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Public transport equity in Shenyang: Using structural equation modelling

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Abstract

In China, with the rapid development of urbanisation, the contradiction between supply and demand has become increasingly severe, particularly in large and medium-sized cities. Improving public transport equity can help to reduce the social exclusion of lower-income and socially vulnerable groups in relation to the urban transport system, and guarantee that public transport systems are given priority in terms of development. Using the concept of transport-related social equity, this study aims to explore the effects of public transport equity in relation to the quality of public transport, public participation, and public transport-related policy using Shenyang as a case study. Data are analysed using Structural Equation Model (SEM). Our findings show that the three latent variables of accessibility, affordability, and social impacts can be seen as representing the main characteristics of public transport equity; while improvements in public transport quality, public participation, and public transport-related polices play a significant role in reducing public transport inequity. Moreover, the findings indicate that public participation has direct, significant, positive influences on public transport quality and public transport-related policies. In terms of policy implications, we suggest that policies designed to improve public transport service quality, extend public transport fare concessions, and promote public participation in the public transport policy decision-making process should be given priority in the next round of urban comprehensive planning in order to reduce public transport-related social inequity in Shenyang and China more generally.

Keywords

Transport and social equity; urban transport policies; public transport; structural equation modelling; Shenyang

Highlights

- Accessibility, affordability and social impacts are seen as representing the main characteristics of public transport equity.
- Improving the quality of public transport is one of the most important ways of reducing public transport inequity.
- There is a direct relationship between public transport equity and public participation and public transport-related policy support.
- Structural Equation Model (SEM) is used to measure and understand public transport equity.

1. Introduction

With the continuous development of the urban economy, the rate of population growth and spatial expansion has accelerated, resulting in a rapidly growing demand for transport facilities and services, particularly in the developing world (Ahmed et al., 2008; ESCAP, 2001). Public transport is the most effective way to resolve urban traffic congestion and environmental pollution (Bull, 2003; Beaudoin et al., 2015). Even more importantly, public transport as a public good plays a vital role in providing individuals and households with a range of day-to-day services and facilities, such as accessing employment, education, healthcare, and familial interaction, especially for low-income people (Cao and Hickman, 2020; Lau, 2020; Zhou et al., 2018). In many cities, there has been a growing realisation that improving public transport services must be the top priority in order to achieve greater social inclusion and improve people's standard of living (Ahmed et al., 2008; Ricciardi et al., 2015). However, the efforts made to improve public transport services have generally been insufficient, particularly for lower-income and socially disadvantaged groups (Cuthill et a., 2019; Di Ciommo and Shiftan, 2017; Litman, 2018, 2020b; Low et al., 2020). Therefore, it is necessary for policymakers to understand more about the influence range and strength of public transport systems from the public’s perspective in order to improve the effectiveness of policy decision-making. In the context of China, Wang et al. (2014) and Zhong et al. (2018) highlighted that there are three main barriers to developing public transport systems: the unbalanced spatial arrangement of bus stops and routes; imbalances in service effectiveness; and imbalances in terms of structural configuration.

However, at present, there are only a few studies that address the issue of transport equity. Most of the previous studies have focused on specific aspects, such as accessibility, the congestion charge, urban road network planning and design, allocation of investment in transport infrastructure, transport disadvantages and so on. On the whole, past studies investigating public transport equity can be divided into the following areas: (1) the economic perspective: studies on transport costs and benefits analysis (Martens and Di Ciommo, 2017); (2) the equitable distribution of traffic infrastructure investment and allocation at the regional or city level (Brocker et al., 2010; Thomopoulos et al., 2009); (3) differences in mobility between different groups of people, and exploring the relationship between supplementing transport services, social exclusion, and well-being (Currie and Delbosc, 2010; Ma et al., 2018). In addition, from the perspective of horizontal equity, some research has focused on discussing the equal distribution of public policies and services through accessibility analysis (Bocarejo et al., 2012; Cao et al., 2019; EI-Geneidy et al., 2016; Lucas et al., 2015). Although the aforementioned studies have provided research results with theoretical and research value, only a few existing studies have specifically focused on public transport equity in a developing country, such as China. To begin with, most existing studies on public transport equity mainly focused on megalopolises, such as Beijing, Shanghai and Guangzhou (Cao and Hickman, 2019a; Jiang et al., 2014; Wang and Zhu, 2010; Zhao, 2015). However, second-tier cities have been largely overlooked. Moreover, transport-related social equity is a complex concept, and it is influenced by many factors at the same time, such as socio-economic demographic characteristics, transport service quality and the built environment. Previous studies have carried out transport-related social equity analysis from different perspectives, but lack a clear theoretical framework and have not investigated causal relationships between the various factors, such the role of socio-demographic characteristics, or measuring variables and examining the interrelationships between each variable. More importantly, public transport, as a public good, should be regarded as a means of reducing social inequity, something which has often been overlooked when evaluating its equity.

Therefore, in order to fill the aforementioned gaps, Shenyang, the capital city of Liaoning province, was selected as the case study area for this research. Using sample data collected from a self-administered survey in Shenyang in 2018, we employ a structural equation model (SEM) to determine the actual interrelationships between factors that influence public transport-related social equity and measured variables. In particular, this paper suggests some answers to the following questions: How can we measure public transport equity? Combined with Chinese public transport-related policies, how can we analyse and determine which factors influence the fairness of public transport services and their infrastructure? Does the development of public transport equity have a different impact on different individuals and social groups, and, if so, to what extent? According to the empirical findings, what would be the most effective policy and strategy suggestions for Shenyang and China as a whole to improve public transport-related social equity?

The remainder of this paper is organised as follows. Section 2 reviews existing literature on transport equity, as well as the measured variables, the affecting variables, and the groups who are disadvantaged by current public transport systems. Section 3 describes the case study, data and methodology used in this research. In section 4, the results of the empirical study are presented. Following that, suggestions regarding polices and strategy implementation are offered in Section 5. In the final section, we summarise the research and highlight key findings and contributions.

2. Literature Review

2.1. Different types of transport equity

Johnson (2012) identified different types of equity, such as procedural, distributional, process, and outcome equity. In the transport planning field, there has been a lot of research discussing the concept of transport equity (Lucas 2012; Martens, 2006). Transport equity can be seen as a kind of pathway to creating social equity between different individuals and groups in society to enable them to access key life activities (Bajada et al., 2016; Martens, 2006), and a lack of supplementary transport services may cause social inequity (Lucas, 2012). However, due to disparate social norms and moral judgements, it is difficult to define what actually constitutes a genuinely fair distribution (EI-Geneidy et al., 2016; Van Wee and Geurs, 2011).

Through detailed exploration, Litman (2002, 2014, 2018, 2020b) concluded that transport equity means the fair distribution of transport-related costs and benefits, and proposed that transport-related equity can broadly be divided into three dimensions: horizontal equity; vertical equity with regard to income and social class; and vertical equity with regard to mobility needs and ability. Horizontal equity, which is also sometimes called "fairness and egalitarianism", involves the equitable distribution of transport resources between individuals and groups regardless of commuters' mobility and travel demands (Litman, 2018, p. 4). By contrast, vertical equity focuses on providing additional transport services and resources to commuters according to their specific demands and needs to try to address the unfair distribution of transport services for society as a whole (Delbosc and Currie, 2011). However, assessment of vertical equity in the transport field is currently insufficient, as it focuses mainly on the discussion of personal demands and perceived opportunities (Beyazit, 2011; Bocarejo and Oviedo, 2012; Cao and Hickman, 2019b, 2020;

Hickman et al., 2017).

2.2. Indicators for measuring transport equity

Di Ciommo and Shiftan (2017) pointed out that one of the primary issues with regard to public transport equity is how to define and select which variables can be used to measure inequity. According to the basic definition, transport equity is the distribution of benefits and costs. Therefore, it is essential for us to find indicators that can be appropriately used to assess the costs and benefits of public transport systems. A number of different variables have been used to evaluate transport equity, of which the most common are affordability, accessibility and social attributes.

2.2.1. Affordability

Litman (2020a) defined affordability as a household's ability to access basic goods and activities at any time they want, such as shopping, work, healthcare and so on. Affordability means that public transport can be reached and afforded by lower or even middle-income groups at an acceptable level. For instance, Falavigna and Hernandez (2016) compared public transport affordability in two Latin American cities, namely Montevideo (Uruguay) and Cordoba (Argentina), and proposed that affordability is one of the major obstacles preventing the urban poor from accessing the full range of public transport services. In China, as a developing country, where some people still earn well below the average income and are categorised as low-income groups, expenditure on making journeys by public transport has a greater impact on their disposable income and household and transport budgets. For this reason, we decided to use affordability indicators to measure transport-related social equity.

In general, the measurement of affordability should include personal or household income and transport expenditure (Falavigna and Hernandez, 2016; Olvera et al., 2013, 2008; Venter and Behrens, 2005). According to Fan and Huang (2011), these methods of measuring affordability have some limitations, such as only using a single measurement and not taking time costs into consideration. Therefore, it is necessary to factor time costs into the affordability analysis. Because the actual amount of income people earn is a somewhat sensitive issue, this paper proposes a new framework for assessing public transport affordability from two perspectives: transport-related time expenditure; and transport-related monetary expenditure, using a series of statements.

2.2.2. Accessibility

Due to the relationship between transport equity and benefit distribution, simply measuring affordability on its own cannot fully reflect the effective distribution of transport services and infrastructure based on personal mobility (Zhou et al., 2018). Therefore, it is essential to add the concept of accessibility into transport equity analysis. Hansen (1959) proposed that accessibility is a method for measuring potential opportunities. In public transport planning, measuring accessibility plays a significant role in evaluating the distribution within a region as a whole, based on the concept of equity (El-Geneidy et al., 2016; Foth et al., 2013). Van Wee and Geurs (2011) proposed that the lack of accessibility to opportunities is the most important indicator of transport-related inequity. In general, accessibility can be divided into placed-based accessibility (Handy and Niemiere, 1997; Song, 1996) and individual-based accessibility (Bocajero and Oviedo, 2012; Kwan and Weber, 2003). Location accessibility focuses on the discussion of how many places or opportunities can be reached from the point of origin within a certain time and budget. There are three measures commonly used to evaluate place-based accessibility, namely gravity-based accessibility measures, cumulative opportunity measures, and utility-based accessibility measures (Deboosere and El-Geneidy, 2018). However, these three measures limit the discussion of objective travel time and distance to the journeys that people make, and do not usually consider the characteristics of individuals and groups. Curl et al. (2011) and Lättman et al. (2016a) highlighted that the traditional measurement methods used cannot capture the real situation very effectively and offer little insight into the connection between social inequity and accessibility. Following the previous studies and research conducted by Hansen (1959), Dalvi and Martin (1976), and Curl et al. (2011), Lättman et al. (2016b) extracted key components of accessibility and proposed a new kind of quantified method for public transport, namely the Perceived Accessibility Scale (PAC). The PAC is based on the personal, subjective assessment of accessibility and has benefits for reducing social inequity, and increasing well-being and quality of life (Lättman et al., 2016a).

2.2.3. Quality of life and physical and mental health

In addition to economic and environmental factors, the social impacts of public transport have been shown to be important (Markovich and Lucas, 2011), and public transport has positive effects on the physical and mental health on commuters, who experience less stress than those who use private vehicles (World Health Organisation, 2011). Therefore, it is necessary to take social impact factors into account when measuring public transport equity, in order to reflect how public transport systems have a positive or negative influence on people's health and quality of life. Banister and Bowling (2004), Mollenkopf et al. (2005) and Spinney et al. (2009) discussed how increased mobility affects the quality of life and showed that the effect is relatively small. However, according to the studies by Currie and Delbosc (2010), there are strong links between transport disadvantages and well-being. With regard to how to measure well-being, Reardon et al. (2019) stated that it can be measured from a subjective well-being perspective by asking people to rank the following items, among others, on a Likert scale from 1 to 10: 'How they are feeling towards their life', 'How emotional they are feeling', and 'How satisfied they are with life', etc.

2.3. Categorising the population

With regard to vertical equity, it is important to categorise groups who are disadvantaged by transport systems, and this is a new theme in the transport-related literature. This is because, normally, personal requirements for accessing travel are based on personal socio-economic demographic characteristics (Litman and Brenman, 2012). Moreover, in terms of transport planning, different population groups may benefit to a greater or lesser extent from transport systems when there is a relatively equal distribution of transport resources and accessibility (Cao and Hickman, 2019a; Delbosc and Currie, 2011; Van Wee and Geurs, 2004; Lucas, 2012; Martens et al., 2019; Welch and Mishra, 2013). People's residential and activity locations may also affect which transport services and benefits they can access (Martens et al, 2019; Welch and Mishra, 2013).

There are diverse methods for classifying population characteristics. Shirmohammadli et al. (2016) pointed out that groups of people who are disadvantaged in relation to transport should be classified based on their socio-economic and socio-spatial characteristics. Specifically, according to their articles on transport equity, socio-economic and geographic demographic characteristics can be classified by levels of income, age, gender, household car ownership, educational level, physical condition, employment status and residential location.

Based on some of the existing research that discusses public transport equity, low-income people who may not be able to drive are more likely to face transport disadvantages, especially the elderly, children, students, women, single parents, people with physical and mental health issues, and households without a car. Ricciardi et al.'s (2015) research conducted in Perth found that there was an unequal distribution of public transport services and facilities among senior citizens, low-income households and households without a car. Martens et al. (2019) found that the high price of public transport and low levels of supplementary services often restrict students in higher education from accessing job opportunities and education. Hine and Grieco (2003) pointed out that women are more likely to experience poor transit services and are less likely to have driving licences and personal vehicles than males. Public transport should be the primary mode of transport used by the aforementioned groups to complete their daily travel. However, some people's travel requirements cannot be fulfilled by using public transport, perhaps due to their family responsibilities for childcare and/or other domestic work (MacDonald, 2016; Martens et al., 2019). In addition, some studies have reported that physical impairment not only applies to the elderly, but also occurs among younger groups, or pregnant women, which limit their access to key life activities, and thus should be taken into account as one of the indicators for measuring transport-related equity (Di Cimmo and Shiftan, 2017; Martens et al., 2019; Villaraza et al., 2017). Last but not least, with regard to low-income groups, Lucas (2016) found that low-income groups often include people who are low-skilled, unemployed, with limited access to private vehicles and who primarily rely on public transport to meet their travel demands. In Norway, Priya and Uteng (2007) found that transport facilities for new immigrants are insufficient, resulting in social exclusion and a reduction in social cohesion. Zhao and Howden-Chapman (2010) observed that hukou status[1] is one of the key transport-related equity indicators in the context of Beijing. They also showed that this is because most migrants without local hukou in Beijing live in the urban fringe areas and rely on public transport, which increases the time they spend commuting (Zhao and Howden-Chapman, 2010;

[1] The registration system (also called hukou in Chinese) was originally established in the 1950s as a measure to curb the flow of rural migrations into the cities (Zhao and Li, 2016). In China, migrants without local urban hukou are also called the 'floating population' (Zhao and Howden-Chapman, 2010).

Zhao and Li, 2016). Space and exclusion have become hot topics for scholars researching transport-related equity issues. People living in rural areas often have limited accessibility to destinations and public transport, increasing the risks of social exclusion (Shergold and Parkhurst, 2012).

2.4. Factors influencing public transport equity

2.4.1. Public transport service quality

At present, most studies on transport equity focus on the discussion of accessibility and affordability, and often overlook aspects of transport service quality, such as convenience and safety. Litman (2018, 2020b) and Villaraza et al. (2017) argued that the quality of transport services is also a significant indicator that should be included in the assessment of transport equity. In terms of public transport planning, high service quality means safely, comfortably, and reliably delivering passengers to their destinations. The quality of public transport services also plays an important role in affecting the behavioural intentions of public transport passengers.

Redman et al. (2013) found that public transport service quality is associated with accessibility. A large number of studies have revealed several attributes that can be used to measure public transport service quality, such as fare price (Hensher et al., 2003), frequency (Levinson et al., 2003) and speed (Pucher et al., 2005). A few scholars have also found that reliability (to what extent actual waiting time corresponds to the times specified on the timetable) (Redman et al., 2013), and frequency of services (Cantwell et al., 2009; Filipovic et al., 2009) affect the quality of public transport services. Other studies have highlighted the importance of making trip information available for travellers (De Oña et al., 2013), ensuring comfort inside the vehicle and usability (convenience) (De Oña et al., 2013; Dell'Olio et al., 2011), and offering a high level of customer service (Friman and Fellesson, 2009) with regard to transport service quality.

Some researchers have also taken personal safety aspects of the entire public transport chain in terms of accessibility into account (Gaitanidou and Bekiaris, 2012). Safety concerns may deter individuals and groups from using public transport, especially women. As women are more likely to use public transport than men, personal safety is a major concern for them (Di Ciommo and Shiftan, 2017; Martens et al., 2019). Safety is a kind of perceived attribute that depends on people's subjective feelings, and should therefore be treated as a cognitive evaluation (De Oña et al., 2013;

Lättman et al., 2016a; Redman et al., 2013).

2.4.2. Public participation

Public participation plays a key role in affecting transport equity (Wang et al, 2014). Public involvement means whether the government or public transport companies invite the public to participate in the process of decision-making and management so as to comprehensively balance the interests of all parties and stakeholders (Giering, 2011). Due to the collaborative nature of public transport services, it is essential to enhance public participation in public transport services. There is a positive association between public participation and service loyalty (Wong et al., 2011). In fact, public attitudes towards services and people's perceptions of management can affect whether they want to participate in public events or forums to express their views. Public participation, in turn, can bring about changes in public transport, if the public's suggestions are acted upon. Therefore, there could be a causal relationship between them. Grengs (2010) also pointed out that the level of public participation and related activities is important for transport equity planning. According to information obtained from the International Association for Public Participation, public participation can be divided into five stages: notification, consultation, involvement, collaboration and authorisation (Giering, 2011). However, in most Chinese cities, public participation mainly concentrates on the processes of notification and consultation, which means that most members of the public have few opportunities to work together with the government.

2.4.3. Public transport-related supportive policy

Transport policies play a significant role in developing sustainable and equitable urban transport systems. According to the concept of vertical equity, transport policies should give preference to those people who are classified as vulnerable, such as offering discounts and special services for them (Ricciardi et al., 2015). In terms of public transport-related supportive policy measures, Ott (2011) argued that the implementation of urban transport policies and planning should take into account the interests of all residents and the key factors that affect public transport equity and people’s quality of life. From the perspective of social equity, Elvik et al. (2009) discussed how road safety policies influence public transport equity. Recently, the Chinese government has issued guidelines for giving priority to the development of public transport, one of the most important aspects of which is to provide concessionary fares to socially-disadvantaged groups (Wang et al., 2014). Accordingly, this paper argues that the aforementioned policies can help people with different socio-economic and socio-spatial characteristics to access transport services and the transport infrastructure in an equitable way.

3. Case Study, Data and Methodology

3.1. Case study

Shenyang was chosen as the study area for this research. Shenyang is the provincial capital of Liaoning and a significant central city in Northeastern China. The entire administrative region of Shenyang consists of nine districts and four counties, with a total land area of 12,860 km^2. According to demographic data from the Shenyang Statistics Bureau (2018), the total number of permanent residents in Shenyang was 7.20 million in 2010, and this had increased to 8.29 million in 2017.

The entire administrative region of Shenyang consists of nine districts and three counties and one county-level city. In this study, we divided the study area into three categories: The central urban area is composed of five districts: Shenhe District, Huanggu District, Dongling District, Tiexi District and Heping District, with a high population and employment density and a short distance to the urban centre. The urban fringe area is composed of four districts, namely Shenbei New District, Yuhong District, Hunan New District and Sujiatun District. Lastly, the suburban area consists of four counties and one county-level city (see Fig. 1). In this research, we mainly focused on the discussion and analysis of the central urban area and urban fringe area, as these two areas contain 70.8% of the city’s total population and 81.4% of its working population.

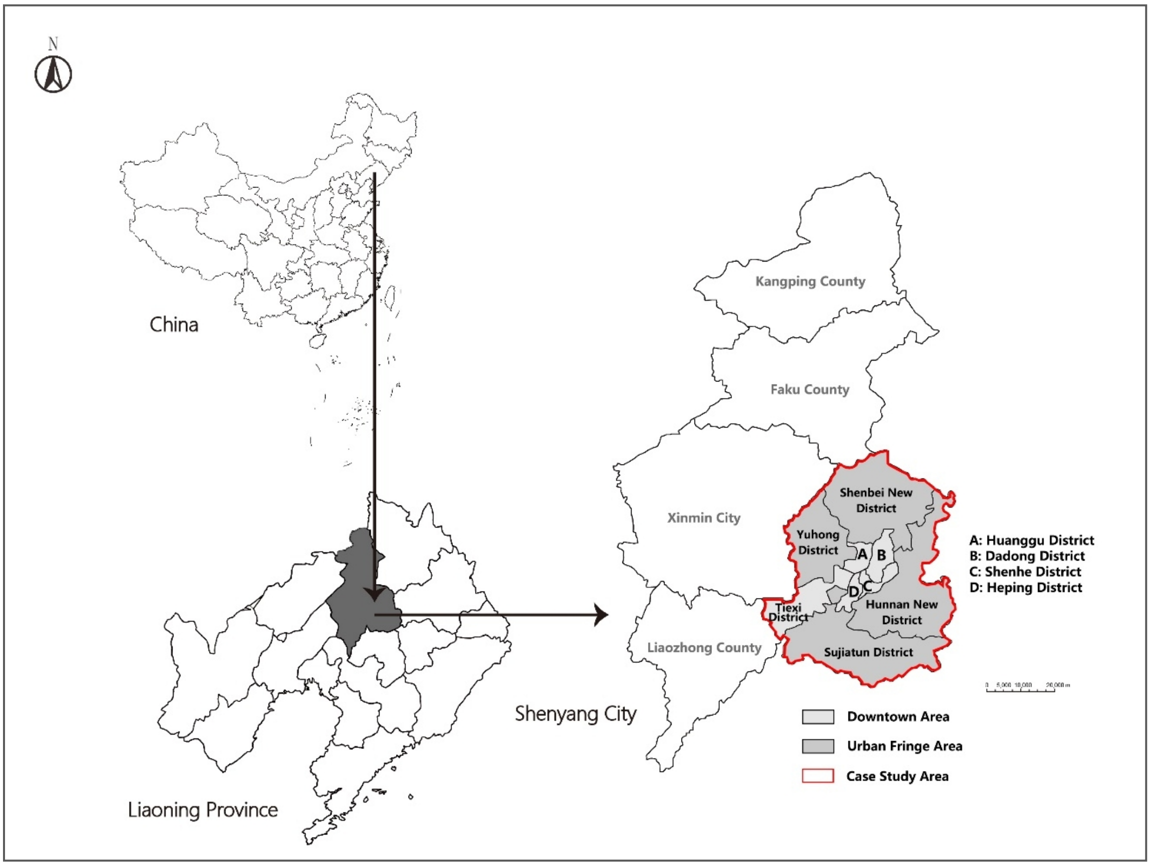

Fig. 1. The case study of Shenyang

In terms of public transport, the metro and buses are the primary modes of public transport operating in Shenyang. Table 1 shows that bus facilities underwent rapid development from 2013 to 2017, with substantial growth in the number of operating routes, operating mileage, and the number of buses, although some problems still remain. These problems erode the advantages of the public transport system and constrain the development of public transport. Zhu (2018) stated that the public transport system in Shenyang has a range of problems, such as the low coverage rate of stations, a low public transport network density, an unbalanced distribution of public transport resources, a large number of overlapping lines and a low operational speed. In order to supplement the public transport system, Shenyang metro lines 1 and 2 were opened in 2010 and covered a total length of 59.6 km in 2016. Currently, two metro lines are operating in Shenyang; however, they share the same transfer station and therefore do not form an effective transport network, which causes congestion and a lack of comfort during rush hours. Moreover, based on data from Shenyang's comprehensive traffic survey conducted in the downtown area in 2017 (see Table 2), only 32.8% of all journeys are made by public transport (ibid.). Comparing the data with that of other megacities in China, Shenyang has a relatively low level of public transport ridership.

Table 1

The growth in buses operating in Shenyang from 2002 to 2017 (Shenyang Statistics Bureau, 2003, 2018).

	2002	2006	2010	2014	2017
Operating vehicle route	140	142	202	223	310
Length of route (Km)	1604	2236	3785	4206	5075
Passenger volume	108809	90558	120000	115096	104263
Number of buses	4420	5096	5013	5573	7679

Table 2

Traffic mode split rate of Shenyang citizens (Source: Authors, adapted from Zhu, 2018)

Travel mode	All transport modes	Excluding walking
Walking	25.0%	-
Cycling	17.5%	23.3%
Bus and rail transit	32.8%	43.7%
Taxi	2.6%	3.5%
Private car	22.1%	29.5%

3.2. Data source and data sample

3.2.1. Data source

In this research, the data collection was conducted in two stages from May to July 2018 in Shenyang. In the first stage, we distributed 100 questionnaires using the face-to-face survey method in order to first test and verify the veracity of our hypotheses. A simple random sampling approach was applied (Valliant et al., 2013). Following this first stage of data collection, we conducted reliability analysis and validity analysis of the questionnaires to verify their effectiveness and accuracy, and ascertain whether the questionnaires were appropriate for factor analysis. The value of Cronbach's alpha, the p-value, and the value of KMO in this study are 0.959 ($\geq$0.90), 0.000 ($P < 0.001$), and 0.954 (greater than 0.70), respectively, which proves that the questionnaires are acceptable and suitable for factor analysis.

Hadiuzzman et al. (2017) claimed that SEM is particularly helpful for large sample analysis, as it requires a sample size of more than 200. Therefore, in the second round of data collection, we enlarged the sample size to increase the accuracy of the analysis based on the questionnaires designed and used in the first stage.

Questionnaires were distributed to residents who lived in the downtown and urban fringe areas of Shenyang using a random sampling approach, the same method used in the first stage. The number of respondents at this stage was 350. The data from stage one and stage two were then combined to conduct the data analysis with a valid sample size of 424 in total. Each individual's socio-economic characteristics of age, highest educational level, and personal monthly income were classified based on the taxonomy used in the Shenyang Statistics Yearbook (2018). In addition, the respondents were also asked to provide basic information about their household characteristics, such as household size, presence of children, and household car ownership.

Table 3 shows the descriptive statistics for the respondents. In terms of individual characteristics, more than half of the respondents were between the ages of 35 and 59 (58.02%), 32.54% were between 18 and 34, and the remaining 0.94% and 8.49% were younger than 17, and older than 60, respectively. There were more female than male respondents. Employed people (80.90%) and students (8.96%) constituted nearly nine-tenths of the sample, while retirees (7.55%) and unemployed people represented the remaining part. In terms of income, 14.62% of the respondents indicated that their personal monthly income was less than 2,000 (CNY), while 32.08% and 30.66% of respondents had personal monthly incomes of 2,001 to 4,000 and 4,001 to 6,000 (CNY) respectively, 9.67% had an income between 6,001 and 8,000 (CNY) per month, and 12.97% had personal monthly incomes of more than 8,000 (CNY). Moreover, the majority of the respondents held local hukou (86.08%). In addition, it was found that more than half of the respondents had a driving licence (71.23%) and about 66.04% lived in households that possessed a car. Over half of the respondents (58.49%) stated that they had children under 12 years old in their household.

Table 3

Socio-economic demographic characteristics of respondents

Individual characteristics		Number	Percentage (n=424)
Age	Under 18	4	0.94%
	18-34	138	32.54%
	35-59	246	58.02%
	60 or over	36	8.49%
Gender	Male	144	33.96%
	Female	280	66.04%
Employment	Student	38	8.96%
	Employed	343	80.90%
	Unemployed	11	2.59%
	Retired	32	7.55%
Highest educational level	Primary school	2	0.47%
	Secondary school	22	5.19%
	Senior high school	46	10.85%
	Undergraduate	304	71.70%
	Postgraduate	50	11.79%
Personal monthly income (CNY)	Less than 2000	62	14.62%
	2001-4000	136	32.08%
	4001-6000	130	30.66%
	6001-8000	41	9.67%
	More than 8000	55	12.97%
Residential location	Downtown	312	73.58%
	Urban fringe area	112	26.42%
Driving licence	Yes	302	71.23%
	No	112	28.77%
Hukou status	Yes	365	86.08%
	No	59	13.92%
Physical barriers (disability)	Yes	8	1.89%
	No	416	96.11%
Studentship	Yes	38	8.96%
	No	386	91.04%
Household characteristics			
Household size	1	14	3.30%
	2	69	16.27%
	3	212	50.00%
	4	62	14.62%
	5	45	10.61%
	More than 5	22	5.19%
Presence of children	Yes	248	58.49%
	No	176	41.51%
Household car ownership	Yes	280	66.04%
	No	144	33.96%

3.3. Description of survey variables

According to the principles of SEM, we categorised the variables as endogenous variables and exogenous variables. Some of these variables can be measured, namely socio-economic demographic characteristics (see Table 5). Apart from the aforementioned measurable variables, the conceptual model also includes a few latent variables that can be represented and measured by the measurable variables. In this study, all the latent variables were measured on a five-point Likert scale ranging from “I completely disagree” (1) to “I completely agree” (5). Detailed descriptions and definitions of these variables can be found below.

3.3.1. Public transport equity

Accessibility

Accessibility is measured using the Perceived Accessibility Scale (PAC) developed by Lättman et al. (2016b). As mentioned earlier, the PAC is a method that can be used to capture perceived accessibility based on a personal, subjective assessment of accessibility. Lättman et al. (2016a) also pointed out that this method has advantages in terms of ease of use, distribution, and accountability of outcomes, making it a useful way of assessing accessibility and a tool for policy planning. The PAC consists of four main items:

- “It’s easy to do (daily) activities with public transport”
- “If public transport was my only mode of travel, I would be able to continue living the way I want”
- “It is possible to do the activities I prefer with public transport”
- “Access to my preferred activities is satisfying with public transport”

Affordability

To measure the perceived affordability of public transport, the survey asked respondents whether they agreed or disagreed with the following two statements: “If public transport was my only mode of travel, the monthly travel cost would be acceptable”; and “If public transport was my only mode of travel, the time cost from origin to destination would be acceptable”.

Quality of life and well-being

Quality of life and well-being are indicators of the social impacts of public transport services (Cantwell et al., 2009), and are represented by the emotional evaluation of using public transport and measured by the two following statements: “using public transport has impacts on my quality of life” ; and “using public transport has impacts on my physical and mental health”.

4.3.2. Public transport-related policy support

To measure public transport policy support, the survey asked respondents whether they agreed or disagreed with the following two statements: “The preferential policy of Shenyang’s One Card Pass has made it beneficial for me to use public transport”; and “Fare subsidy policies have made it beneficial for me to use public transport”. In this study, fare subsidy policies refer to those aimed at senior citizens and students.

3.3.3. Public transport service quality

Public transport service quality is a complex concept. Based on the literature review of public transport service quality, the service attributes were selected, and measured using the thirteen elements listed in Table 4. Detailed descriptions of these variables are also provided in Table 4. Respondents rated these on a five-point Likert scale ranging from “I completely disagree” (1) to “I completely agree” (5).

Table 4

Description of public transport service quality variables

Category	Variable Name	Description
Public Transport Service Quality	Safety	Safety on board
	Temperature	Temperature in vehicle
	Cleanliness	Cleanliness of the vehicle
	Courtesy	Courtesy or helpfulness of staff and drivers
	Priority Seat	Priority seats are reserved for vulnerable groups
	Inclusive design	Inclusive design for public transport vehicles and station
	Waiting environment	Furniture and conditions at station
	Frequency	Frequency of services
	Punctuality	Punctuality of services
	Crowding	Vehicle crowding during rush hours
	Speed	The speed of the trip
	Ease of transfer	Ease of transfer to other public transport mode or line
	Information	Availability of service information via smart-phone and internet

3.3.4. Public participation

Two variables were used to measure public participation. For each variable, we selected two statements based on the relevant literature, namely: “The government often invites participation and listen to our views”; and “The government provides an unimpeded channel through which I can report and complain about any public transport problems that I encounter. Participants were asked to grade their feelings towards the channels of participation that are provided by the government.

3.3.5. Socio-demographic characteristics

Finally, in order to verify the hypotheses more effectively, the survey combined the list of variables relating to the socio-demographic characteristics and residential location of respondents, which were controlled as the exogenous variables. These variables comprised: age, gender, educational background, individual income, employment status, driving licence, Hukou status, mobility constraints, studentship, and residential location, household structure, household car ownership, and presence of a child aged between 0 and 12 years old in the household. Table 5 provides detailed descriptions of these variables.

Table 5

Socio-economic characteristic variables

Category	Variable Name	Variable explanation
Individual characteristics		
Gender	Gender	0 (Male);1 (Female)
Age	Age	1 (Under 18); 2 (18-34); 3 (35-59); 4 (60 or over)
Education	Edu	1 (Primary); 2 (Secondary); 3 (Post-secondary); 4 (Undergraduate); 5 (Postgraduate or above)
Monthly income (RMB[2])	Income	1 (Less than 2000); 2 (2001-4000); 3 (4001-6000); 4 (6001-8000); 5 (More than 8000)
Employment status	Empl	0 is employed and self-employed; 1 otherwise
Driving Licence	Licence	0 if yes;1 otherwise
Hukou status	Hukou	0 if yes;1 otherwise
Physical barriers	Barriers	1 if yes; 0 otherwise
Studentship	Student	1 if student; 0 otherwise
Residential location	Location	1 (Downtown); 2 (Urban fringe area)
Household characteristics		
Household size	HHsize	Number of household members
Child presence	Child	1 for presence of children aged 0-12 years old in the household; 0 otherwise
Household car ownership	Car	1 if yes; 0 otherwise

[2] 1GBP ≈ 9 RMB

3.4. Structural equation modelling

The literature emphasises the complex relationships between public transport equity, government policy support, and public participation. At the same time, several variables not only influence public transport equity, but they also affect each other. For example, government policy support and public participation are the intermediary variables between decision-making transparency and public transport equity. Beyond that, public transport equity is a complex concept that is difficult to observe and requires several variables to represent it. Therefore, SEM can be used as an appropriate method to assess the complex relationship between public transport equity and its affecting factors.

SEM is a powerful multiple statistical method that can be used to explore and test the causal relationships between observed variables and latent variables, which has been widely used in various research fields, such as sociology, psychology, and pedagogy since the 1970s (Fornell and Lacker, 1981; Hadiuzzman et al., 2017). Nowadays, SEM is widely applied in the domain of transport (Cao and Yang, 2017; De Vos, 2017; Ye and Titheridge, 2017). In addition, SEM has several advantages over the regression analysis method. First, SEM can handle multiple dependent variables simultaneously. Second, it can ignore the measurement errors of independent variables and dependent variables. Third, it is also similar to factor analysis, allowing a latent variable to consist of one or more observed variables. Moreover, SEM also offers the benefit of simultaneously capturing the direct, indirect, and total effects (Aditjandra et al., 2012; Cao et al., 2007; Cervero and Murakami, 2010; Cao and Yang, 2017; Jahanshahi and Jin, 2016a, b). The total effects are the summation of the indirect and direct effects.

In general, an SEM model consists of a measurement model and a structural model. The measurement model describes the relationship between latent variables and observed variables, whereas, the structural model represents the relationship between each latent variable.

The basic equation of the measurement model takes the following form (Byrne, 2016):

For the exogenous variables,

$$x = \Lambda_x \xi + \delta \qquad (1)$$

For the endogenous variables,

$$y = \Lambda_y \eta + \varepsilon \qquad (2)$$

Where x is the vector of observed exogenous variables; and Λ_x is the component matrix of the exogenous variables x on the ξ exogenous latent variables; δ is the error vector of the exogenous variables; Λ_y is the component matrix of the endogenous y on η endogenous latent variables; ε is the error vector of the endogenous variables.

The basic equation of the structural model takes the following form:

$$\eta = B\eta + \Gamma\xi + \zeta \qquad (3)$$

In which, η is the vector of endogenous latent variables; ξ *is the vector of* exogenous latent variables; B is the structural coefficient matrix between latent variables; Γ is the structural coefficient matrix of exogenous variables on endogenous variables; ζ is the vector of residual errors.

3.5. Conceptual model

Within the SEM, confirmatory factor analysis (CFA) methods are used to obtain the latent variables by selecting a series of observed variables as indicators (Delbosc and Currie, 2011). Scholars have long debated the question of what is the minimum number of indicators necessary to explain each latent variable? Kline (2015, p. 195) offered the following rationale regarding the rule for how many indictors there should be for each latent variable: "If a standard CFA model with greater than or equal to two factors has two indicators per factor, the model is identified". Moreover, he also highlighted that: "In order for a CFA model with a second-order factor to be identified, there must be at least three first-order factors. […]. And each first-order factor should have at least two indictors" (ibid., p. 319). Moreover, when the sample size is greater than 400, the CFA model allows only two indictors for each latent variable (Marsh and Hau, 1999; Boomsma and Hoogland, 2001). Thus, it can be argued that it is acceptable to have two observed indictors with which to explain the latent variables. In this study, observed variables were selected with careful consideration based on studies of public transport-related social equity. A summary and descriptions of latent variables and their observed variables are provided in Table 7 and Fig. 2. Latent variables are presented in ellipses and connected with their observed variables (represented by rectangles).

Moreover, SEM comprises a measurement model that requires the construction of hypothetical relations between several variables and uses the modelling results to test the validity of these assumptions. Based on the aforementioned previous literature on public transport-related social equity and the availability of data, the potential relationships and effects of relationships between public transport equity, public transport service quality, public participation, and public transport-related supportive policy measures were tested. Fig. 2 depicts the conceptual framework used in this research. In addition, the properties of the variables were defined according to the conceptual framework and hypotheses (see Table 6). We assumed that public transport equity (Equity), public transport-related policy (Policy), and public transport quality (Quality), and the second-order variables of public transport equity (accessibility, affordability, and social impact) are endogenous variables; and demographic characteristics and public participation (Participation) are exogenous variables. The causal hypothetical relationships between these endogenous and exogenous variables are listed and described in Table 6 and Fig. 2.

Table 6

Hypotheses tested by conceptual model

Research Hypothesis	Description	References
H1	All observed variables can determine and measure their latent variables.	Confirmatory Hypothesis
H2	Public transport service quality (Quality) is positively associated with public transport equity.	Confirmatory Hypothesis
H3	Public participation (Participation) has a significant positive association with public transport equity.	Pioneering Hypothesis
H4	Public transport-related policy support (Policy) has significant positive impacts on public transport equity (Equity).	Pioneering Hypothesis
H5	Public participation (Publication) has a direct positive effect on public transport-related supportive policy measures (Policy).	Pioneering Hypothesis
H6	Public transport-related policy support (Policy) has a significant positive impact on public transport quality (Quality).	Pioneering Hypothesis

H7	Public participation has a significant positive effect on public transport quality (Equity).	Confirmatory Hypothesis

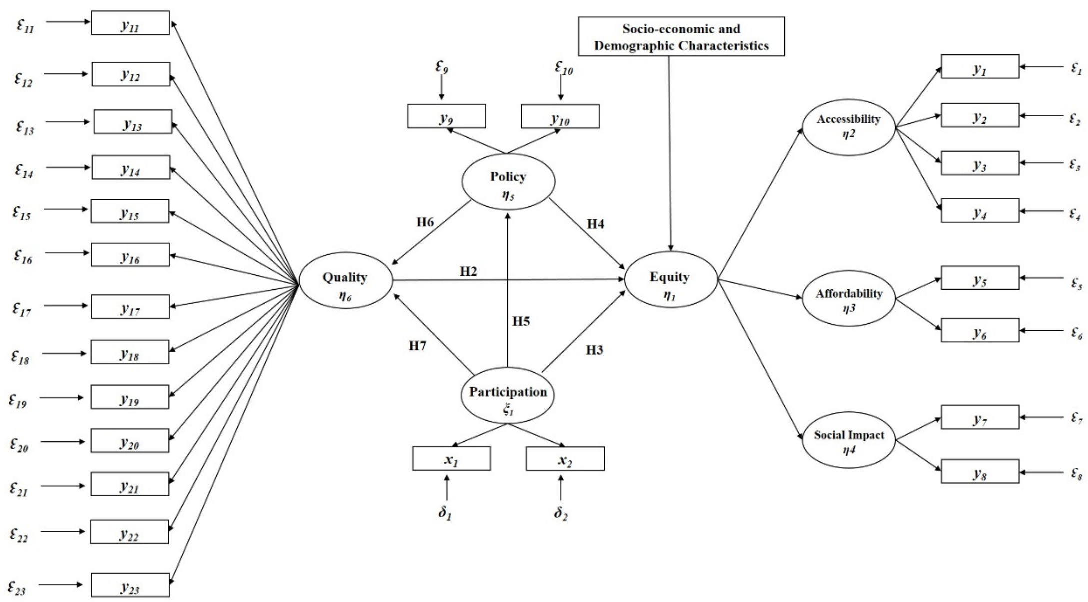

Fig. 2. Conceptual model of the study

Table 7

Summary of latent variables and their observed indictors

Latent variable		Notion	Observed variable	Notion
Public transport-related equity (η_1)	Accessibility	η_2	Easy to do daily activities	y_1
			Only mode of travel	y_2
			Possible to do activities	y_3
			Access to preferred activities	y_4
	Affordability	η_3	Monthly travel cost	y_5
			Time cost	y_6
	Quality of life and well-being	η_4	Quality of life	y_7
			Physical and mental health	y_8
Public transport-related policy support		η_5	Travel pass	y_9
			Fare subsidy policies	y_{10}
Public transport service quality		η_6	Safety	y_{11}
			Temperature	y_{12}
			Cleanliness	y_{13}
			Courtesy	y_{14}
			Priority seat	y_{15}
			Inclusive design	y_{16}
			Waiting environment	y_{17}

		Frequency	y_{18}
		Punctuality	y_{19}
		Crowding	y_{20}
		Speed	y_{21}
		Ease of transfer	y_{22}
		Information	y_{23}
Public participation	ξ_1	Frequently invited	x_1
		Complaint and feedback channel	x_2

4. Results

In general, the maximum likelihood estimation (MLE) is widely used to estimate the parameters of the probability distribution and test the model fit in SEM; the data should be continuous and follow a normal distribution (Byrne, 2016; Cao, 2016). However, the data may violate the multivariate non-normal assumption (Byrne, 2016; Wang and Lin, 2017). The Bootstrapping procedure is an important method that can be used to obtain the variance-covariance matrix (Cao, 2016), and to guarantee the stability of parameter estimations and the greater accuracy of values. In order to test the goodness-of-fit for the model that we devised, shown in Fig. 2, we chose a wide range of model fit indices: Chi-square/Degree of Freedom, Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), Parsimonious Goodness of Fit Index (PGFI), Comparative Fit Index (CFI), Non-normal Fit Index (NNFI), and Root Mean Square Error of Approximation (RMSEA). These variables are widely and frequently selected to evaluate the goodness-of-fit (Byrne, 2016; Hair et al., 2014). The results of the model are as follows: χ^2/df =2.95, smaller than 5.0; AGFI=0.91, GFI=0.93, NNFI=0.92, and CFI=0.90, all of which are higher than 0.90; and the RMSEA of 0.068 is smaller than 0.08 (see Table 8). Therefore, the results show that the model's degree of fit is particularly good.

Table 8

Goodness-of-fit measures

Model fit indices	Cut-off value	Model-based value
Chi-square/Degree of freedom	<5	2.95
Goodness of Fit Index (GFI)	>0.90	0.93
Adjusted Goodness of Fit Index (AGFI)	>0.90	0.91
Parsimonious Goodness of	≥0.50	0.69

Fit Index (PGFI)		
Comparative Fit Index (CFI)	>0.90	0.90
Non-Normal Fit Index (NNFI)	>0.90	0.92
Root Mean Square Error of Approximation (RMSEA)	≤0.08	0.068

Indicators and determinants of latent variables

As previously mentioned, the SEM consists of a measurement model and path analysis. In this research, the model has a few latent variables that are derived from the observed variables. Table 9 shows the standardised outcome of the measurement models (Fig. 3 shows the paths of the standardised coefficients). The p-value of the standardised path coefficient between public transport equity and accessibility and affordability is at the 0.01 level, and the social impact is at the 0.1 level, suggesting that accessibility, affordability, and social impact are significant indicators of public transport equity. Moreover, the standardised load coefficient indicates the effect size and extent of interaction of the observed variables on the latent variables. The higher the coefficient between the observed variables and the latent variables, the more representative it is of the latent variables (Schreiber et al., 2006). According to the data shown in Fig. 3 and Table 9, the standardised load coefficients of the public transport equity measurement model and its representative variables are 0.98 (affordability), 0.98 (accessibility), and 0.14 (social impact), respectively, suggesting that public transport equity is better explained by affordability and accessibility, while the social impact is relatively low. Therefore, improving the level of accessibility and affordability can have a significant effect on promoting public transport equity. It is difficult to measure perceived accessibility, affordability, and social impact; therefore, we built a two-stage model to represent these three variables. The latent variable of social impact measures a subjective judgement about the effect of public transport on an individual's quality of life and well-being; the latent variable of accessibility measures an individual's access to different kinds of services by public transport, and; the latent variable of affordability measures the perceived capability of travellers to afford their travel costs and time costs when public transport is required.

Table 9

Standardised path coefficients between public transport equity and its observed variables

Path Relationship			Std. R.W.	Rank
Social impact (η_4)	←——	Public transport equity (η_1)	0.144*	3
Accessibility (η_2)	←——	Public transport equity (η_1)	0.983***	2
Affordability (η_3)	←——	Public transport equity (η_1)	0.984***	1
y_1	←——	Accessibility (η_2)	0.831***	2
y_2	←——	Accessibility (η_2)	0.804***	3
y_3	←——	Accessibility (η_2)	0.675***	4
y_4	←——	Accessibility (η_2)	0.870***	1
y_5	←——	Affordability (η_3)	0.927***	1
y_6	←——	Affordability (η_3)	0.714***	2
y_7	←——	Social Impact (η_4)	0.936***	1
y_8	←——	Social Impact (η_4)	0.706**	2

*Note: ***Indicates significant at p-value<0.01, **Indicates significant at p-value<0.05, * indicates significant at p-value<0.1*

Effects of relationships between public transport quality, public participation, policy support, and public transport equity

The structural model describes the relationship between each of the latent variables. Fig. 3 and Table 11 show the results of the structural modelling with standardised total, direct, and indirect effects on public transport equity. In the structural model, the parameters are all assumed to have a statistical difference of zero representing statistically significant. In this case, the strengths of the relationships between the exogenous variables and public transport equity are very different. The endogenous latent variables of public transport service quality have a total positive effect on public transport equity, with a standardised regression weight of 0.996 (the statistically significant level is 0.001). This finding is in line with the previous research on the connection between public transport service quality and public transport equity (Litman, 2018; Villaraze et al., 2017). The standardised indirect effects of public transport service quality on accessibility, affordability, and social impact are 0.963, 0.956, and 0.129, respectively, indicating that improving the quality of public transport services can also improve the accessibility and affordability of public transport for respondents in

Shenyang, as well as having positive impacts on society more generally. Regarding the observed variables of public transport service quality, the results show that the order of the 12 observed variables of public transport equity is as follows: ease of transfer (0.89), speed (0.89), punctuality (0.88), priority seat (0.88), waiting environment (0.88), inclusive design (0.87), frequency (0.87), crowding (0.87), cleanliness (0.86), safety (0.82), courtesy (0.79), information (0.68), and temperature (0.37), suggesting that the environment has a minor effect on the quality of public transport services.

Public participation has a direct effect on public transport equity, public transport service quality, and policy support, and an indirect effect on public transport equity through public transport service quality and policy support, with a standardised total value of 0.920. The results support our hypotheses that public participation and policy help to improve public transport equity. Public participation is one of the most important methods for managing urban public transport systems. Effective public participation can strengthen the feedback function of public transport policies and public transport service quality, thus improving public transport equity (Chen and Ji, 2011; Neshkova and Guo, 2012).

The endogenous latent variable of policy support has relatively weak effects on public transport. It has a direct effect on public transport equity, but at the same time, it also affects public transport equity by influencing the quality of public transport services, with a standardised total value of 0.417. This suggests that strengthening policy support measures, such as the "public transit first" and "low fares, free tickets for elderly and disabled people" initiatives have positive effects on the quality and equity of public transport services. This finding supports the results of empirical studies in terms of public transport subsidies and discounts for the poor, which can reduce the gap in accessibility and travel affordability between low-income and high-income groups, and also reduce the negative impacts of social inequity for low-income groups (Ahmed et al., 2008; Guzman and Oviedo, 2018). Moreover, all the public participation and policy support latent variables have significant associations with their respective observed variables.

Effects of socio-demographic characteristics on public transport equity

In order to verify our hypotheses, the effects of socio-economic demographic characteristics were also controlled in the model. Table 10 shows the results. As expected, gender has significant and negative effects on public transport equity. Women are more likely to be disadvantaged in terms of income and driving skills compared to men, and public transport has become the main mode of travel used for shopping and commuting. However, the living environment, traffic environmental conditions and other objective factors may exacerbate public transport inequity for females (Hine and Grieco, 2003). In accordance with findings from previous studies conducted by Di Ciommo and Shiftnan (2017), our results show that respondents with a physical disability tend to experience social exclusion when using public transport. This can be explained by the fact that respondents with physical impairments, illness, and health problems have limited opportunities to use public transport and mobility services. Furthermore, income level and employment status also have significant effects on public transport equity. Socially vulnerable groups are often associated with low-incomes and unemployment, and are more dependent on public transport, as they tend to have fewer alternative transport modes available to them. There are two possible reasons for this: first, most low-income groups live in the suburbs where the transport infrastructure is inadequate and there is insufficient public transport provision, which could make commuting on a daily basis more difficult for them (Di Ciommo and Shiftan, 2017; Litman, 2018, 2020b; Zhao, 2015). Second, transport costs account for a relatively high proportion of low-income groups' total consumption (Lucas, 2011). In addition, our results show that the individual characteristic of being a student is also statistically significant and has negative effects on public transport equity. This finding is in line with previous studies investigating the affordability and accessibility of daily travel for students (Kammruzzaman et al., 2011; Shoham et al., 2005). In terms of other socio-economic characteristics, such as age, education, driving licence, hukou status and so on, they all failed the significance test and therefore do not have a statistically significant influence on public transport equity, at least in this study.

Table 10

Direct effects of socio-economic variables on public transport equity

Variable Name	Std. R.W.	p-value
Individual Characteristics		
Gender	**-0.102**	*
Age	-0.050	0.391

Edu	-0.013	0.841
Income	**-0.092**	**
Empl	**-0.104**	**
Licence	0.105	0.148
Hukou	0.029	0.594
Barriers	**-0.181**	***
Student	**0.140**	**
Location	-0.016	0.746
Household Characteristics		
HHsize	0.071	0.189
Child	**-0.100**	*
Car	-0.064	0.173

*Note: ***Indicates significant at p-value<0.01, **Indicates significant at p-value<0.05, * indicates significant at p-value<0.1*

Table 11

Direct effects, indirect effects, and total effects between exogenous and endogenous variables

Path Relationship			Path Coefficient			Hypothesis	Results
			Direct Effects	Indirect Effects	Total Effects (Std. R.W.)		
Equity	←——	Quality	0.966**		0.966***	H2	Support
Equity	←——	Policy	0.189**	0.228***	0.417***	H6	Support
Equity	←——	Participation	0.216**	0.704***	0.920***	H3	Support
Quality	←——	Participation	0.329***	0.581***	0.910***	H7	Support
Policy	←——	Participation	0.927***	-	0.927***	H5	Support
Quality	←——	Policy	0.627***	-	0.627***	H4	Support

*Note: ***Indicates significant at p-value<0.01, **Indicates significant at p-value<0.05, * indicates significant at p-value<0.1*

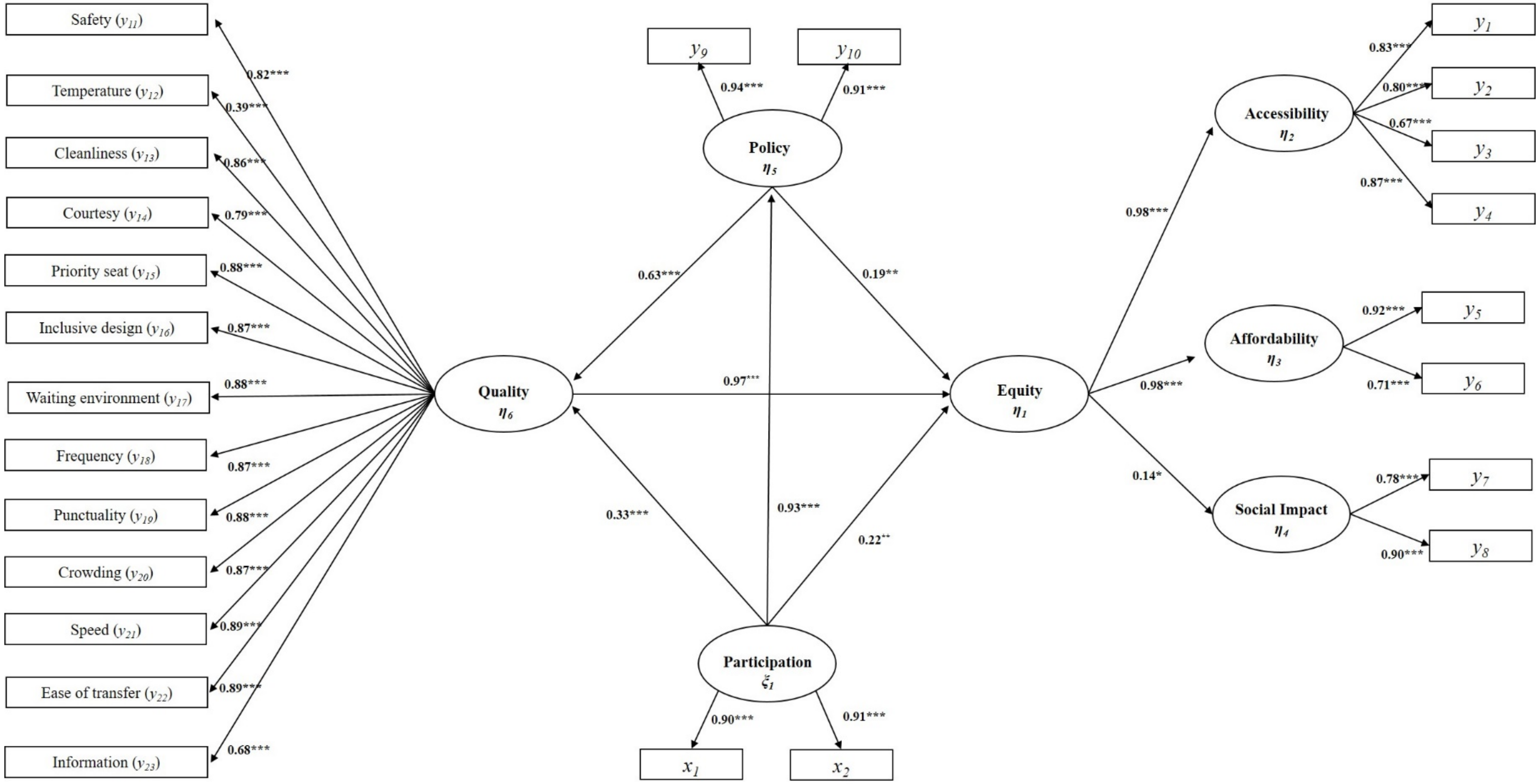

Fig. 1. The results of the public transport equity model

*Note: ***Indicates significant at p-value<0.01, **Indicates significant at p-value<0.05, * indicates significant at p-value<0.1*

5. Discussion and Policy Implementations

Based on the findings and analysis of Shenyang's public transport system, the following policy implications are suggested and can be used to inform public transport policies and strategies. We hope that the subsequent discussion, policy and strategy recommendations can provide references for improving public transport equity in Shenyang that can be generalised to other Chinese cities.

5.1. Improving public transport service quality

First, the findings highlight the crucial importance of public transport quality in improving public transport equity. According to the results of the structural model, the observed variables of public transport with relatively high scores are ease of transfer, and speed of public transport. Therefore, the administrative department with responsibility for traffic in Shenyang should promote the preferential development of urban mass rapid transit to achieve an equitable and sustainable urban traffic system. For example, based on urban comprehensive planning and citizens' travel habits, seamless transfers on the public transport system can be achieved by improving the design of transfer-related facilities and optimising the transfer organisation process. Moreover, speed is also vital in improving perceived public transport equity. Redman et al. (2013) presented evidence that the introduction of priority bus lanes can as much as double the original speed of buses. However, there are currently only 20 priority bus lanes in Shenyang, covering a total distance of 71.6 km (Zhu, 2018). Bus lanes account for only 6.8% of the total road network, which represents a large disparity with other cities, such as Chengdu and Shenzhen. Furthermore, Zhu (2018) also pointed out that there are some main trunk roads without bus lanes within the first ring road, which means that buses can only travel at low speeds. In order to increase the speed of public transport, it is suggested that priority bus lanes should be extended to form bus lane corridors, particularly in the case of the main trunk roads in the central urban area. In addition, an advanced public transport system (APTS) could improve the real-time scheduling and management of the public transport system, and ultimately increase its overall running speed (Liang and Wei, 2017). Therefore, an APTS with several sub-systems, such as vehicle monitoring and dispatching systems, and a comprehensive scheduling management system could be introduced in Shenyang in order to improve the operating efficiency and running speed of public transport.

5.2. Facilitating public participation in decision-making about public transport-related policies

According to the results derived from the total effects of the model, we can see that improving public participation has significant attributes for mitigating public transport inequity. Effective public participation can contribute to improved management of urban traffic, which will promote the programmatic and normalised development of public transport systems (Chen and Ji, 2011). Given that the implementation of urban traffic policies will affect the travel rights of all citizens, opinions and suggestions from members of the public should be embraced. An effective negotiation mechanism of policy settlement should also be created to reflect the positive effects of the public's contribution in terms of public transport-related policy rationalisation. At the same time, a sound feedback mechanism can show the public that their opinions are being taken into account, and thus make them more enthusiastic about participating in policy decisions (Chen and Ji, 2011). Regardless of what forms the channels of participation take, a sound feedback and evaluation mechanism should be created to enable the public to follow up on the results of their feedback. In particular, it is important to point out that public participation in public transport policy decisions should be mobilised by hosting consultations, interviews and surveys.

5.3. Strengthening subsidy policies

The improvement and optimisation of safeguarding policies for vulnerable groups are an important means of improving public transport equity. The results show that safeguarding policies for vulnerable groups have a positive effect on public transport equity. Zhou et al. (2018) highlighted that public transport is a kind of public good, providing daily services and infrastructure for the public, and especially for vulnerable groups. Our findings also show that demographic characteristics, such as unemployment and low-incomes, are the most significant variables affecting public transport equity. This indicates that improving transport affordability for the aforementioned groups should be taken into consideration when formulating public transport policies. Current public transport subsidy policies in Shenyang have mainly focused on physically vulnerable groups, such as elderly people or people with disabilities, and students. However, we would argue that lower-income cohorts should also be offered subsidies, for example, 50 per cent discounts on their monthly public transport travel cards. For example, in London, the Department of Society Security (DSS) introduced a job-seeking allowance system for low-income people who are over 18 and who work less than 16 hours per week, which involved subsidising their travel costs (Amaral et al., 2009). In addition, there is also a lack of transfer discounts for people in Shenyang who cannot get to their destination directly, meaning that they have to transfer to other means of transport or routes, which may result in more people driving private vehicles due to the inconvenience of using public transport. Based on the experiences of more advanced transport development in Singapore, Taipei, Seoul, Paris, and Shanghai, Liu et al. (2016) highlighted that preferential policies can be divided into two categories: ‘transfer for free’ and ‘transfer fixed charge’, based on criteria such as margin of preference, time-limited discounts and frequency limited discounts. Yen et al. (2017) discussed preferential policies for public transport transfers and concluded that they have a positive effect on the usage of public transport and on transport equity. We therefore suggest introducing a reasonable transfer discount into the price settlement mechanism in Shenyang in order to improve public transport equity, particularly for lower-income groups or people who need to make several transfers to reach their final destinations.

6. Conclusions

Our research has explored the effects of public transport equity in terms of public transport quality, public participation, and public transport-related policy using Shenyang as a case study. The results show that the SEM can be used as a powerful tool with which to analyse data and show comprehensive relationships between variables, and which has high explanatory power and portability. It can also be used as an alternative method to explore the hidden relationships between external factors and public transport equity.

This paper constructed an SEM to explore and examine the determinants of passengers' perceptions of public transport equity and the interrelationships between public transport service quality, public participation, public transport-related supportive policy measures, and public transport-related social equity. Consistent with the SEM, a hypothesised model proposed a direct positive association between public transport quality and public transport equity; and between public participation and public transport equity; and also showed both an indirect and a direct association between public transport-related policies and public transport equity.

Our findings show a highly statistically significant direct link between public transport equity and public transport quality, indicating that improving the quality of public transport is one of the most important ways of reducing public transport inequity. Furthermore, the results also show a direct relationship between public transport equity and public participation and public transport-related policy support. It is worth pointing out that the total effects of public participation are much greater than the effects of public transport-related policy support measures in terms of improving public transport equity. In addition, changes in public participation are significantly associated with changes in public transport-related policies and quality, indicating that encouraging public participation can have a positive influence on public policies and public transport equity. Moreover, public transport-related policies, such as concessionary fares and travel cards, have benefits in reducing levels of social disadvantages and giving disadvantaged groups better access to daily services and goods, thereby making it easier for them to access more key life activities and opportunities. The findings also show that improving the quality of the public transport infrastructure can help to increase public transport equity.

This research makes several important contributions. First, we built a solid model with which to measure and gain greater understanding of public transport equity, which can also be replicated in other contexts, such as South America (Guzman and Oviedo, 2018; Oviedo and Guzman, 2020; Pereira et al., 2019), the United States (Ermagun and Tilahun, 2020; Li and Landis, 2019), and Europe (Attard, 2020; Cao and Hickman, 2019b; Lucas, 2012). Second, our research contributes to 'public transport priority development' policies in China as well as considering how public participation systems affect public transport related-social equity. Finally, unlike traditional methods of measuring public transport equity that mainly focus on a single aspect, this research simultaneously measures and evaluates public transport equity on the basis of three dimensions, namely accessibility, affordability, and social impact.

This research does have some limitations, however. First, we could increase the sample size as well as the different types of observed indicators in order to better represent each latent variable.

Additionally, an advanced spatial analysis could be carried out in order to measure public transport equity in greater depth (Chen et al., 2006), such as by evaluating the spatial distribution of public transport infrastructure and services for different social groups in both the downtown and urban fringe areas, particularly in terms of lower-income and socially disadvantaged groups.

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