents the evaluation of the rater on the evaluation indicator *Ci*.

(3) Grey Class Determination

Grey numbers refer to numbers that are uncertain within a range, usually denoted by "D". The whitening weight function is a functional expression that represents the likelihood of various values within a grey class. Here, based on the five evaluation grades set in the first step, five grey classes are established.

The whitening weight function values of the five evaluation grades can be obtained, as shown in Table 2.

Table 2 Whitenization weight function value of each evaluation level

	Very satisfied	satisfied (	general	dissatisfied	Very dissatisfied
1	1	0.7778	0.5556	0.3333	0.1111
2	0.7143	1	0.7143	0.4286	0.1429
3	0.2	0.6	1	0.6	0.2
4	0	0	0.3333	1	1
5	0	0	0	0	1

Through the whitening weight function values of each evaluation level, the data can be calculated, such as the calculation of the first gray class, as shown in Table 3.

Table 3 Part of the data The first grey class whitening weight function value table

index	B1		B2			B3		B4	
	C1	C2	C3	C4	C5	C6	C7	C8	C9
evaluation number	1.0000	1.0000	0.7778	0.7778	0.7778	0.7778	0.5556	0.7778	0.5556
	0.7778	0.7778	0.5556	0.7778	1.0000	0.5556	0.7778	0.7778	0.3333
	0.5556	0.7778	0.7778	1.0000	1.0000	1.0000	0.7778	0.7778	0.7778

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	0.5556	0.7778	0.7778	0.7778	0.7778	0.7778	0.7778	0.7778	1.0000
	1.0000	0.7778	0.7778	0.7778	0.5556	0.5556	0.5556	0.7778	1.0000
	0.1111	0.3333	0.5556	0.5556	0.7778	0.7778	0.7778	0.7778	0.5556
	0.7778	0.7778	0.7778	0.7778	0.5556	0.5556	0.3333	0.5556	0.7778

(4) Calculation of grey evaluation index coefficient

The grey evaluation coefficient xi of the evaluation index Ci is calculated, as shown in table 4 :

Table 4 Grey evaluation coefficient of each evaluation index

index	B1		B2			B3		B4	
	C1	C2	C3	C4	C5	C6	C7	C8	C9
1	197.89	195.45	203.89	208.56	217.89	220.12	213.45	201.01	211.23
2	235.00	230.72	222.15	221.29	227.57	227.00	225.86	225.29	223.57
3	160.20	169.40	159.80	149.80	136.20	133.80	142.60	158.60	145.80
4	28.67	31.00	28.00	25.00	13.67	11.67	18.00	30.33	22.00
5	1.00	1.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00

(7) Determining the Resulting Grey Class

In summary, the evaluation grade corresponding to the second grey class is "Satisfied".

5. Conclusion

The findings indicate that while elderly individuals are generally satisfied with the service quality of public transit, issues persist, including limited comfort and safety risks associated with boarding and alighting. As society continues to age, the issue of elderly mobility becomes increasingly critical. Public transit, being one of the most common and rapid modes of transportation, has become one of the primary choices for urban elderly travel. Despite the slower speeds and shorter distances between bus stops, which contribute to a lower accident rate compared to other forms of travel, elderly individuals still face numerous challenges when opting for public transit. The following suggestions are proposed:

(1)Improvement of Platform Information Displays: Due to physical conditions, some elderly people are more prone to accidents when boarding and alighting. Most buses in China are not wheelchair accessible, with steps that pose a risk of falls when the bus is crowded.

(2)Platform Facilities: The design of seat heights can be inconvenient for elderly individuals with mobility issues, making it difficult to sit or stand to board the bus. Additionally, the lack of backrests on many seats means a lack of support and a sense of security for the elderly. Platform design should consider passenger comfort, with the inclusion of seats that have backrests to enhance the comfort while waiting for the bus.

(3)In-vehicle Facilities: The main facility for increasing elderly travel satisfaction is the arrangement of seats. The comfort and safety of public transit seats significantly impact the travel experience of elderly passengers. When arranging seats, consideration should be given to the design, such as backrests, armrests, cushions, and seat colors, as well as the designation of priority seating for the elderly.

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