

# Public transport travel mode chain and its implications for commute satisfaction: Take Xi'an as an example

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**Abstract:** The continuous expansion of urban population and space scale, the continuous increase of daily average traffic trips and per capita travel distance, and the increasingly frequent urban economic activities have formed diversified travel demands. Based on the survey data, this study combs the commuter travel mode chain of Xi'an with public transport as the main body, and explores the satisfaction of current commuter bus passengers. First of all, the impact factors of each link of the public transport travel mode chain are sorted out. Based on the three levels of reachability, accessibility and connectivity, this paper proposes an evaluation index system of urban public transport commuting service, including convenience, safety, comfort, reliability and other specific indicators. Secondly, the commuting satisfaction evaluation scale is constructed to evaluate the subjective experience of travellers in the travel process. The results show that there is a gap between the expectation of commuters and the perception of public transport service attributes. Among them, "convenience" and "comfort" of public transport are the most important service quality attributes related to the satisfaction of commuters, and residents are the least satisfied with the convenience of transit, and public transport lines fail to meet the commuting needs of some residents. When transport operators provide services that meet passengers' expectations, passenger satisfaction and PBT utilization rate will be improved, service quality of public transport mode chain will be improved, sustainable transport will be promoted, and energy consumption and emissions will be reduced.

**Keywords:** Public transportation; Travel mode chain; Commuter satisfaction

## 1. Introduction

With the acceleration of urbanization, the urban regional space is expanding, the level of urban traffic motorization is developing rapidly, the activity space and scope of residents' travel are expanding, and the content of travel demand is becoming increasingly diversified and complex. To reduce travel costs, residents tend to link multiple trips in the form of travel chains. Travel chain refers to a round-trip trip composed of people to complete one or more activities and travel purposes arranged in a certain time sequence. It contains a lot of information about time, space, ways and activity types<sup>[1]</sup>. These information are interrelated and interactive<sup>[2]</sup>. The travel chain can well depict the traveler's activities, the choice and order of travel, and reflect the dynamics of traffic travel<sup>[3]</sup>. Public transport travel chain refers to two or more consecutive trips completed by public transport as the main travel mode<sup>[4]</sup>. Commuter travel is the most basic and important travel for urban residents<sup>[5]</sup>. Compared with other travel, commuting travel has obvious regularity<sup>[6]</sup>. According to the 2019 Xi'an Urban Transport Development Annual Report, the highest proportion of residents' travel modes in the central urban area is 24.4%, the proportion of cars is 15.7%, the proportion of regular public transport is 23.2%, and the proportion of rail transit is 13.7%. It can be seen that public transport is still the main mode of transportation for residents. At present, the transportation development of large and medium-sized cities in China is moving from a development stage that emphasizes the increase of facility supply to a new stage of quality transportation improvement that pays more attention to the traveler's experience<sup>[7]</sup>. Improving residents' travel satisfaction rather than mobility or accessibility has become its ultimate transportation policy goal<sup>[8]</sup>. Therefore, it is of great significance to study the satisfaction of urban residents with public transport for the formulation of transport policies, the improvement of public transport service quality and the promotion of sustainable development of urban transport.

## 2. Overview of commute satisfaction

Commuting satisfaction is a subjective evaluation and psychological feeling of residents on commuting status in the context of specific urban development<sup>[9]</sup> is also a direct reflection of residents on urban layout and traffic planning and their impact. At present, the research on commuting satisfaction has been carried out from multiple perspectives. First, the research found that residents with different attributes have different commuting satisfaction. For example, Meng Bin and others conducted an empirical analysis on the social attribute differences of commuting satisfaction of urban residents in Beijing, and found that the commuting satisfaction of ordinary civilians and young workers is relatively high. The commuting satisfaction of high-income class and young white-collar workers is relatively low<sup>[10]</sup>. Secondly, from the perspective of commuting characteristics, Wu Jiangjie and others investigated the impact of commuting time on personal subjective well-being. Empirical results show that commuting time has a significant negative impact on personal happiness and life satisfaction<sup>[11]</sup>. Wang Deqi and others, based on the questionnaire survey of Beijing residents, speculated that the high cost of commuting caused by the long commute distance and time is one of the main factors causing the negative evaluation of the citizens<sup>[12]</sup>.

For commuters, the difference of travel modes will cause different levels of emotional changes, including positive and negative emotions. In particular, the high satisfaction of punctuality, comfort, convenience and other characteristics of commuting will greatly promote the positive emotions of commuters, while the long commute time, congested road conditions and crowded traffic environment will lead to the negative emotions of commuters<sup>[13]</sup>. With the development of low-carbon travel, many scholars turn to the study of public transport travel. The accessibility, reliability and safety of public transport are particularly important to travel satisfaction<sup>[14]</sup>. Although the subway, bus and train are all public transport, their impact on commuting satisfaction is also different. Some studies show that the commuting time is more than 32 minutes, and public transport travel is more laborious than railway travel<sup>[15]</sup>. However, railway, walking, jogging and cycling are the stereotype of well-to-do and well educated commuters. They prefer railway to bus, and take non motorized travel as a way of exercise<sup>[16]</sup>. Punctuality is also an important factor for residents to consider commuting<sup>[17]</sup>. When the need for punctuality is met, commuters will further pursue the utility value of commuting time, that is, whether they can use time efficiently in the commuting process, such as preparing work, reading, processing documents, etc. Compared with other travel modes, rail transit can provide commuters with an opportunity to make full use of their en route time, which can further enhance their extra satisfaction and improve their positive emotions<sup>[18]</sup>. At the same time, most studies show that as the imbalance of work and living environment leads to the increase of commuting space distance, private cars can flexibly participate in other social activities on the long commute road, and the consequent sense of convenience promotes the positive mood of commuters<sup>[19]</sup>.

Long distance, high time consumption and multi link travel bring many inconvenience to commuters, so it is necessary to analyze and evaluate the whole commute process<sup>[20]</sup>. Based on the public transport travel chain, this paper studies the operation characteristics of different public transport commuting modes and the satisfaction of transfer behavior, studies the impact of travel chain on residents' commuting travel experience from a humanistic perspective, explores the research path based on personal subjective satisfaction for urban transport development, and provides a set of humanistic planning methods based on commuting satisfaction for the formulation of urban transport policies and the improvement of transport facilities, So as to promote the healthy and sound development of the city.

## 3. Methods

### 3.1. Data

In this paper, Xi'an, a mega city, is selected as the case study area. The questionnaire survey will be conducted mainly around the subway and bus stops from May to August 2022. The questionnaire includes respondents' social attribute characteristics, public transport commuting travel information, public transport travel mode chain satisfaction evaluation, commuting satisfaction evaluation and other issues. A total of 460 residents completed the questionnaire. After removing the invalid questionnaire, a total of 448 questionnaires were used for further analysis. Among 448 valid samples, residents are aged 16-45, and most of them commute from bus to subway or from subway to bus, accounting for 48.4%, and the proportion of subway through is higher than that of bus through. Among the commuting hours, the proportion of extreme commuting (more than one hour) in the 31-60 minute period is small,

accounting for only 1.6%. Most residents need to make one or two transfers during commuting, with one transfer accounting for 46.9% and two transfers accounting for 35.9%. During commuting, most residents need an additional 11 to 20 minutes of walking time to connect their homes and workplaces (as shown in Table 1).

Table 1: Statistics of survey samples

Sociodemographic characteristics	Number	Percentage	Commuter information	Number	Percentage
Gender		%	Commute mode		%
male	196	43.8	bus+subway	217	48.4
female	252	56.3	bus	84	18.8
Age			subway	147	32.8
16-30	210	46.9	Transfer times		
31-45	217	48.4	0	63	14.1
46-60	21	4.7	1	210	46.9
			2	161	35.9
			$\geq 3$	14	3.1
			Commute time (mins)		%
			0-30	126	28.1
			31-60	266	59.4
			61-90	49	10.9
			91-120	7	1.6
			$\geq 120$	0	0
			Additional walking time (mins)		
			0-10	189	42.2
			11-20	252	56.3
			21-30	7	1

### 3.2. Variables

Based on literature review, combined with the purpose of public transport service and the characteristics of public transport system, the satisfaction evaluation indicators of urban public transport mode chain service attributes are selected from two aspects. On the one hand, considering that the service purpose of public transport is to meet the travel needs of urban residents in terms of safety, convenience, comfort and reliability, the evaluation indicator set of the model is determined from the three dimensions of public transport accessibility, accessibility and connectivity. There are many indicators reflecting the characteristics of commuting, but commuting mode, commuting distance and commuting time are the most basic three commuting indicators. Commuting mode is the carrier of commuting, which reflects the commuting distance and restricts the commuting time, and determines the basic characteristics of commuting to a certain extent; Commuting distance and commuting time, while characterizing the commuting intensity, interact with each other to influence the choice of commuting tools. Therefore, the selected indicators not only take into account the space distance, but also reflect the quality of public transport services, bus congestion and bus accessibility as much as possible.

## 4. Commuting characteristics and satisfaction evaluation of urban residents

### 4.1. Reliability and Validity Analysis of Public Transport Commuter Travel Mode Chain Indicators

This paper uses the commuter satisfaction evaluation data of residents on various measurement indicators of public transport, and uses factor analysis and reliability analysis methods to analyze the service attribute dimensions of residents on each link of public transport travel mode chain (as shown in Table 2). Factor analysis is actually a process of multivariate dimensionality reduction. KMO sampling appropriateness test and Bartlett sphericity test were conducted on the data: KMO=0.863, which is more than 0.60 of the recommended standard. The probability value of Bartlett sphericity test is 0, which is less than the significance level (0.01), indicating that there is a correlation between the analyzed variables. If there is correlation, factor analysis is suitable (as shown in Table 3).

Table 2: Reliability Statistics

Reliability Statistics			
Dimension	Cronbach's alpha	Cronbach's alpha based on standardization	Number of items
Waiting (reachability)	0.775	0.847	8
Riding (accessibility)	0.758	0.811	7
Transfer (connectivity)	0.828	0.833	6

Table 3: KMO and Bartlett test

KMO and Bartlett's test of sphericity			
KMO sampling suitability quantity			0.863
Bartlett's test of Sphericity		Approximate chi-square	13321.834
		Df	253
		Sig.	0.000

#### 4.2. Analysis on Satisfaction of Xi'an Residents with Public Transport Commuters

Table 4: Analysis on commuting satisfaction of public transportation mode chain in Xi'an

Analysis on Commuter Satisfaction of Xi'an Public Transport Mode Chain					
Items	Mean value	Standard deviation	Items	Mean value	Standard deviation
<b>Convenience of waiting</b>	3.39		<b>Riding safety</b>	3.96	
Stations within walking distance	3.16	1.020	The vehicle runs stably and safely	3.91	0.745
Reasonable waiting time	3.62	0.801	Provision of security facilities in the vehicle	4.00	0.531
<b>Waiting safety</b>	3.88		<b>Riding comfort</b>	3.74	
Personal and property security design	3.88	0.650	Cleanliness	4.02	0.545
<b>Waiting reliability</b>	3.835		Seats and armrest availability	3.56	0.727
The departure time is punctual and reliable	3.78	0.857	Congestion	3.25	0.867
Clear route and schedule	3.89	0.688	Attitude of drivers and passengers	4.12	0.600
<b>Waiting comfort</b>	3.86		<b>Transfer convenience</b>	3.06	
Complete waiting service facilities	3.84	0.713	Time wastefulness	3.02	1.024
Good waiting order	3.84	0.734	Transfer frequency	3.11	1.149
The waiting environment is clean and sanitary	3.89	0.710	Road connectivity	3.05	0.944
<b>Riding convenience</b>	3.71		<b>Transfer safety</b>	3.91	
Operation time and lines	3.48	0.885	Personal and property security design	3.91	0.579
Service frequency	3.77	0.766	<b>Transfer comfort</b>	3.75	
Convenience of ticket purchase and payment	3.89	0.732	Clean and tidy	3.83	0.762
			Congestion	3.67	0.663

The data in the third part of the questionnaire, "residents' satisfaction with Xi'an's public transport service attributes and overall commuting", were used to analyze Xi'an's public transport commuting satisfaction. The results are shown in Table 4, the residents' overall satisfaction with Xi'an's public transport is 3.67. From the perspective of the service attributes of the public transport commuting mode chain, tourists have the highest evaluation on the "safety" of each link of the public transport travel mode chain, with the waiting safety of 3.88, the riding safety of 3.96, and the transfer safety of 3.91. Residents have the lowest evaluation on the "convenience" of public transport, among which the "convenience" of transit has become a key factor affecting residents' satisfaction with commuting, with an average score of only 3.06. The two options "transfer time includes walking, queuing and waiting" of the "convenience" of transfer and the "road connectivity" result in blocked transfer, which affects the transfer efficiency of residents. "Convenience" of waiting includes "walking to the station location" and "reasonable waiting

time". Relevant studies have found that the proportion of people walking from the departure place to the public transport station and from the station to the destination is the highest, usually accounting for more than 70% [21]. The length of walking time and distance at the stations will have an important impact on whether travelers choose public transportation. The "convenience" of taking the bus mainly means that "the operation time and lines meet the commuting needs". The survey found that the public transport operation time basically meets the commuting needs of most residents, mainly because the operation route fails to meet the commuting needs of some residents, and residents need to transfer to complete commuting. The residents have relatively high comprehensive evaluation on the "comfort" of public transport, and the highest evaluation on the "comfort" of waiting is 3.86 on average, of which "sound waiting service facilities" and "good waiting order" are 3.84, and "clean waiting environment" is 3.89. The comprehensive evaluation of the "comfort" of the transfer is 3.75, mainly because the evaluation of the "sanitary condition during the transfer process" is 3.83, while the evaluation of the "congestion degree during the transfer process" is 3.67. The comprehensive evaluation of the "comfort" of the car is 3.74, which is also due to the high evaluation of the "sanitation in the car" and the "attitude of drivers and passengers", which are 4.02 and 4.12 respectively. However, the evaluation of "availability of vehicle seats and armrests" and "degree of crowding in the vehicle" are low, 3.56 and 3.25 respectively, which are lower than the average level. Ettema et al. elaborated that travel affects residents' overall well-being from three aspects: residents participate in activities that affect their well-being through travel, travel experience affects activity experience, and travel experience itself affects residents' well-being [22]. Public transport commuting experience mainly refers to the impact of congestion on their satisfaction.

#### 4.3. Regression analysis on influencing factors of residents' general satisfaction

The following multiple regression equations are used to study the influencing factors of tourists' overall satisfaction with Xi'an's public transport:

$$Y=A+b_1X_1+b_2X_2+ b_3X_3+b_4X_4+e \quad (1)$$

Y stands for "residents' commuting satisfaction", and  $X_1$ ,  $X_2$ ,  $X_3$  and  $X_4$  respectively stand for "convenience of public transport", "safety of public transport", "reliability of public transport" and "comfort of public transport". Table 5 shows that the two dimensions of "comfort of public transport" and "convenience of public transport" have a significant impact on the overall satisfaction of public transport in Xi'an.

With the improvement of people's living standards, travelers have higher and higher requirements for public transport service. The key link of transit transfer is particularly important for the improvement of public transport service level. The influencing factors of public transport transfer are complex and are greatly influenced by travelers. Through the analysis of the impact of bus subway/bus transfer, it is found that the clear location of transfer stations will increase their travel. While convenience is the first consideration for transit subway travelers, economy has the most significant impact on attitude in transit transfer.

Table 5: Regression analysis of influencing factors on overall commuting satisfaction of public transportation in Xi'an

independent variable	Coefficient value	T value	p value
Convenience	0.393	7.754	< 2e-16 ***
Safety	0.9634	5.044	8.21e-07 ***
Reliability	0.8643	3.330	0.000983 ***
Comfort	0.331	6.596	4.58e-13 ***
Sample		448	
Adjusted R <sup>2</sup>		0.8209	

Note: \*\*\*, \*\* and \* represent significant collinearity regression at 1%, 5% and 10% levels respectively.

## 5. Conclusions

In an increasingly urbanized world, the study of commuting has attracted much attention due to its impact on the environment, society and economy. Based on the above analysis, some basic understandings can be drawn: ① By using the residents' satisfaction evaluation data on Xi'an's public transport commuting, it can be concluded that the dimensions of Xi'an's public transport performance are composed of "convenience of public transport", "reliability of public transport", "safety of public

transport" and "comfort of public transport"; ② In terms of residents' satisfaction evaluation on the service attributes of Xi'an public transport travel mode chain, residents' satisfaction evaluation on the 23 elements of Xi'an public transport performance is polarized, but systematically, the overall satisfaction with Xi'an public transport is 3.67; From the perspective of dimension, "reliability of public transport" is the highest (mean 3.84), followed by "safety of public transport" (3.83), "convenience of public transport" and "comfort of public transport" are 3.39 and 3.78 respectively; At the same time, regression equation analysis shows that the two dimensions of "convenience of public transport" and "comfort of public transport" have a significant impact on the overall satisfaction of public transport in Xi'an. Among them, the transfer convenience includes transfer time (walking, queuing, waiting), transfer frequency and road connectivity with the lowest satisfaction, and residents have differences on the commuter line's failure to meet their commuter needs.

On the whole, residents have a positive attitude towards the development of public transport in Xi'an, which is closely related to the increasing improvement of internal and external transport in Xi'an and the continuous breakthrough of public transport bottlenecks since the new century; At the same time, the survey of residents' perception of commuting shows that there are still some problems in the development of public transport in Xi'an. In view of this, this paper proposes:

(1) People oriented, creating a beautiful and comfortable riding experience for passengers

Increase humanized design in buses and stations, including passages and seats specially designed for the elderly and disabled, low chassis and wide doors for passengers to get on and off the bus; Provide humanized services, including full and timely ride information, friendly and enthusiastic staff, and warm and stable ride experience; Use modern marketing strategies to shape the bus brand and bring passengers a better consumption experience. Beautifying and unifying the external appearance of the vehicle, unifying the driver's dress, providing a variety of bus models, extensive media publicity, periodic promotion, etc., to create a modern public transport brand for the people in modern Beijing.

(2) Establish the strategy of giving priority to the development of public transport

Giving priority to the development of urban public transport system is an inevitable way for modern cities, an effective way to solve urban congestion and pollution problems, and the key to building a resource saving and environment-friendly sustainable urban transport system. We will accelerate the construction of bus, subway and other rail transit lines with high-capacity public transport as the development direction. Compared with ordinary public transport, subway and other rail transit have high punctuality rate, fast operation speed and can well meet commuter travel. Coordinate various public transport modes, build an integrated public transport system, and formulate appropriate policies to guide passengers to choose different public transport modes and transfer between modes according to different functional orientations of each mode, so as to equalize passenger flow, reasonably use resources, increase express routes and air-conditioned bus routes at large stations, and reduce the overall congestion of public transport.

(3) Improve the intelligence and informatization level of public transport system

The advanced information technology, computer technology, data communication technology, sensor technology, electronic control technology, automatic control theory, operational research, artificial intelligence, etc. will be effectively applied to the service, management and control of the entire public transport system to improve the mobility and safety of buses and enhance the ability to respond quickly to emergencies. Establish a series of intelligent information systems, including a large-scale, all-round, real-time, accurate and efficient transport integrated management and dispatching system, bus passenger feedback and information system, road network flow information system, bus internal information system, etc., to form an information network, share information input and output, integrate each other, and form a dynamic bus operation system. According to passenger feedback, road network information input and bus internal information, we can scientifically arrange train numbers, supervise bus operations, set routes and stops, make full use of the traffic capacity of the road network, control waiting time, improve punctuality and improve service quality.

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