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Impact of Perceived Uncertainty on Public Acceptability of Congestion Charging: An Empirical Study in China

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Abstract: Severe traffic congestion is now a common problem in major cities worldwide, causing huge economic, environmental, and social losses to overall welfare. Governments are now considering congestion charging as an effective way to manage congestion. However, since congestion charging has not yet been implemented widely, the public remains uncertain about it. Few scholars have explored public uncertainty about congestion charging. This paper examined how the public perceived uncertainty toward fairness and efficiency affects willingness to accept congestion charging. Through an experimental study of stated preference, this paper analyzes the influence of observable variables and unobserved latent variables on public acceptability and compares the results with a traditional discrete choice model. The results indicated that the public's perceived uncertainty about congestion charging will have significant negative effect on acceptability and that the perception of fairness has an even larger effect. As for uncertainty about the effectiveness of congestion charging on alleviating congestion, the implementation efficiency of the government is the most significant. For uncertainty about fairness, whether charge collection and revenue allocation are reasonable is the most significant. These findings provide an empirical basis for reducing public uncertainty and increasing public acceptance of congestion charging.

Keywords: congestion charging; perceived uncertainty; ICLV model

1. Introduction

In recent years, with the development of urbanization, the contradiction between the supply and demand of urban transportation is becoming increasingly prominent especially in mega cities and metropolitan areas, such as Beijing. From an economic point of view, the essence of congestion pricing is to guide people to choose their mode of travel rationally and thereby alleviate urban traffic congestion. Charging based on road traffic congestion as an effective economic instrument for traffic demand management, is beginning to be discussed. However, while congestion charging is theoretically effective, it faces many obstacles in practice. Urban road congestion is a systematic problem, and correspondingly, reasonable policies must be formulated to achieve maximum effect. While it is feasible to collect traffic congestion fees, public opinion about such fees remains to be investigated. This paper examines how public perceived uncertainty toward fairness and efficiency affects willingness to accept congestion charging in the Beijing context.

Regarding the acceptability of congestion charging, most of the public that has been surveyed has directly or indirectly expressed their disapproval or disagreement with it [1]. While they can refer to successful foreign experience, a China Youth Daily Social Investigation Center poll showed that 75.4% of people oppose congestion charging. The public objections are based on self-interest and uncertainty about how it will work. Among those who disagree, 54.6% of the public think that public transport is imperfect and congestion charging will not solve the congestion problem effectively; 53.7% of the public are concerned about how congestion fees will be used; and 20.2% of the public are skeptical about how to effectively charge congestion fees as there are no concrete implementation rules. Therefore, suspicion and uncertainty about policy measures for congestion charging have become a major obstacle.

Uncertainty is one of the main reasons why the public does not support the implementation of the new policy [2]. From the perspective of policymakers, only by taking full account of the public's demands, can the policy for easing road congestion be sustainable and effective. Thus, in the face of public disapproval due to the perceived uncertainty caused by congestion charging, the key to understanding and supporting the public's skepticism is to study and analyze the perceived uncertainty and determine how the public perception of congestion charging affects their willingness to accept it. Meanwhile, various studies have identified factors influencing willingness to accept congestion charges using straightforward econometric models. While delivering useful insights, these studies do not provide insight into the underlying psychological mechanisms. To fill this gap, this study used different scenarios, combined with an analysis of uncertainty, to explore how different congestion pricing modes and pricing levels influence the public's willingness to accept congestion charges. This paper attempts to answer the following questions: First, what aspects of congestion charges are perceived by the public as uncertain? Second, how do behavioral or psychological factors indirectly influence policy acceptance via perceived uncertainty? Third, how does perceived uncertainty affect public willingness to accept congestion charges? The analysis is based on Stated Preference surveys with regular commuters in Beijing and the model is estimated using an integrated choice and latent variable model (ICLV), which simultaneously merges classic choice models with the structural equation approach (SEM) for latent variables.

The remainder of this paper is organized as follows. Section 2 reviews the literature on congestion charging and uncertainty. Section 3 presents the methodology of this study, including experiment design, data collection, measurements of key concepts, and methodology. Descriptive analysis results and model estimation results are shown in Section 4. The discussion and conclusion are presented in the final two sections.

2. Literature Review and Theoretical Framework

2.1. Congestion Charging Case Study

Despite its low acceptability, congesting charging has been implemented in a few cities around the world. In 1975, for the first time, Singapore imposed a congestion charge in the downtown area using a schema of manually charged "Regional Pass." After 1998, Singapore adapted to an electronic toll collection system. In the decades after its implementation, the number of cars entering the toll area has decreased by 44%, and the average speed has also increased from 11 min/h to 21 min/h. Private car travelers have changed to public transport, and the car sharing rate increased from 33% to 69% after congestion charging was put in place [3]. The implementation of congestion charging has not only significantly improved road congestion and traffic accidents, but it has also increased transportation revenue, building a foundation for further improvements in the road traffic system. Seoul began to implement road congestion charging in 1996. After implementation, road traffic volume decreased by 24.9%, and the traffic speed increased by 55.9%. London also began collecting congestion charges for vehicles entering the downtown area in 2003, resulting in a reduction of traffic volume in the region by approximately 27%, and bus travel became 25% faster [4]. In Stockholm, Sweden, traffic flow decreased by 22% within seven months of the implementation of a pilot congestion charging system, and it was reduced by 18% after the official implementation. Milan's traffic volume into the toll area decreased by an average of 14.2% after the implementation of congestion pricing. In addition, the traffic volume at the early peak period decreased by 23%, and the number of people using public transportation increased by 6.2% [5]. Comparisons of the congestion charging systems for the above-mentioned countries or cities, including areas where congestion charging occurs, times when costs are increased, the prices charged, and how the money collected is used, are shown in Table 1.

Table 1. Successful applications of road congestion charging measures.

Countries/Cities	Singapore	Seoul	London	Stockholm
Time	1975	1996	2003	2006
Charging area	Central Business District, highways, main roads	Main roads leading to downtown (Nanshan Highways 1 and 3)	Central London	City center
Charging periods	According to the size of traffic volume	Monday to Friday 7:00 to 19:00, Saturday 7:00 to 15:00	Working days from 7:00 to 18:00, holidays are not levied	Working days 6:00 to 18:29, holidays are not collected
Prices charged	0.5–5 Singapore dollars (1 SD = 0.7252 USD)	2000 won (1 won = 0.0008852 USD)	11.5 pounds (1 pound = 1.2975 USD)	Up to 30 kroons per time, up to 105 kroons per vehicle per day (1 Kroon = 0.1102 USD)
Use for congestion charges	Used for road and highway construction	Used to develop public transport	Used for traffic development in the area	For road construction

2.2. *Influencing Factors on Public Willingness to Accept Congestion Charging*

While some cities have successfully implemented congestion charging, many others have encountered obstacles in the implementation process. The biggest challenge is acceptance by the public. Many studies have extensively analyzed the factors that influence the public's willingness to accept congestion pricing policies, including the design of the system's policies, the fairness and effectiveness of the charge, and psychological factors.

2.2.1. Congestion Charging System Attributes

The design of the mechanism of a congestion charging system is related to the willingness of the public to accept congestion charging, such as the level of charging, charging method, charging time, and charging area.

According to Kockelman and Kal-manje [6], the price level for congestion pricing, the times when charges are in place, the area in which charging takes place, and other charging mechanism attributes are closely related to the acceptability of congestion charges. The congestion charging in London was successfully completed, but Birmingham and Manchester had to repeal the policy due to strong public objection. One of the important reasons was that the latter cities had to implement different charging schemes in two regions, instead of only one regional charge in London. Bonsall and Cho [7] and Glazer et al. [8] found that public acceptability of complex charging mechanisms, such as time-based charging or charging based on congestion delays, is lower than fixed-rate charging. Hensher and Li [2] believe that the more complex a congestion charging mechanism is, the more difficulty the public will have in understanding it, which has led to public disapproval. Camila et al. [9] suggest that when people are more aware of what road pricing is, they are more willing to support new charging schemes, with such support being highest when there is a level of awareness between 33% and 67%. For more complicated charging schemes, public objection is mainly due to a lack of understanding of the schemes. Milan's example also shows that the public prefers a simple charging plan, as demonstrated by the 2011 referendum in which 80% of voters agreed to change to a new, simpler charging plan. Additionally, regarding the price mechanism, research has found that the price level has a significant impact on public acceptance of fixed-rate charges, credit-based charges, and time-based charges [10].

2.2.2. The Use of Congestion Charges

The acceptability of congestion charges is also related to the concrete use of its revenue. According to a survey conducted in London, if the revenues are used to improve traffic construction and reduce vehicle purchase tax, the public support rate will increase from 43% to 63%. Furman [11], in a survey of drivers in Southern California, mentioned that, when congestion charging income was returned to the public through various forms, such as reducing vehicle registration fees, the people's support rate for the policy increased by 7%. Harrington et al. [12] found that the relevant government agencies should return the income generated by the charges directly or indirectly to road users, for example, reducing vehicle registration fees, fuel tax, etc. Ison [13] believes that use of road toll revenue to improve public transport construction is the income distribution form that is most acceptable to the public, especially for the improvement of public transport in the areas where road pricing is implemented. Schuitema and Steg [14] propose that the public is more willing to accept the use of a fixed-price charge for car users than a variable price. Lyons et al. [15] found that the public's willingness to accept charging policies increased when congestion revenue was used to ease traffic. Ubbels et al. [16] found that people are more willing to accept congestion charging if revenue is allocated to cancel or subsidize existing vehicle taxes or reduce fuel taxes. Chen and Sun [17] believe that the main reason for the low support rate is that the public thinks that urban roads should be used free of charge as public goods. In addition, the income from congestion charging should be used to reduce taxation for road use; the establishment of a transportation subsidy fund will compensate for economic and social costs generated by congestion. While revenue allocation to direct travel subsidies can raise the overall welfare level of society, it is difficult to implement.

2.2.3. The Effectiveness of Congestion Charging

If road congestion charging can achieve the purpose of alleviating congestion, and the public believes that congestion charging is effective, they will tend to support road congestion charging. Schade and Schlag [18] believe that if people expect congestion charging to effectively alleviate the congestion problem, it will have a higher acceptability. Jaensirisak et al. [19] found that non-driving travelers, especially those who believe that congestion charges are effective, are more willing to accept congestion charging since they do not have to actually pay the congestion fee. Rienstra et al. [20] found that the acceptability of congestion charges will change over time. If people feel that road charges are effective in relieving congestion, then they are more inclined to support congestion charging. Many scholars have also conducted comparative studies of public acceptability before and after the implementation of the policy and found that public acceptance was higher after implementation. Gehlert et al. [21] believe that the attitude of the public about the road pricing policy will change before and after its implementation. Hess and Börjesson [22] pointed out that public attitudes about charges did indeed become more positive after introduction of the charges as a result of a broken status quo bias. When people see that the congestion has eased, they will think that the road charging is effective.

2.2.4. The Fairness of Congestion Charging

At present, most studies on the fairness of congestion charges focus on the analysis of the impact of congestion charging on groups with different income levels, based on the assumptions and prerequisites of the study. One group of researchers, such as Small [23], believe that congestion pricing on roads is beneficial to high-income people. This is because high-income people are relatively sensitive to the value of time (VOT). They are willing to spend money to save time. On the contrary, road congestion charges are not so beneficial for low-income people. However, other scholars, such as Mahendra [24], when surveying North America and Europe, found that it is beneficial to both high-income groups and low-income groups; European cities are just the opposite of the USA, because in many European cities, public transport facilities are well-developed, while in the USA, private transport is still dominant. In Europe, low-income people can choose public transport to avoid losses, while in U.S.A., they have no other way around it. In addition, studies of cities such as San Francisco [25], Stockholm [26], and Oslo [27] found that, since high-income people often live in areas with underdeveloped public transportation, they can only choose driving. Huang Haijun's [28] study shows that congestion charging will only benefit road management departments and groups with high time value. Therefore, most of the public are concerned with the fairness of congestion charging.

2.2.5. Perception of the Congestion Problem

The acceptance of congestion charges will also be affected by certain psychological factors. Schade and Schlag [18] found that groups who believe that traffic congestion is the most serious problem are more likely to accept congestion charging than those who believe the most serious problems involve the environment. Jaensirisak et al. [19] believe that if the public feels that the current traffic situation is unacceptable, it will show a higher acceptance of congestion charges. According to Oberholzer-Gee and Weck-Hannemann [29], some drivers are only concerned about the use of their own vehicles, not the congestion charging. Odioso et al. [30] studied the effects of social and personal perception on public acceptance of congestion charging and found that the perception of personal issues has a significant impact on its acceptability, while social issues show no significant effect. However, Nordlund and Garvill [31] found that when people perceive that traffic congestion and other problems will seriously affect the social environment and their personal lives, they will choose to maintain the collective interests. Eriksson et al. [32] found that perception of the problem has a direct impact on improving transit acceptability.

There exist many studies explored the psychological factor in discrete choice analysis, for example, Schade and Schlag (2003), found that groups who believe that traffic congestion is the most serious problem are more likely to accept congestion charging than those who believe the most serious problems are about environment. Jaensirisak et al. (2005) believe that if the public feels that the current traffic situation is unacceptable, it will show higher acceptability to congestion charges. According to Oberholzer-Gee and Weck-Hannemann (2002), some drivers are only concerned about the use of their own vehicles, not the congestion charging.

Various psychological factors will influence public acceptance, however, how these factors influence each other and finally lead to the influence on the utility, needs to be further clarified. Especially, the uncertainty about the policy will have significant influence on the public acceptance (Bonsall and Cho, 1999). Actually, the psychological factors will both influence the decision choice directly and indirectly (via perceived uncertainty and perceived fairness).

However, when taking a closer look at this aspect, little attention has been paid to shed light on how the psychological factors influence perceived uncertainty, and therefore both directly and indirectly influence the public acceptance.

Behavioral science researchers believe that the cognitive activities of the "black box" (such as a traveler's own attitudes, perceptions, values, lifestyle, etc.), can have a very important influence on choice behavior, but the traditional discrete model cannot be used to analyze the influence of latent variables such as perception and attitude on behavioral response. To this end, some scholars attempt to put the psychological factors in the "black box" into the model, so as to improve the explanatory power of the model. Ben-Akiva et al. combined the discrete choice model and the structural equation model and put forward the integrated choice and latent variable (ICLV) model.

These factors are systematically considered in the model construction and experimental design in Section 3.

2.3. Perceived Uncertainty and Hypothesis Development

Many studies [19,33,34] have examined congestion charging, most of these are concentrated in developed regions such as Europe and North America. Considering the differences between Western countries and China in terms of public transportation environment, public travel preferences, and policies, it is necessary to investigate congestion charging in the context of China.

At present, most studies use the traditional discrete choice model to explore the effect of congestion charging mechanism factors on the public's willingness to accept, such as the type of charge, the use of congestion charges, and the impact of compensation measures [18–20,35–38]. There are also some studies that use structural equation models to study the influence of latent variables, such as the public's psychological factors, on their willingness to accept [39,40]. Few studies have considered the effect of the charging mechanism, individual characteristics, and psychological factors on the willingness to accept congestion charging [41]. Some have only studied the influence of other perceptual factors, and the influence of public perception uncertainty is not comprehensively studied.

Perceived uncertainty refers to the perception that individuals lack sufficient information to predict or make decisions [42]. According to Ellsberg [43], people tend to choose what they understand or are familiar with, rather than choosing what they do not understand, which leads to people's attitude toward cost and risk. Ellsberg [43] and Kahneman and Tversky [44] consider this to be risk aversion behavior. People are influenced by cognitive factors such as psychological cognition attitude when making decision. When public perception of congestion charging is uncertain, it will affect their willingness to accept congestion charging.

Therefore, from the perspective of perceived uncertainty about congestion charging, this study provides a unique perspective for studying the public acceptability of congestion charging, and comprehensively considers congestion charging, individual characteristics of the public, and perceived uncertainty factors on their willingness to accept. By adding the latent variable factor of perceived uncertainty on the basis of a traditional discrete choice model, the paper comprehensively analyzes and researches the direct or indirect influences of the public's perceived uncertainty on its willingness to accept. The combination of the latent variable and discrete choice model provides a comprehensive analysis of the acceptance of congestion charging by the public. The theoretical framework is showed in Figure 1.

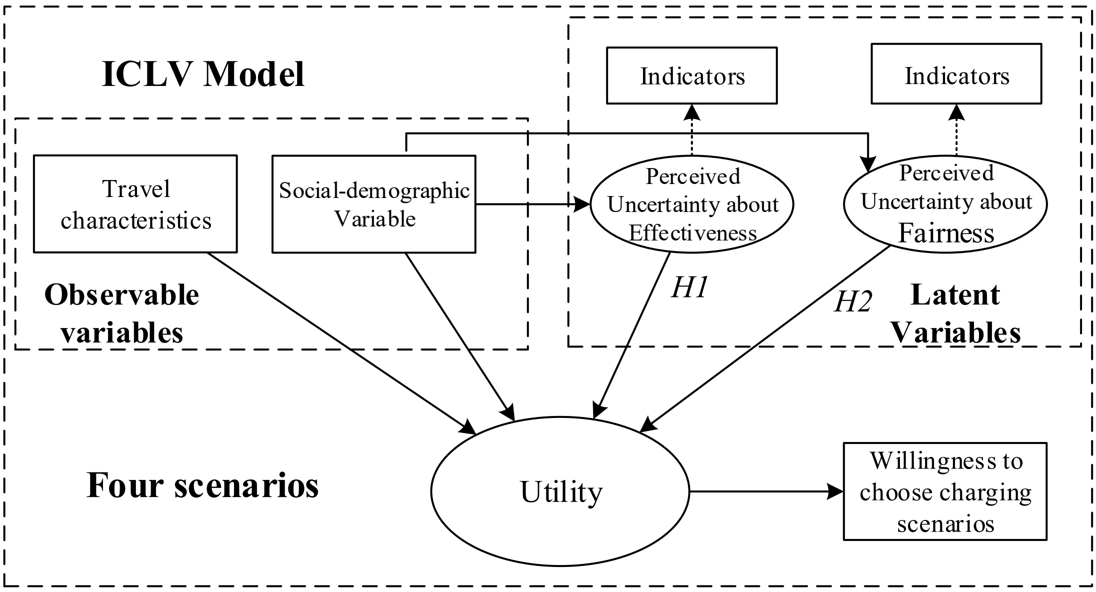

Figure 1. Modeling framework for the integrated choice and latent variable model (based on the general framework in Reference [45].

2.3.1. Perceived Uncertainty about Effectiveness

In terms of uncertainty about the effectiveness of congestion charging, Hensher and Li [2] believe that the public's objection to a new congesting pricing policy mainly has do with uncertainty as to whether the charges can achieve the goal of alleviating congestion. Especially when a charging policy is formally implemented without a trial operation, people will doubt the effectiveness of the charging policy [46]. Jones [34] also believes that public opposition to congestion pricing policies is mainly due to uncertainty about their effectiveness. Borger and Proost [47] found that the public's uncertainty about the cost of traveling after the collection of congestion charges is a major reason for the low support rate for congestion charges. Zhang and Feng [48] believe public doubts about congestion charging must be dispelled in order to raise public support rate for the policy. Hårsman and Quigley [49] found that if congestion charges can reduce travel time by 10%, the support rate for it will increase by 2%. Kim et al. [50] believes that the reason the general public opposes congestion charging is due to distrust of the government. Verhoef et al. [51] believe that people are worried that the technology of the charging system may not work correctly. People are also worried that once the charging process has been effectively implemented, it will cause secondary congestion; they are also concerned with whether it is necessary to choose toll roads after payment. Thus, we want to test:

Hypothesis 1. *Perceived uncertainty about effectiveness has a negative impact on people's willingness to accept congestion charging.*

2.3.2. Perceived Uncertainty about Fairness

In terms of perceived uncertainty about the fairness of congestion charges, Teubel [52] believes that one of the obstacles to the successful implementation of congestion charging is that most social groups have doubts about the fairness of the charging measures. When Du et al. [53] answered the question of process-oriented fairness in the context of a research organization, he believed that if people have the right to control the process, their perception of fairness will be improved. Since the public pays for congestion charging, the unclear use of the congestion charges will yield an unfair perception. Therefore, whether relevant information on congestion charges is transparent, and whether the public has enough information, have a major influence on public perception of fairness [2]. Borger and Proost [47] believe that the public's uncertainty about the use of congestion pricing is one of the important reasons for the low support rate before the implementation of the policy. Thus, we want to test:

Hypothesis 2. *Perceived uncertainty about fairness has a negative impact on people's willingness to accept congestion charging.*

3. Methodology

3.1. Experiment Design

3.1.1. Attributes and Level Design

Based on the literature, the three attributes that have the greatest impact on public acceptance are selected: Charging method, charging price, and revenue allocation. Then, different factor levels are determined to set concrete scenarios for the Stated Preference (SP) survey. Different charging methods and charging prices are combined to create different scenarios.

- The charging method attributes are mainly designed on two different levels, time-based charging, and intercepted charging. Time-based charging refers to collecting different fees for all road sections according to peak and non-peak periods of congestion. 7:00 to 9:00 and 17:00 to 19:00 are peak hours of congestion [54]. Intercepting charging here means that congestion charging is charged at the same price every day for a defined congested area. We set Beijing's Third Ring Area as a charging area. For time-based charging, commuters who enter this area from 7:00 to 9:00 and 17:00 to 19:00 will be charged a peak-period charge, and they will be charged at a non-peak rate at all other times. For intercepted charging, at any time of the day, commuters will be charged if they enter the Third Ring Road area.
- The charging price attribute is set according to foreign experience, the amount of daily congestion charges collected accounts for about 5%–10% of the local residents' income [55]. In 2016, the per capita disposable income in Beijing was 52,530 yuan (1 US dollar = 6.4379 yuan), and the amount of congestion charge in Beijing was between 7.19 and 14.39 yuan. According to the aforementioned charging methods, four different price levels are set at different peak and non-peak periods of congestion. The interception charging method is used to study the public's willingness to choose different levels of price.

- At present, there is no uniform standard for the use of congestion charges. Typical examples include the three-point principle proposed by Small [23]. This article mainly refers to the distribution principle, while considering fairness in terms of the use of the revenue and the requirements of external costs, and finally determines the uses of the four types of congestion charging: (1) To subsidize government financial expenditures, (2) to improve construction of facilities such as road safety and road conditions, (3) to improve construction of public transportation facilities, and (4) to subsidize or reduce taxes on the use of vehicles.

In summary, the three attributes of the stated preference experiment design and the different attribute levels are given in Table 2.

Table 2. Experimental attributes and level settings.

Attributes	Levels
Charging methods	Time-based charging; Intercepting charging
Charging price	(1) Time-based charging, Peak period/Non-peak period: 10 yuan/5 yuan; 12 yuan/6 yuan; 14 yuan/7 yuan; 16 yuan/8 yuan; (2) Intercepting charging: 7 yuan/9 yuan/11 yuan/13 yuan
Revenue allocation	(1) to subsidize government financial expenditure, (2) to construct facilities, including ensuring improved road safety and road conditions, (3) to improve construction of public transportation facilities, (4) to reduce taxes on the use of vehicles.

3.1.2. Scenario Design

This paper uses a stated preference experiment for three attributes that will affect public acceptance: Charging method, charging price, and revenue allocation. Each of the charging methods considers four different price levels. The charging price level is bound up with the concrete utilization of congestion charges. When setting congestion pricing level, we took 5% to 10% of Beijing's per capita daily income as the reference for congestion pricing. On this basis, four price levels are set up from low to high. Each price level corresponds to a different usage of congestion charges. The higher the charge price is, the more charges received, so more revenue can be allocated for different purposes.

This paper focuses on the public acceptability of congestion pricing schemes, so we considered each of the four scenarios as price-labeled packages. Respondents compared four different scenarios and selected their most acceptable scenarios. Our concern is whether commuters accept the congestion charge policy and how perceived uncertainty influences their acceptance of it. Therefore, in the model estimation stage, we did not deal with the level of factors, rather we regarded the decision-making situation as a whole.

Four scenarios can be obtained: Scenario A, scenario B, scenario C, and scenario D (showed in Table 3). In the questionnaires, the scenario settings are described based on the assumption that Beijing's Third Ring Area is the charging zone. Therefore, the following description is in the questionnaire to help respondents enter the scenarios: Image that Beijing's Third Ring Area is the charging zone. In the following scenarios, two different ways of charging are adapted separately, one is time-based charge where the congestions fee is charged according to the time you enter the charging zone; another one is the intercepting charging. In intercepting charging, when you enter the charging zone, a fixed amount of congestion fee will be charged.

Table 3. Design of SP investigation scheme for congestion charging.

Scenario A	A1 Charging method: Charging by time period Charging price: High peak period is 10 yuan, and low peak period is 5 yuan Revenue allocation: To subsidize government spending	A2 Charging method: Intercepting charging Charging price: 7 yuan for entering the charging area Revenue allocation: To subsidize government spending
Scenario B	B1 Charging method: Charging by time period Charging price: High peak period is 12 yuan, and low peak period is 6 yuan Revenue allocation: To improve road safety, road conditions, and other construction	B2 Charging method: Intercepting charging Charging price: 9 yuan for entering the charging area Revenue allocation: To improve road safety, road conditions, and other construction
Scenario C	C1 Charging method: Charging by time period Charging price: High peak period is 14 yuan, and low peak period is 7 yuan Revenue allocation: 1. To improve road safety, road conditions, and other construction 2. To improve public transportation facilities	C2 Charging method: Intercepting charging Charging price: 11 yuan for entering the charging area Revenue allocation: 1. To improve road safety, road conditions, and other construction 2. To improve public transportation facilities
Scenario D	D1 Charging method: Charging by time period Charging price: High peak period is 16 yuan, and low peak period is 8 yuan Revenue allocation: 1. To improve road safety, road conditions, and other construction 2. To improve public transportation facilities 3. To subsidize or reduce the use of vehicle-related taxes	D2 Charging method: Intercepting charging Charging price: 13 yuan for entering the charging area Revenue allocation: 1. To improve road safety, road conditions, and other construction 2. To improve public transportation facilities 3. To subsidize or reduce the use of vehicle-related taxes

3.2. Model Construction

The traditional model of public response to congestion charging is based on the alternatives of direct observation attributes (mainly time and cost) (selection set) and observed public characteristics, while the intrinsic reason for individual preference formation and certain latent variables, which cannot be directly observed in the process, have been regarded as the "black box" in traditional discrete analysis and cannot be fully explained.

Behavioral science researchers believe that the cognitive activities of the "black box" (such as a traveler's own attitudes, perceptions, values, lifestyle, etc.), can have a very important influence on choice behavior, but the traditional discrete model cannot be used to analyze the influence of latent variables such as perception and attitude on behavioral response [41]. To this end, some scholars attempt to put the psychological factors in the "black box" into the model, so as to improve the explanatory power of the model. Ben-Akiva et al. [45] combined the discrete choice model and the structural equation model and put forward the ICLV model.

In this paper, an ICLV hybrid choice model, which combines latent variables with discrete choice models, is used to study the influence of some directly observed attribute variables and unobserved latent variables on public acceptance of congestion charging. Specifically, in the discrete choice model, the MNL model is used to set the observable variable X_i (individual features, travel characteristic) and the latent variable (the perceived uncertainty of congestion charging validity X_1^* and the perceived uncertainty of congestion charging fairness X_2^*). According to the principle of maximizing utility, the utility function U is used to estimate people's choice. The ICLV model consists of two structural models and two measurement models (Figure 2).

(1) Structural Model

In the structural equation model of the latent variable, the structural model is used to describe the influence of the public's individual characteristics on the two latent variables of perceived uncertainty.

Then, the influence of the public's individual characteristics X_i(i = 1, 2 ... 5) on the perceived uncertainty of the effectiveness of congestion charging X_1^* can be expressed as:

$$X_1^* = \gamma_{X_1,1}X_1 + \gamma_{X_2,1}X_2 + \gamma_{X_3,1}X_3 + \gamma_{X_4,1}X_4 + \gamma_{X_5,1}X_5 + \eta_1 \quad (1)$$

The influence of the public's individual characteristics X_i (i = 1, 2 ... 5) on the perceived uncertainty of congestion charging fairness X_2^* can be expressed as:

$$X_2^* = \gamma_{X_1,2}X_1 + \gamma_{X_2,2}X_2 + \gamma_{X_3,2}X_3 + \gamma_{X_4,2}X_4 + \gamma_{X_5,2}X_5 + \eta_2 \quad (2)$$

If the utility of public choice not to accept congestion charging is $U_{non-acceptability} = 0$, the relative utility function of situation A, situation B, situation C, and situation D is chosen as follows:

$$\begin{aligned} U_i = \beta_{i,0,1} + \beta_{i,X_1,1}X_1 + \beta_{i,X_2,1}X_2 + \beta_{i,X_3,1}X_3 + \beta_{i,X_4,1}X_4 + \beta_{i,X_5,1}X_5 \\ +\beta_{i,X_6,1}X_6 + \beta_{i,X_7,1}X_7 + \beta_{i_8,1}X_8 + \beta_{i,X_9,1}X_9 + \beta_{i,X_{10},1}X_{10} \\ +\beta_{i,X_1^*,2}X_1^* + \beta_{i,X_2^*,2}X_2^* + \varepsilon_i \end{aligned} \quad (3)$$

where i = 1, 2, 3, 4 represent situations A, B, C, D, respectively; $\beta_1, \beta_2, \gamma_1, \gamma_2$ are the estimated parameters; η_1, η_2 are random errors, which obey standard normal distribution; and $\varepsilon_A, \varepsilon_B, \varepsilon_C, \varepsilon_D$ are the utility function error item, which assumes the extreme distribution of Class I.

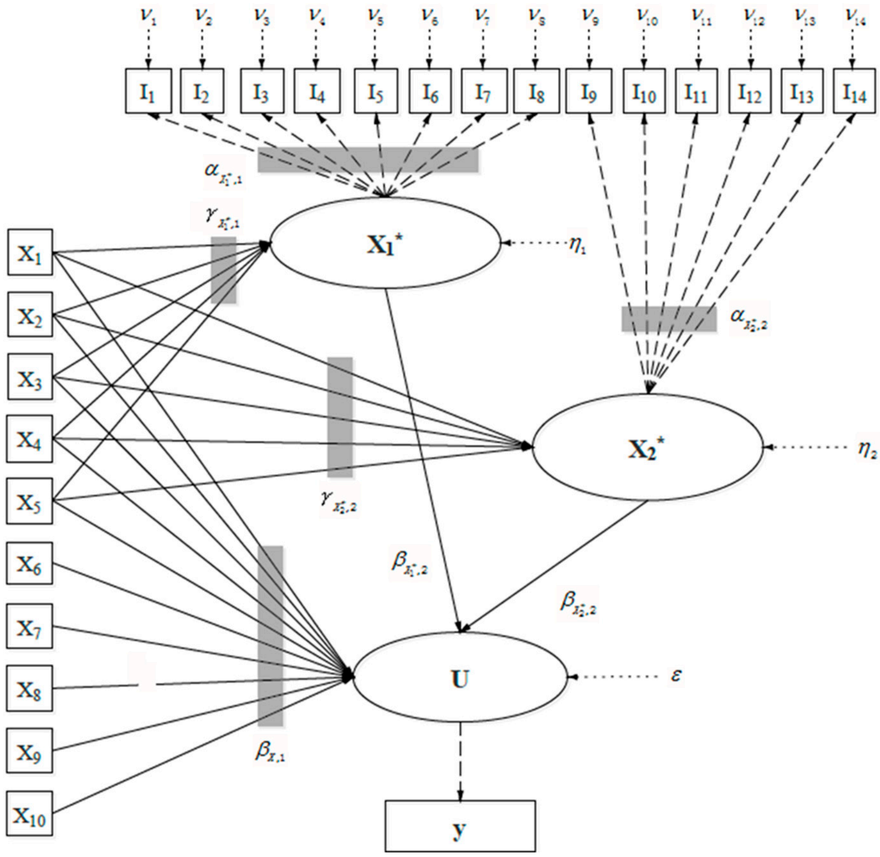

Figure 2. Willingness of public to accept congestion charging of ICLV model [45].

(2) Measurement Model

The measurement equation between X_1^* and X_2^* and the indicators I can be expressed as:

$$I_j = \alpha_{X_1^*,j,1}X_1^* + \nu_j(i = 1, 2, \ldots, 14) \quad (4)$$

The measurement equation of the selected item y can be expressed as:

$$y = \begin{cases} 1 & \text{acceptable} \\ 0 & \text{non–acceptable} \end{cases}$$

In addition, $\alpha_{X_2^*,1}, \alpha_{X_2^*,2}$ are the parameters to be estimated; $\nu_i (i = 1, 2, \cdots, 14)$ is the random error of the measurement equation, obeying the standard normal distribution.

When estimating the parameters in the model, the maximum likelihood estimation method is adopted, and the likelihood function can be expressed as [57]:

$$P(y, I|\bullet) = \int_{X^*} P(y|X, X^*; \beta) \bullet f_I(I|X^*, \alpha) \bullet f_{X^*}(X^*|X; \gamma) \quad (5)$$

where $f_{X^*}(X^*|X;\gamma)$ is the probability density function of the indicators for the latent variables. $P(y|X, I; \beta)$ is the choice probability conditional on both observable and latent explanatory variables. $f_I(I|X^*, \alpha)$ is the measurement equation where unobservable latent variables X^* are operationalized by a set of indicators I by means of a linear factor model. Since the parameters of the model are relatively complex, the available methods are sequential and simultaneous estimation methods [45]. Sequential approach to include latent variables in a discrete choice model is to perform a sequential estimation procedure that involves, in the first step, the estimation of the latent variable part and the computation of the factor scores. In the second step, the choice model is estimated by using the factor scores obtained to replace the latent variables as additional exogenous variables. The estimation of the latent variables can be solved by SEM (AMOS and other software), and the discrete choice model can be solved using NLogit or Stata software. However, this method does not allow the correlation between latent variables, which cannot guarantee an unbiased parameter estimation, and it will underestimate the standard error [45,56]. In order to reduce the error of parameter estimation, this paper chooses the simultaneous method to estimate the parameters in the model [57]. The model presented in this paper was estimated by using the SEM software package Mplus. For the joint estimation of the choice and latent variable model, the MLR estimator, and for integration, the Monte Carlo simulation was used.

3.3. Data Collection

To test the acceptability of congestion charging in Beijing, questionnaires were sent out in the Beijing Area, where the residents will be influenced by the policy. Before the formal investigation, a field study and an on-line pre-test platform, in the form of questionnaires, were conducted. 66 respondents were invited to carry out the scale test, and based on their estimated time to complete the questionnaire and their validation test, a preliminary screening mechanism was devised to delete invalid questionnaires. In order to ensure the validity of the data, the time for answering and the area in which the subjects resided were restricted. According to the pre-test, where the respondents took 4–8 min to finish the questionnaires, we broaden the threshold and set our filtering schema as 2–10 min. If the answering time was too short, the respondents may not read the topic carefully; or rather, if it was too long, respondents may have made too many modifications to the answers, leads to biased or complicated results. Therefore, only questionnaires finished more than 2 min less than 10 min are considered, and all the respondents come from Beijing in the screening process. The questionnaires were sent mainly through the internet platform (Wechat, QQ) and e-mail to random inhabitants of the Beijing municipality (people living in the city) with the help of Weibo public, a firm promotes internet, consulting, transportation, finance, and other types of companies, in order to ensure that the test population was as wide as possible. In addition, according to the results from the pre-test, the formal test set the shortest answer time as 40 s to ensure the validity of the data collected. Validation tests were also included to further screen invalid questionnaires. Finally, a total of 936 questionnaires were received, and 87 questionnaires were removed from the valid set. Therefore, 849 questionnaires were usable.

The distribution of valid sampled commuters (849 individuals) is presented in Table 4. Generally, there are more male (51.00%), young (51.59% under 30 years old), and highly-educated (more than 85% with a bachelor's degree) commuters. The relative high level of education is because the job threshold is higher in the Beijing urban district, which is one of the most developed areas in Northern China. Among all the respondents, almost 20% are students who may be less affected by congestion charging. Additionally, around 20% are freelancers or self-employed travelers who may have more flexible work schedules and can choose to avoid the congestion-charging period. Most of the respondents' families have a traditional Chinese family structure, with about three family members. They may experience congestion when parents go to work and children go to school. Of respondents, 46.41% have at least one private car. Congestion pricing will have a direct impact on the travel costs of these people.

Table 4. Demographic characteristics of questionnaires.

Socio-Demographic Attributes		No.	Pct. (%)
Gender	Male	433	51.00%
	Female	416	49.00%
Age (years)	Under 18	13	1.53%
	19–30	425	50.06%
	31–45	235	27.68%
	46–55	127	14.96%
	Over 55	49	5.77%
Education level	High school and under	125	14.72%
	Bachelor's degree	456	53.71%
	Master's degree and above	268	31.57%
Annual income	Less than ¥30,000	234	27.56%
	¥30,000–¥80,000	262	30.86%
	¥80,000–¥200,000	257	30.27%
	More than ¥200,000	96	11.31%
Job	Student	173	20.38%
	Private enterprise/self-employed/Freelancer	151	17.79%
	Enterprise and institution workers	314	36.98%
	Enterprise and institution managers	124	14.61%
	National civil servants	68	8.01%
	Retirement Employment	19	2.24%
Family members	1–2 members	97	11.43%
	3–4 members	558	65.72%
	5 or more members	194	22.85%
Private car	Yes	394	46.41%
	No	455	53.59%

3.4. Measurement

At present, in the study of the public acceptability of congestion charging, many studies have analyzed the influence of various observable variables such as individual characteristics and system characteristics of congestion charging mechanisms on their willingness to accept. However, these studies discussed little about the effect of public perceptions of uncertainty about the effectiveness and fairness of congestion pricing. According to the theory of loss aversion, people tend not to accept services or policies with which they are not familiar [57]. The public's perception of congestion charges will directly affect their willingness to accept congestion charges. According to the literature review, the perception of congestion charges is mainly determined by two aspects, effectiveness and fairness. This paper classifies the perceived uncertainty of congestion pricing by the public into two categories, uncertainty about the effectiveness of congestion pricing and uncertainty about the fairness of congestion charging. The indicators are showed in Table 5.

Table 5. Latent variables and indicators.

Latent Variables	Indicators	Source
Perceived uncertainty about effectiveness (X_1^*)	I_1 Uncertainty about whether a congestion charge policy can effectively relieve congestion	Hensher and Li [2]
	I_2 Uncertainty about whether congestion charges can effectively save travel time	Hårsman and Quigley [49]
	I_3 Uncertainty about the effect without a trial operation	Samuelson and Zeckhauser [46]
	I_4 Uncertainty about whether charging equipment is accurate	Verhoef et al. [51]
	I_5 Uncertainty about whether there will be a timely and effective response to the problem after implementation	Verhoef et al. [51]
	I_6 Uncertainty about whether relevant departments can effectively implement congestion charging	Kim et al. [50]
	I_7 Uncertainty about whether to choose alternative routes or travel modes	Verhoef et al. [51]
	I_8 Uncertainty about travel cost	Borger and Proost [47]
Perceived uncertainty about fairness (X_2^*)	I_9 Uncertainty about whether the procedure for setting the congestion rates is fair	Hensher and Li [2]
	I_{10} Uncertainty about whether the charging process is fair	Gaunt et al. [58]
	I_{11} Uncertainty about whether the use of congestion charges is fair	Gaunt et al. [58]
	I_{12} Uncertainty about whether congestion charges can be practically used in urban traffic construction	Jones [34]
	I_{13} Uncertainty about whether congestion charges are fair to different income groups	Jonas [59]
	I_{14} Uncertainty about whether the charges for different vehicle types (corporate cars and private cars) are fair	Borger and Proost [47]

4. Results

4.1. Result of Latent Variable Model

The estimation of the parameters of the latent variable is shown in Table 6, which are the standardized model results.

First, the perceived uncertainty of congestion charging validity (X_1^*) constitutes eight indicators, from which it can be seen that the biggest indicator of perceived uncertainty about congestion charging effectiveness is a concern about the effect of congestion charging on alleviating congestion (I_1). Then, the implementation efficiency (I_6) of the government is also uncertain, and the least-perceived uncertainty is whether there will be a timely and effective response system to the problem after implementation (I_5).

Second, the perceived uncertainty of congestion charging fairness (X_2^*) constitutes six basic indicators, where the coefficient value of whether the collection and revenue allocation are transparent is most significant (I_{10} and I_{11}), indicating that the public's perceived uncertainty about whether the congestion charging is transparent will have the maximum impact on the public's perceived uncertainty. Indicator I_{12}, the uncertainty of whether congestion charging can be effectively used in urban traffic construction, such as improving road conditions, developing public transport, and so on, is also significant. People worry that the revenue will be used in ways that will not benefit the payers. Transfer payment is a common means of public finance, however, in the context of congestion charging, if the payment is used for other items, instead of road construction and public transportation, people will be more reluctant to accept the policy.

In order to further explore the influence of latent variables of perceived uncertainty on the willingness to accept congestion charging, this study conducted a maximum likelihood estimation of the structural model in the ICLV model to analyze the influence of individual characteristics (showed in Table 7). It can be seen from the results that gender, age, and education level have a significant effect on the perceived uncertainty about the effectiveness and fairness of congestion charging, and the women's perceived uncertainty about the effectiveness of congestion charging is more obvious than that of men. The level of education positively affects perceived uncertainty in terms of willingness to accept, people with a higher level of education are more concerned about effectiveness. Annual income and occupational factors have no obvious effect on the public's perceived uncertainty, but the annual income factor has a negative effect on the perceived uncertainty of congestion charging fairness. The lower the annual income, the greater the perception of fairness. A possible explanation is that when annual income increases, a travelers' value of time also increases; therefore, they consider it to be fair to pay a certain congestion fee to avoid congestions.

Table 6. Parameter estimates for the measurement model.

Indicators	Perceived Uncertainty about the Effectiveness (X_1^*)		Perceived Uncertainty about Fairness (X_2^*)	
	Loading	T Value	Loading	T Value
I_1 Uncertainty about whether a congestion charge policy can effectively relieve congestion	0.835 ***	48.847		
I_2 Uncertainty about whether congestion charges can effectively save travel time	0.615 ***	17.749		
I_3 Uncertainty about the effect without a trial operation	0.745 ***	31.796		
I_4 Uncertainty about whether charging equipment is accurate	0.695 ***	28.153		
I_5 Uncertainty about whether there will be a timely and effective response to the problem after implementation	0.579 ***	16.208		
I_6 Uncertainty about whether relevant departments can effectively implement congestion charging	0.770 ***	34.703		
I_7 Uncertainty about whether to choose alternative routes or travel modes	0.738 ***	28.915		
I_8 Uncertainty about travel cost	0.707 ***	26.093		
I_9 Uncertainty about whether the procedure for setting the congestion rate is fair			0.816 ***	38.605
I_{10} Uncertainty about whether the charging process is fair			0.858 ***	53.927
I_{11} Uncertainty about whether the use of congestion charges is fair			0.871 ***	55.275
I_{12} Uncertainty about whether congestion charges can be practically used in urban traffic construction			0.541 ***	3.551
I_{13} Uncertainty about whether congestion charges are fair to different income groups			0.748 ***	27.164
I_{14} Uncertainty about whether the charges for different vehicle types (corporate cars and private cars) are fair			0.799 ***	32.966
McFadden's R^2	0.035		0.046	

Number of samples: 894. Note: *** represents $p < 0.01$.

Table 7. Parameter estimates for the structural model.

Explanatory Variables	Perceived Uncertainty about the Effectiveness (X_1^*)		Perceived Uncertainty about Fairness (X_2^*)	
	Coefficient	*p* Value	Coefficient	*p* Value
Gender (X1)	0.073 *	0.078	0.099 ***	0.006
Age (X2)	0.161 **	0.030	0.052 **	0.026
Education level (X3)	−0.034 *	0.052	0.084 **	0.029
Annual income (X4)	−0.023	0.187	−0.044 *	0.081
Occupation (X5)	−0.045	0.256	−0.035	0.380

Number of samples: 894. Note: *** represents $p < 0.01$, ** represents $p < 0.05$, * represents $p < 0.1$.

4.2. Result of Choice Model

From the traditional Multinominal Logit Model (MNL) model and the ICLV hybrid choice model, it can be seen that the parameters of the individual characteristic variables and travel characteristic variables are similar. In individual characteristics, gender and age are still the main factors that influence the public's willingness to accept congestion charging; the influence of education level and occupation on the willingness of the public to accept low price congestion charging measures is significant. In travel characteristics, the impact of travel mode is significant, indicating that the motorist group is more likely to refuse the high price level congestion charging. At the same time, due to the addition of perceived uncertainty, the ICLV model can better reflect people's internal mental processes in terms of whether to accept congestion charges.

The results are showed in Table 8. As we hypothesized above, individuals' perceived uncertainty offers a significant explanation of their willingness to accept congestion charges. More specifically, individuals with higher perceived uncertainty about the effectiveness and fairness of public congestion charging are less likely to accept congestion charges. These results support H_1 and H_2. Comparing the two latent variables, which are the perceived uncertainty about public congestion charging effectiveness and perceived uncertainty about fairness, the influence coefficient of these two latent variables on public acceptability can be found. The public's perception of the fairness of congestion charging has a greater effect on their willingness to accept the four scenarios. This shows that people are more concerned about whether the use of congestion charges is fair and reasonable.

Table 8. Parameter estimation results of traditional MNL model and ICLV model.

Variable	Situation A		Situation B		Situation C		Situation D	
	MNL	ICLV	MNL	ICLV	MNL	ICLV	MNL	ICLV
Gender X_1	−0.954 ***	0.848 **	−0.821 **	−0.703 **	−0.472 *	−0.327 *	−0.776 **	−0.647 *
Age X_2	−0.398 **	−0.489 ***	−0.694 ***	−0.803 ***	−0.207	−0.355 **	−0.554 ***	−0.670 ***
Education level X_3	−0.532 **	−0.610 *	−0.227	−0.410	−0.078	−0.311	−0.026	−0.222
Annual income X_4	0.068	0.077	0.085	0.100	0.098	0.022	0.078	0.087
Occupation X_5	−0.229 **	−0.290	−0.220 *	−0.193	−0.239 *	−0.214	−0.169	−0.134
Travel distance X_6	−0.183	−0.036	−0.107	−0.340	0.532	0.320	−0.042	−0.294
Travel time X_7	−0.201	−0.200	−0.289	−0.296	−0.285	−0.307	−0.337 *	−0.543 *
Travel frequency X_8	−0.295 *	−0.430 *	−0.275	−0.375	−0.248 *	−0.397 *	0.097	−0.054
Delay time X_9	−0.033	−0.038	0.112	0.061	0.098	0.036	0.116	0.107
Travel mode X_{10}	0.143	0.160	0.271 *	0.247 *	0.245 **	0.265 **	0.294 **	0.273 **
Perceived uncertainty of congestion charging effectiveness X_1^*		−0.326 *		−0.594 *		−0.838 **		−0.616 **
Perceived uncertainty of congestion charging fairness X_2^*		−0.711 **		−1.098 ***		−1.167 ***		−1.045 ***

Number of samples: 894. Note: *** represents $p < 0.01$, ** represents $p < 0.05$, * represents $p < 0.1$.

According to Table 9, the R^2 value of the choice model is slightly larger than that of the MNL model, indicating that the explanatory power of the ICLV model is better than the traditional MNL model. At the same time, the AIC value and BIC value of the choice model are smaller than that of the traditional MNL model. Therefore, it can be concluded that the ICLV hybrid model with latent variables is better and has stronger explanatory power [45].

Table 9. Fitting degree index of MNL model and ICLV.

Fitting Degree Index	MNL Model	ICLV Model
R^2	0.315	0.335
AIC	462.9	457.6
BIC	519.8	511.9

5. Discussion and Implications

5.1. Discussion of Results

Based on the MNL and ICLV models, this paper analyzes how social demographic, commuting attributes, and perceived uncertainty influence the public acceptability of congestion charging.

In individual characteristics, gender and age have significant negative effects on public acceptability. Compared with women, men prefer not to accept the congestion charging. The older they are, the more they oppose the policy, and they are also more sensitive to the high price level of the charging schema.

A possible explanation is, in the context of China, still, that men are more interested in national or social policy measures, while women tend to care less about this aspect. This result may be different in another metropolitan area with different culture background. In addition, male drivers account for a relatively high proportion of all drivers in China (seven males to three females, according to the National Bureau of Statistics in 2017), so intuitively men are more sensitive to congestion charging. This is similar to the conclusion of Chen and Sun [17], but the conclusions are not consistent with the results of Jaensirisak et al. [19]; this may be due to the culture differences in Chinese and Western countries. With respect to commuting attributes, the influence of travel mode on public acceptability is significant, and the groups choosing public transport (bus/rail transit) or bicycle/electric car/motorcycle are more willing to accept the high price congestion charging, while the private car travel group has a lower level of acceptance. This is natural since the private car travel group is directly affected by congestion charging. As a result, the group is more resistant to a congestion charging policy.

Based on the parameter estimation of the ICLV model, the public's perceived uncertainty of fairness is more significant than perceived uncertainty of effectiveness. The greater the public's perceived uncertainty, the less they will accept the policy of congestion charging. From the analysis of factors affecting the effectiveness of congestion charging, the influence of gender, age, and education level on the perceived uncertainty of effectiveness is significant. The effect of age is the greatest; older people perceive more uncertainty about effectiveness. Older groups, including retirees, may have less access to information than younger groups. Then, according to the results of the measurement model, public uncertainty about whether congestion charging can ease traffic congestion influences their uncertainty about effectiveness the most. Hensher and Li [2] argue that the main reason for the public's opposition to congestion charging is the question of whether congestion charging can effectively ease traffic congestion. In addition, the results of the study also show that the public is concerned that even if congestion charging does ease congestion, they do not know whether the government can effectively implement congestion charging, which is closely related to the executive power of the government.

From the analysis of the factors affecting the effectiveness of congestion charging, the influence of gender, age, education level, and income on the perceived uncertainty of fairness is significant. Among them, gender is the most influential factor. Male perception of the fairness of congestion pricing is more uncertain than female perception, which can be confirmed from the fact that men are more sensitive to congestion pricing. Low-income groups have more doubts about the fairness of congestion pricing, mainly because they believe that if congestion pricing is implemented, it will greatly increase their travel costs. From the results of the measurement model, the public's uncertainty about whether the use of congestion fees is transparent is the most important. The use of congestion fees has a great impact on the public's willingness to accept a congestion charging policy. If the charge from the policy is used within the transportation system, such as reducing taxes and fees associated with vehicle use, or improving public transportation, it is more acceptable. If the charging policy is used in areas other than transportation, such as general public funding, it is less acceptable. The reason for this is that the payer directly benefits from the charging policy.

5.2. Implications

According to the empirical analysis results of this paper, it can be concluded that the perceived uncertainty of congestion charging significantly affects willingness to accept congestion charges. As congestion charging has not been implemented in China, the public does not yet have a deep understanding of the implementation methods and purposes of congestion charging. The effectiveness and fairness of charges easily become the focus of public skepticism. Therefore, in order to reduce the public's perceived uncertainty about congestion charges, launching relevant policy publicity is an important measure for increasing the acceptability of the charging policy and ensuring its smooth implementation.

5.2.1. Social Characteristics

Men are more resistant to congestion pricing policies. At the same time, men's perceived uncertainty about the effectiveness and fairness of congestion charges is greater than that of the women. Therefore, government departments should focus on communicating and promoting congestion-charging related information to male travelers.

The higher priced policies have a significant negative effect on the acceptability of congestion charging. On the other hand, the groups that use public transport and bicycle/motorcycle travel are more inclined to accept the high-price policy because congestion charges will not affect them very much. It is natural that the private car travel group is more sensitive to the high price level of congestion charging; therefore, getting more support from the public transportation group (people who travel using public transportation or by bicycle/motorcycle) is an important and efficient strategy for increasing the overall acceptability of congestion charges in the initial stage of the policy. Meanwhile, the private car group is the most affected group. Therefore, it is also necessary to strengthen the marketing directed toward drivers and prove the effectiveness of congestion charging. Publicity methods for this could include car radios that stresses the time efficiency and convenience, in terms of reducing traffic congestion, of conducting congestion charging.

Finally, from the perspective of individual characteristics, marketing to older groups should be stressed. Publicity methods for this include newspapers, social media such as WeChat or Weibo (Facebook in China), and Internet sites that are free to access. It should be noted that the government should be in a dominant position in the research and promotion of congestion charging so that the public can feel the government's execution and determination to implement the policy.

5.2.2. The Perceived Uncertainty of the Effectiveness of Congestion Charging

The public's perceived uncertainty about the effectiveness of congestion pricing will significantly affect its acceptability. Therefore, the publicity should focus on the effectiveness of congestion pricing measures and publicize it to reduce the perceived uncertainty of effectiveness.

First of all, the relevant government departments should organize experts to analyze the feasibility of congestion charging and educate the public about the principles of congestion charging. The public should be informed of the achievements of the feasibility study and about successful experiences in other countries, thereby reducing the public's uncertainty and doubts about the effectiveness of congestion pricing.

Second, before the official implementation, it is necessary to conduct small-scale pilots in appropriate areas. The purpose of this is to make the public feel that the government has completed detailed and comprehensive preparations for the implementation of this strategy. This can show that preparations have gone beyond the theoretical research stage, and the results can be publicized. The effectiveness of the pilot areas can be demonstrated, and the people in the pilot areas can be interviewed to understand their true feelings about the implementation of strategies, such as the effects of congestion charging, advantages and disadvantages, etc. The empathy effect will reduce public uncertainty, especially when information is received from similar groups. Therefore, pilot studies are conducive to improving the acceptability of congestion charging. In addition, the features of the congestion charging mechanism should be as simple as possible and easy for the public to understand.

5.2.3. Perceived Uncertainty of the Fairness of Congestion Charges

From the results of this study, the public perceived uncertainty about the fairness of congestion charging has a greater impact on their willingness to accept it. The more a congestion pricing policy can show fairness, the less the public's perceived uncertainty will be, and the higher public willingness to accept it.

First of all, the use of congestion charges must be transparent and open to public. The reason the public does not support congestion pricing policies is that they are uncertain about how congestion charges will be used. Therefore, whether in China's own situation or drawing on foreign experience, congestion charging must ensure the openness and transparency of revenue usage. When the public clearly knows the distribution and the use of the charges, it will help to increase public awareness of charging policies and confidence in the government. Through various means, the public right to information on the revenue allocation should be ensured to the utmost extent, and the concept of public participation can also be implemented. Only in this way can public concerns be eliminated. For example, people from all walks of life can be invited to conduct extensive discussions and demonstrations. An opportunity for the public to express their opinions can, through this form, maximize support by the people and reduce the negative impact to a certain extent.

Second, congestion charges must take into account the interests of different groups. Lower-income groups have greater uncertainty about the fairness of congestion charging. As higher-income groups have higher time value, they are more willing to obtain unimpeded trips by paying congestion charging, while the lower-income groups have relatively low time value. They may be unable to bear the increase in travel expense caused by congestion charges. Therefore, low-income groups are more sensitive to whether congestion pricing is fair, so when implementing congestion pricing, low-income groups can be subsidized to reflect the vertical equity of the charging policy for vulnerable groups.

6. Conclusions

In this paper, through an SP experiment, an ICLV hybrid model combining latent variables and discrete choices is constructed to analyze the influence of observable variables and unobserved latent variables on public acceptability.

The empirical findings show that gender and age have a significant negative effect on public acceptability of congestion charging. Compared with women, men are more reluctant to accept congestion charging. Senior citizens are more likely to resist congestion charges, and the higher the price level, the more obvious this effect is. There are differences in the perceived uncertainty for different levels of education, but there is no significant difference in the effect of education on the willingness to accept congestion charges; therefore, the indirect effect of education level on willingness to accept has been estimated by the proposed ICLV model using latent variables of perceived uncertainty. Commuting attributes have a greater impact on the willingness to accept congestion charges. The public transport group is more inclined to choose the high price level, while the private car group has a higher probability of not accepting congestion charges. The public's perceived uncertainty about the effectiveness of congestion pricing and the perceived uncertainty of the fairness of congestion charges have a significantly negative impact on public acceptability of congestion pricing. The higher the level of the charges, the more significant the impact is. Moreover, the public's perceived uncertainty about the fairness of congestion charges has a greater impact on people's willingness to accept it, which also explains why studying different groups' responses and each individual's behaviors are so essential to promoting the acceptability of the policy, which has been extensively studied in this paper.

Scholars have conducted various studies on congestion charging and acceptance by the public. They mainly study the impact of system factors of congestion charging. No scholars have explored public perception of uncertainty about the acceptability of congestion charging. The studies on willingness to accept congestion charges are mostly based on discrete choice models. The traditional discrete choice model can only analyze the effect of observable variables. In this paper, the ICLV model is established to better analyze the impact of observable variables and to explore the inner mental decision process of personal response using latent variable factors of public acceptance. However, the model in this paper only introduces the influence of the latent variables of public perception uncertainty on the willingness to accept congestion charges. Other factors, including psychological latent variables, may also have an impact on public acceptance, so the model can be further modified to better explain the public's willingness to accept congestion charges. Meanwhile, the SP experimental design can be further improved in our next step, e.g., with orthogonal method. In the current version, different prices are bounded with different uses, which could be modified in the future. In the further research, orthogonal experimental design should be used to study how different levels of charging and use of revenue influence public acceptability, based on further literature and focus group analysis.

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