Research paper

Analysis of truckers' intentions in choosing freeways or parallel national and provincial roads

Ning Zhang [a], Yiping Wu [a,*], Jian Rong [b], Juan Shao [a], Jiayuan Chen [a], Chenjing Zhou [b]

[a] *Beijing Key Laboratory of Traffic Engineering, Faculty of Architecture, Civil and Transportation Engineering, Beijing University of Technology, Beijing, China*
[b] *School of Civil Engineering, Guangzhou University, Guangzhou, China*

ARTICLE INFO

ABSTRACT

The traffic volumes of trucks on freeways and parallel national and provincial roads significantly vary; moreover, the utilization rate of freeways is markedly low at times. Implementing effective traffic volume guidance to change the travel route choice intentions of truckers is a critical approach to improving the utilization rate of freeways. Travel route choice intentions are influenced by numerous factors, such as personal and travel characteristics. In this study, based on structural equation modeling (SEM), 186 truckers on freeways and 522 truckers on parallel national and provincial roads were collected using structural equation modeling (SEM) based on a questionnaire survey in Guangxi, China. Relationship models of the influencing factors of travel route choice intentions for truckers on freeways and on their parallel roads are constructed separately by SEM to explore the direct and indirect effects of the personal characteristics, travel characteristics, economic factors, and travel choice habits of truckers on travel route choice intentions. The model results for truckers on freeways indicate that only travel characteristics significantly affected travel route choice intentions, and this effect was negative. For truckers on parallel national and provincial roads, travel characteristics exerted the most significant positive effect on travel route choice intention; by contrast, travel route choice intention was most negatively affected by economic factors. The results for the two models reveal that personal characteristics, and travel choice habits exert no significant effects on the travel route choice intentions of truckers on freeways and parallel roads. In addition, the results of the mediation analysis demonstrate that personal characteristics have a significant indirect effect on travel choice habits mediated by travel characteristics. Based on the study findings, several recommendations can be suggested as guidelines to facilitate the shifting of the traffic volume of trucks.

1. Introduction

Beijing Transport Institute (2021) and Shanghai Urban and Rural Construction and Transportation Development Research Institute (2022) have reported that road freight volume in Beijing and Shanghai, two of the largest and most representative cities in China, increased steadily between 2015 and 2019. The rise in road freight volumes and the policy of prohibiting trucks from entering the city have led to an increase in the volume of trucks on freeways and on national and provincial roads. Traffic congestion on intercity roads is also rapidly rising (Han et al., 2018). Traffic operational conditions have been shown to be significantly influenced by the increase in truck volume (Cherry & Adelakun, 2012). Meanwhile, the traffic volume of freeways markedly varies from that of parallel national and provincial roads in certain regions. In many cases, the traffic volume on freeways is average or even low, whereas the traffic congestion on parallel national and provincial roads is heavy (Romero et al., 2020). Freeways, being fully closed roads characterized by tolls or inflexible routes for short-distance travel, have low utilization rates at specific times and even during rush hours.

An efficient approach to improving the utilization rate of roads would be to guide traffic volume in road networks (Gruner & Vollrath, 2021). This method involves guiding the travel route choices of truckers. Several studies have indicated that route choice behavior is primarily determined by route choice intentions. According to the theory of planned behavior (TPB), intention directly and significantly affects behavior (Ajzen, 1991; Han et al., 2020; Liu et al., 2017; Zhao & Gao,

2022). Accordingly, the route drivers plan to travel is a subjective probability or possibility that they intend to choose (Hao et al., 2020). Numerous studies have verified that the relationships between antecedent variables and behavior intention are potentially complex (e.g., various direct and indirect effects) (Hao et al., 2020). Zudhy Irawan et al. (2022) determined that exploring the intention of travel choices is the basis not only for understanding travel choice decisions but also for implementing relevant guiding policies before the trip. Therefore, the travel route choices of truckers on freeways and parallel roads are represented by travel route choice intentions in the current study. The influencing factors and relationships among factors for travel route choice intention were extensively analyzed. This study aims to support the development of more effective guiding measures for truckers before they make travel decisions.

Few studies have been conducted on the causal mechanism of travel route choice intention. Some studies using TPB or the mixed logit model have determined that the travel route choice of drivers is affected by personal and travel characteristics (Bamberg et al., 2003; Bamberg & Schmidt, 2003). Meanwhile, the travel route choice intentions of drivers could be correlated with travel choice habits that are commonly described as recent and frequent travel routes chosen by drivers. Frequently repeated behaviors tend to become habituated and automated (Gardner, 2009). Habits manifest in the form of simple alternatives, hampering behavioral change, particularly in commuting (Lizana et al., 2021). Jain and Tiwari (2020) used descriptive analysis with a chi-square test to examine the relationships between income, travel tolls, and other related factors. They showed that the variability in travel choices need to be understood from the perspective of economic factors.

Using mathematical statistics or discrete choice models, the aforementioned studies revealed the direct impact of those influencing factors on travel route choice intentions. Nonetheless, Lanzini and Khan (2017) clarified that the indirect effects of those influencing factors on travel choice intentions should be sufficiently considered. Numerous drivers were not willing to adopt an initiative policy aimed at changing their travel intentions by merely considering the direct effects of factors (Kennedy et al., 2009). For example, with the help of structural equation model (SEM), Bouscasse et al. (2018) found that environmental concern indirectly promoted public transport habits when treating perceptions towards public transport as a mediator. Although Agrawal and Peeta (2021) used the multiple-indicator multifactor model (a variant of SEM) to analyze the causal mechanisms underlying the decision of drivers to choose a freeway or arterial road, it failed to further explore the differences in travel preferences of different driver groups. According to Walker (2001), considering the difference between groups would better explain the selection process, correct cognitive biases, and test the behavioral hypothesis of the decision-making process. Owing to the different road characteristics of freeways and national and provincial roads, certain differences in the travel demand of truckers who choose these two roads may exist. Clarifying these differences would contribute to formulating more effective truck guidance strategies, aimed at improving the utilization rate of freeways.

This study proposes the application of a systematic SEM framework, using the data from the intercity travel route choice survey completed by truckers in Guangxi (China) in 2021. The aims are as follows: (i) to identify the influencing factors for the travel route choice intention of truckers on freeways and their parallel national and provincial roads; (ii) analyze the direct and indirect impact relationships among factors; and (iii) explore the differences in travel preferences of truckers on the two types of roads. First, based on the different characteristics of freeways and national and provincial roads, the structural equation models for truckers on freeways and national and provincial roads are respectively constructed, with the mediating effects considered. Subsequently, the factors significantly affecting the travel route choice intention of the two types of trucker groups are identified, together with the relationships among factors. Second, the direct and indirect impact relationships among factors and travel route choice intention are analyzed based on

the results of the two types of SEM and their mediation models. Third, the differences in factors significantly affecting travel route choice intention and the influencing relationships between the two types of trucker groups are compared and discussed.

The remainder of this paper is organized as follows: Section 2 presents a comprehensive review of the related literature on the current research subject. Section 3 introduces the method and our research hypotheses. Section 4 presents the data used in this study. Section 5 provides our modeling results. Section 6 presents the significant findings. Finally, Section 7 summarizes the key findings, conclusions, and recommendations for future studies.

2. Literature review

2.1. Existing model frameworks

Travel route choice behavior is primarily studied using mathematical statistics and theoretical models. Mathematical statistical techniques, such as analysis-of-variance approaches, can adequately explain the direct effects among factors. Thus, the relationship between variables and intercity travel route choice behavior is typically explored using mathematical statistics based on experimental data (Bachoo et al., 2013; Toledo et al., 2020). Several theoretical models, such as discrete choice models, are also used to conduct more extensive research on travel route choice behavior (e.g., the identification of significant influencing factors and interaction between factors). Among these models, the most representative studies employ discrete choice models, including various logit models, based on perfect rationality (PR) or bounded rationality (BR).

In the study based on PR, various logit models were constructed in accordance with the random utility maximization (RUM) principle (Bekhor & Albert, 2014; Ben-Elia et al., 2013; Gan & Ye, 2014; Khoo & Asitha, 2016; Moghaddam et al., 2019; Romero et al., 2020; Zhang et al., 2012). These studies assumed that travelers had complete knowledge of the advantages and disadvantages of all possible choices and thus selected the one with the highest utility. Ben-Akiva and Lerman (2018) presented a comprehensive structure of the multinomial logit model (MNL) and its application in travel behavior modeling. Nonetheless, several studies have demonstrated that people lacked accurate information or were interfered by complex situations to obtain optimal decisions, causing them to choose an option that was satisfactory but may not be of maximum utility consciously (Simon, 1978). This finding also implies that travelers exhibit bounded rationality. With the emergence of BR theory, various logit models have been developed based on prospect theory (PT), cumulative prospect theory (CPT), or regret theory to analyze travel route choice behavior (Chorus, 2010; Di & Liu, 2016; Jou & Chen, 2013; Mai et al., 2017). Iraganaboina et al. (2021) analyzed the effects of travel characteristics, roadway features, and traffic information, in addition to their interactions, on travel route choice behavior (freeway or intercity arterial). A mixed-MNL model based on random regret minimization-was developed. Machine learning has recently become crucial for travel behavior research because its prediction or classification accuracy is much better than traditional discrete choice models (Hagenauer & Helbich, 2017; Koushik et al., 2020; Liu et al., 2019; Zhou et al., 2019).

Indeed all aforementioned methods can be used to identify and quantify direct effect relationships between variables that can be directly measured and travel route choice behavior, as well as the interaction between the variables; however, they failed to identify the indirect effect relationships or quantify latent psychological and behavioral variables effectively (e.g., travel choice habits) that cannot be directly measured (Goldbach et al., 2019; Song et al., 2021). Travel choice behavior stems from a combination of factors, hence the importance of a comprehensive analysis of the causal mechanism of route choice behavior, as well as the determination of possible indirect effect relationships. SEM has been used to explore various impact relationships

among factors in previous studies (Cheng et al., 2019; Chorus et al., 2007; Javid et al., 2013; Zhao & Gao, 2022). Using SEM, Choocharukul (2008) explained the direct and indirect effects among various factors, such as the likelihood of route diversion, the attitude of the traveler, socioeconomic characteristics, and travel habits. To assess the route choice of exporters Fan et al. (2019) developed a routing model and derived a structural equation for widely accessible customs data. However, the differences between traveler groups were not discussed sufficiently. Exploring these differences among traveler groups not only improves the explanatory power of models but helps develop more effective route guidance strategies for different groups (Alizadeh et al., 2019), improving the utilization rate of freeways.

2.2. Influencing factors for travel route choice intention

Previous studies have shown the travel route choice of a driver was influenced by several interdependent factors. These factors can be classified as travelers' personal characteristics, economic factors, travel characteristics, and travel choice habits. The personal intention and behavior differences in travel route choice may vary with the influencing factors (Bamberg et al., 2003; Bamberg & Schmidt, 2003; Ben-Akiva et al., 1985; Choocharukul, 2008; Gomez et al., 2017; Sun et al., 2013).

2.2.1. Personal characteristics

The personal characteristics of drivers are usually considered as a series of important independent or common variables affecting travel route choice intentions, such as age and gender (Basu et al., 2021). Further studies showed that drivers' experience was also an important variable (Ringhand & Vollrath, 2019). For truckers on freeways and parallel national and provincial roads, personal characteristics may also be an important factor influencing travel route choice intentions. Meanwhile, according to the study by Knorring et al. (2005), drivers would make route choice decisions based on the expected travel time, while they usually highly depended on their experience to estimate travel time. Therefore, the personal characteristics of truckers are considered to indirectly affect travel route choice intentions through travel characteristics. Choocharukul (2008) indicated that drivers always chose familiar routes to save time and ensure traffic safety. This condition reflected that drivers' personal characteristics affected route decisions indirectly because of travel choice habits.

2.2.2. Economic factors

Existing research found that economic factors were one of the most important elements influencing drivers' travel route choice intentions among a variety of relative factors (Burgdorf & Eisenkopf, 2018; May et al., 2010). Travel tolls were the most widely used variable in representing economic factors in previous research (Adurthi et al., 2022; de Souza et al., 2021; Toledo et al., 2020). According to the study of Sun et al. (2013), travel tolls had significant effects on the travel route choice intentions of truckers. With the increase of the freeway tolls, the probability of drivers choosing freeways decreased (whether peak or non-peak hours) (Jou & Yeh, 2013). Therefore, it is predicted that economic factors might significantly influence the travel route choice intentions of truckers when choosing freeway or parallel roads.

2.2.3. Travel choice habits

Previous research showed that it was difficult to break drivers' travel choice habits (He & Thøgersen, 2017). Habits can be explained as repeated behavior, where daily travel is a common example of habitual decisions. Daily travel choices usually become the most attractively alternative without analyzing the attributes of the whole set of choices (Lizana et al., 2021). This phenomenon could be explained by the fact that commuters prefer a familiar route to guarantee punctuality when they are required to arrive on time (Choocharukul, 2008). Thus, travel choice habits may influence travel route choice intentions significantly.

2.2.4. Travel characteristics

Generally, travel characteristics were represented by vehicle types, the total weight of vehicle and cargo, travel distance, travel time, travel purpose, and others. Existing research found that travel distance and cargo types were important variables influencing truckers' travel route choice intentions (Bacero et al., 2022). Travel distance was positively related with travel route choice intentions (Ben-Elia et al., 2008), and the probability of changing routes increased with travel distance. Vehicle types and the total weight of the vehicle and cargo had negative effects on choosing routes with high travel tolls (Adurthi et al., 2022; Cherry & Adelakun, 2012). The probability of choosing routes with higher tolls decreased as the total weight of vehicles increased. Therefore, it is expected that truckers' travel route choice intentions might be influenced by travel characteristics. Moreover, in order to ensure arriving at a destination on time, drivers would choose the route they habitually traveled (Jou et al., 2007). Thus, travel characteristics may have an effect on travel route choice intentions mediated by travel choice habits.

3. Conceptual framework

3.1. Method

The structural equation model (SEM) is a tool that can process many observed variables and specified latent variables by their linear combinations and investigate complex relationships among various endogenous variables and exogenous variables (Lee et al., 2008). SEM consists of multiple measurement models and a structural model. The structural model can explore the complex relationships among latent variables, including direct and indirect impacts, while the measurement model uses specific observed variables to characterize latent variables. Therefore, the SEM is adopted into this study to explore the relationship between travel route choice intention and its influencing factors.

Measurement models are normally specified as two sets of equations, see Equations (1) and (2):

$$X = \wedge_x \xi + \delta \tag{1}$$

$$Y = \wedge_y \eta + \varepsilon \tag{2}$$

where X denotes the vector of observed exogenous variables, Y denotes the vector of observed endogenous variables, $\wedge_x$ denotes the matrix of structural coefficients for latent exogenous variables to their observed indicator variables, and $\wedge_y$ denotes the matrix of structural coefficients for latent endogenous variables to their observed indicator variables. Additionally, ξ and η denote the vector of latent exogenous and endogenous variables, respectively; δ and ε denote the vector of measurement error terms for observed exogenous and endogenous variables, respectively.

A structural model relating the exogenous and endogenous latent variables can be expressed as Equation (3):

$$\eta = B\eta + \Gamma\xi + \zeta \tag{3}$$

where B denotes the matrix of structural coefficients between endogenous latent variables, Γ denotes the matrix of structural coefficients for exogenous latent variables to endogenous latent variables, and ζ denotes the unexplainable part of latent variables involved in the model.

Generally, determining the composition of the measurement model is the premise of constructing the SEM. Exploratory factor analysis (EFA) is commonly used for this purpose, which is a statistical method used to identify the number and nature of the latent variables that lead to data variability (Hassan & Abdel-Aty, 2011). In this work, the input codes of the observed variables in questionnaires were first determined, and EFA was performed in SPSS to reduce the dimension of the observed variables in the questionnaire.

However, we were unable to judge the fitting quality of latent

variables by questionnaire data after EFA was performed. Thus, confirmatory factor analysis (CFA) was carried out to verify whether the observed variables (questionnaire items) expressed the latent variables in the SEM correctly so as to correct the observed variables that were not part of these latent variables (Kiatkawsin & Han, 2017). The measurement model was considered reasonable if the reliability, one-dimensionality, and validity of the model met the requirements. Reliability refers to the confirmation degree between each variable of the model. It can be evaluated by composite reliability (>0.6) and Cronbach's alpha (>0.3). One-dimensionality means that a set of observed variables are associated with a single latent variable. It is satisfactory only if the factor loadings of each observed variable are significant and the respective standardized coefficients are larger than 0.5 (Pojani et al., 2018). Validity includes convergent validity and discriminant validity. Convergent validity requires a significant correlation among different questionnaire items measuring the same latent variable, and it can be evaluated by average variance extraction (AVE) (>0.36). The problem of multicollinearity will appear when the correlation among latent variables in the structural model is strong. Discriminant validity is fulfilled when two latent variables are not strongly correlated with one another (Wijnen et al., 2002).

3.2. Hypotheses

Summarizing the aforementioned analysis, we present two hypothetical frameworks regarding the relationships among factors influencing the travel route choice intentions of truckers on freeways and on parallel national and provincial roads, respectively. The hypothetical framework of truckers on freeways includes personal characteristics, travel characteristics, travel choice habits, and travel route choice intentions. The SEM hypotheses for truckers on freeways are as follows, and the model framework is presented in Fig. 1.

Model hypotheses for truckers on the freeway.

H1. Travel choice habits (TH), personal characteristics (PC) and travel characteristics (TC) significantly affect travel route choice intentions (TCI);

H2. The influence of personal characteristics (PC) on travel route choice intentions (TCI) is indirectly mediated by travel characteristics (TC) and travel choice habits (TH);

H3. The influence of travel characteristics (TC) on travel route choice intentions (TCI) is indirectly mediated by travel choice habits (TH).

However, considering that freeway tolls and parallel national and provincial roads are free of charge, truckers on parallel roads might pay more attention to the influence of economic factors. Therefore, economic factors are also included in the hypothetical framework for truckers on parallel national and provincial roads, in addition to the personal characteristics, travel characteristics, travel choice habits, and travel route choice intentions. Based on the framework of Fig. 1 and the model hypotheses for truckers on the freeway, the hypothesis (H4) that
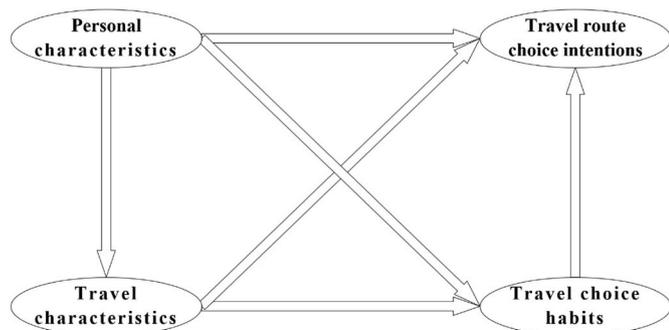

Fig. 1. Model hypothesis framework for truckers on the freeway.

economic factors (EF) significantly affect travel route choice intentions (TCI) is incorporated into the SEM hypotheses for truckers on parallel roads.

4. Materials

4.1. Data collection

The investigation was carried out on six freeways and their parallel roads in Guangxi, China, from August 26 to 28, 2021. As shown in Fig. 2, the specific starting and ending points of these roads are Baise to Jingxi, Jingxi to Longbang, Liujing to Qinzhou, Liuzhou to Wuzhou, Mailing to Hezhou, and Fenghuang to Guanyang.

The survey was conducted using a subjective questionnaire. We obtained relevant data by distributing paper questionnaires to truckers face to face in the service areas and toll stations of freeways as well as gas stations and road sections of parallel roads. In general, there are two kinds of classical survey methods for travel route choice intentions: a stated preference (SP) survey examining human responses to hypothetical situations and a revealed preference (RP) survey investigating human responses derived from a real-life choice situation in the physical world (Hassan & Abdel-Aty, 2011). We employed both RP and SP survey in this study.

Based on the characteristics of truckers driving on freeways and parallel roads, the five parts of the questionnaire were constructed as follows: 1) Personal characteristics, mainly including gender, age, driving years, occupation, and education level; 2) Economic factors, including the rationality of tolls, expected toll rate discounts, etc.; 3) Travel characteristics, including cargo types, the total weight of the cargo and vehicle, vehicle types, the nature of freight, etc.; 4) Travel choice habits, including the recent mileage and frequency of driving on freeways and parallel roads, etc.; 5) Travel route choice intentions, mainly including travel considerations, and the reasons for choosing freeways and parallel roads. Specifically, the relevant data of expected toll rate discounts, travel considerations and the intentions for choosing freeways or parallel roads were collected by SP survey; while travel choice habits and the rationality of tolls were collected by RP survey. Table 1 shows an example of partial questions from the questionnaire.

4.2. Descriptive analysis

A total of 748 questionnaires were returned during the data collection process. After checking for missing and abnormal values and performing data cleaning, 708 questionnaires were used for analysis. Among them, 186 questionnaires were collected on freeways, and 522 questionnaires were collected on parallel national and provincial roads. The sample statistics are listed in Table 2 and include various characteristics of the truckers. It can be determined that most of the surveyed truckers are middle-aged males with extensive driving experience. The proportion of males is more than 97%, and their age and driving years are concentrated in the 26–45-year range (accounting for more than 74%) and 3–20-year range (accounting for more than 78%), respectively.

Meanwhile, most of the trucks on freeways are engaged in own-account (accounting for 64%), long-distance travel (travel distance >50 km accounting for 71%), with a median vehicle and cargo weight (the total weight of vehicle and cargo <40 tons for 84.4%). For trucks on parallel national and provincial roads, most are also own-account (accounting for 73.2%), with median vehicle and cargo weight (the total weight of vehicle and cargo <40 tons for 82%), while 52.9% of the vehicles are engaged in short-distance travel (travel distance <50 km). Moreover, most of the truckers on both freeways and their parallel roads mainly consider tolls (accounting for 50.8% and 63.6%, respectively) and believe that the current freeway tolls are high (accounting for 67.7% and 71.9%, respectively).

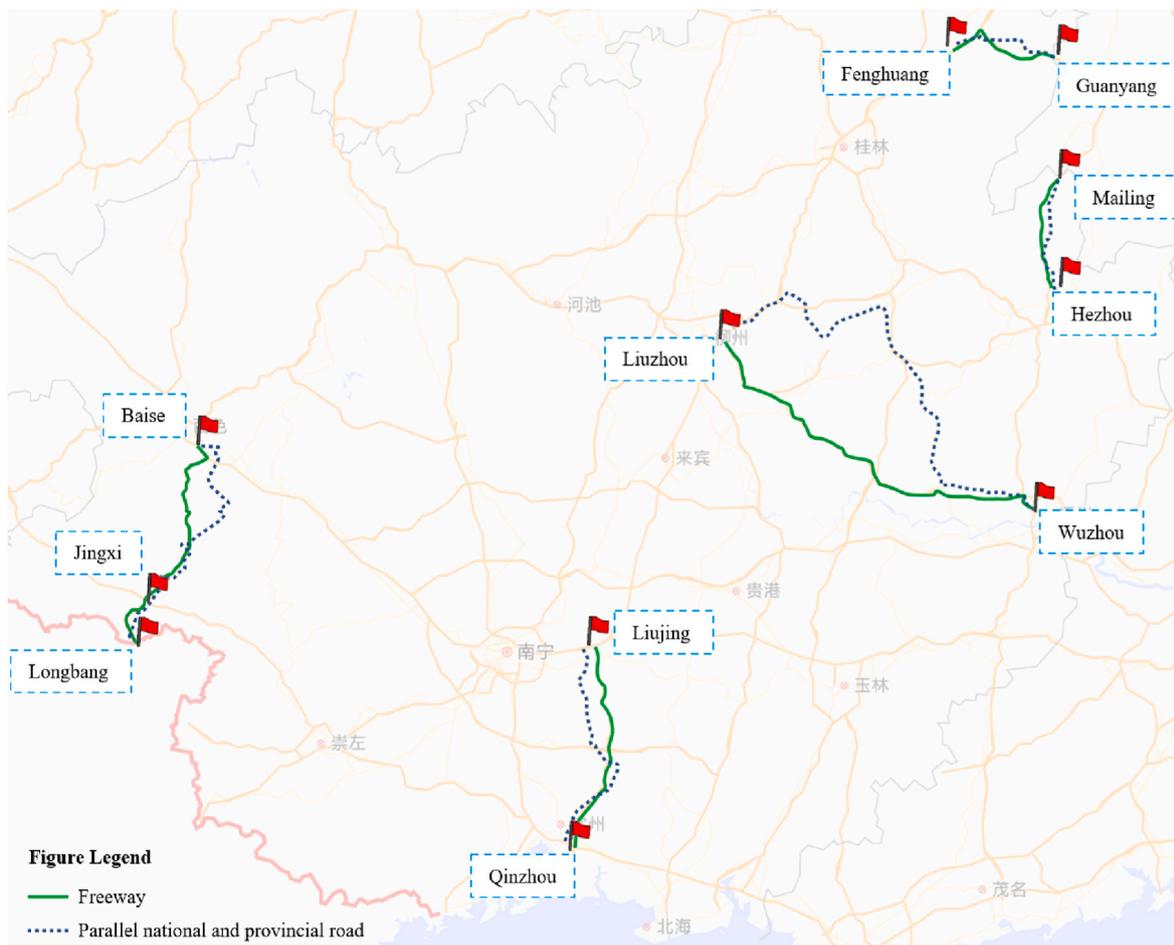In view of the result that most truckers driving on both freeways and

Fig. 2. The roads surveyed in Guangxi.

Table 1
Example of the survey questionnaire.

Parts	Questions	Answers
Personal characteristics	Gender	☐ Male ☐ Female
Travel characteristics	The total weight of vehicle and cargo	☐ <10 t ☐ 10–40 t ☐ >40 t
Economic factors	Reasonableness of freeway toll	☐ Inexpensive ☐ Reasonable ☐ Expensive
Travel choice habits	Kilometers driven on freeways per recent travel	☐ <50 km ☐ 50–100 km ☐ >100 km
Travel route choice intentions	Reasons for choosing freeway	☐ Short travel time ☐ High comfort ☐ Good services

their parallel roads considered the freeway tolls to be high, we continued to analyze the impact of freeway toll rate discounts on truckers' travel route choice intentions through SP survey data. As shown in Fig. 3, when the toll rate discounts reach about 80%, 43.1% of truckers have a willingness to use the freeways; at 75%, more than half (accounting for 55%) of truckers have a willingness to use the freeways. Therefore, the number of truckers using freeways over parallel roads will rise with increasing toll-rate discounts.

5. Results

5.1. Rationality of measurement model

According to EFA results, the four meaningful factors of personal characteristics, travel characteristics, travel choice habits, and travel route choice intentions obtained by the questionnaire on freeways were used for SEM. Five meaningful factors acquired by the questionnaire on parallel roads were also used, which included personal characteristics, economic factors, travel characteristics, travel choice habits, and travel route choice intentions. Based on the hypothesis stated above for SEM, the personal characteristics and economic factors are exogenous latent variables represented by ξ. Travel characteristics, travel choice habits, and travel route choice intentions are endogenous latent variables represented by η. Meanwhile, the observed variables describing the exogenous and endogenous variables are denoted by X and Y, respectively. Table 3 shows the statement of variables used for the SEM.

In addition to EFA, variables were verified by the CFA to test the reliability, one-dimensionality, and validity of the measurement models. As shown in Tables 4 and 5, all the factor loadings of each variable are significant, and standardized coefficients are larger than 0.6. These data show that each latent variable can be effectively reflected by its observed variables. However, we also find that some standardized coefficients are less than 0.6 in the model of truckers on parallel national and provincial roads. This means that some of the latent variables in the model are not perfectly reflected by their observed variables but are still acceptable. All composite reliabilities of latent variables are larger than 0.6, and the Cronbach's alphas are larger than 0.3, indicating that the consistency of each measurement model and its observed variables are

Table 2
Statistical results of sample characteristics.

Variable	Options	Freeway truckers	Truckers on parallel national and provincial roads
Gender	Male	181 (97.3%)	515 (98.7%)
	Female	5 (2.7%)	7 (1.3%)
Age	18–25	12 (6.5%)	29 (5.6%)
	26–35	65 (34.9%)	171 (32.8%)
	36–45	74 (39.8%)	256 (49%)
	>45	35 (18.8%)	66 (12.6%)
Driving years	<3	15 (8.1%)	50 (9.6%)
	3–10	80 (42.7%)	279 (53.4%)
	11–20	67 (36.2%)	134 (25.7%)
	>20	24 (13%)	59 (11.3%)
Nature of freight	State-owned enterprise	4 (2.2%)	12 (2.3%)
	Private enterprises	63 (33.8%)	128 (24.5%)
	Own-account	119 (64%)	382 (73.2%)
Total weight of vehicle and cargo	<10 t	59 (31.7%)	224 (43%)
	10–40 t	98 (52.7%)	204 (39%)
	>40 t	29 (15.6%)	94 (18%)
Travel distance	<50 km	54 (29%)	276 (52.9%)
	>50 km	132 (71%)	246 (47.1%)
Travel considerations	Travel cost	95 (50.8%)	332 (63.6%)
	Travel time	55 (29.8%)	108 (20.7%)
	Comfort	36 (19.4%)	82 (15.7%)
Kilometers driven on freeways per recent travel	<50 km	28 (15.1%)	199 (38.1%)
	50–100 km	50 (26.9%)	143 (27.4%)
	>100 km	108 (58.1%)	180 (34.5%)
Kilometers driven on parallel national and provincial roads per recent travel	<50 km	43 (23.1%)	130 (24.9%)
	50–100 km	57 (30.6%)	134 (25.7%)
	>100 km	86 (46.2%)	258 (49.4%)
Reasonableness of freeway tolls	Inexpensive	1 (0.6%)	7 (1.3%)
	Reasonable	59 (31.7%)	140 (26.8%)
	Expensive	126 (67.7%)	375 (71.9%)

ideal. Although the Cronbach's alpha of the model for economic factors in parallel roads is 0.211, it is still acceptable when combining consideration for other parameters of economic factors. For the convergent validity, the convergent validity (AVE) of each measurement model is greater than 0.4, which indicates that the observed variables can be reasonably explained by the latent variables.

Table 6 reports the discriminant validity between the latent variables in the two types of SEMs. It can be found that the square root of the AVE of each latent variable is greater than the corresponding Pearson correlation. Therefore, each latent variable can represent different factors, and the problem of multi-collinearity is not present.

5.2. Rationality of structural model

The χ^2 test that measures the discrepancy between the hypothesized

model and the data is usually used to assess the goodness-of-fit of the hypothesized model. However, when the sample size is more than 200, the p-value is always significant in almost all studies (Newsom, 2012). Therefore, alternative global fitting indexes, such as the Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), Normative Fit Index (NFI), Comparative Fit Index (CFI), and Tucker and Lewis Index (TLI) were adopted here. Different from the χ^2 goodness-of-fit test, they are not easily affected by the sample size. When each fitting index value is greater than 0.9, it generally means good fitting. In addition, the Root Mean Square Error of Approximation (RMSEA) and the Standardized Root Mean Square (SRMR) were included to assess the goodness-of-fit of the proposed model. RMSEA and SRMR values of less than 0.08 will generally indicate an adequate fit (Byrne, 2001).

Fig. 4 shows the standardized path coefficients of the SEM for truckers on parallel national and provincial roads. The goodness-of-fit of the proposed model is evaluated according to the above criteria, where the specific model parameters are: $\chi^2 = 113.278, \chi^2/df = 1.987, P < 0.001, \text{GFI} = 0.968, \text{AGFI} = 0.948, \text{NFI} = 0.926, \text{CFI} = 0.961, \text{TLI} = 0.947, \text{RMSEA} = 0.044$, and $\text{SRMR} = 0.0456$. Thus, according to the results, the goodness-of-fit of this model is satisfactory.

Fig. 5 shows the standardized path coefficients of the SEM for truckers on freeways. According to the criteria stated above, the goodness-of-fit of the model is also acceptable. The specific model parameters are: $\chi^2 = 85.859, \chi^2/df = 2.259, P < 0.001, \text{GFI} = 0.915, \text{AGFI} = 0.852, \text{NFI} = 0.914, \text{CFI} = 0.950, \text{TLI} = 0.930, \text{RMSEA} = 0.085$, and $\text{SRMR} = 0.0613$.

5.3. Analysis of SEM results

5.3.1. The SEM of truckers on parallel national and provincial roads

As shown in Fig. 4, personal characteristics have a significant positive effect on travel characteristics and travel choice habits ($p < 0.001$, the weight is 0.380; $p < 0.01$, the weight is 0.153). Travel characteristics affect travel choice habits and route choice intentions significantly and positively ($p < 0.001$, the weight is 0.504; $p < 0.05$, the weight is 0.2). Travel route choice intentions are significantly and negatively affected by economic factors ($p < 0.05$, the weight is -0.223). However, the direct effect of personal characteristics and travel choice habits on travel route choice intentions is not significant. Our study analyzes the indirect effect of personal characteristics on travel route choice intentions, where personal characteristics affect travel route choice intentions through travel characteristics and habits. Table 7 shows the unstandardized results of the mediation model between personal characteristics and travel route choice intentions. The bootstrap estimation method is further adopted in the study, and percentile and bias-corrected estimations are obtained.

As shown in Table 7, the direct effect of the personal characteristics on travel route choice intentions without mediation factors is not significant ($p = 0.617$). When travel characteristics and habits are included as mediators, the p-value of paths 1, 2, 3, and the total effects are also not significant ($p = 0.065, 0.541, 0.631$, and 0.104, respectively). Therefore, the travel route choice intentions are not affected by personal characteristics.

Some mediating effects among other factors can also be observed in Fig. 4. The effect of travel characteristics on travel route choice intentions might be partly mediated by travel choice habits, and personal characteristics might affect travel choice habits through travel characteristics. As shown in Tables 8 and 9, travel characteristics have no significant direct effect on travel route choice intentions ($p = 0.071$). When travel choice habits are included as a mediator, the indirect effect of travel characteristics on travel route choice intentions is still not significant ($p = 0.646$). Therefore, there is no mediation effect in the influence of travel characteristics on travel route choice intentions. Besides, the direct effect of personal characteristics on travel choice habits is significant ($p = 0.019$). When travel characteristics are included
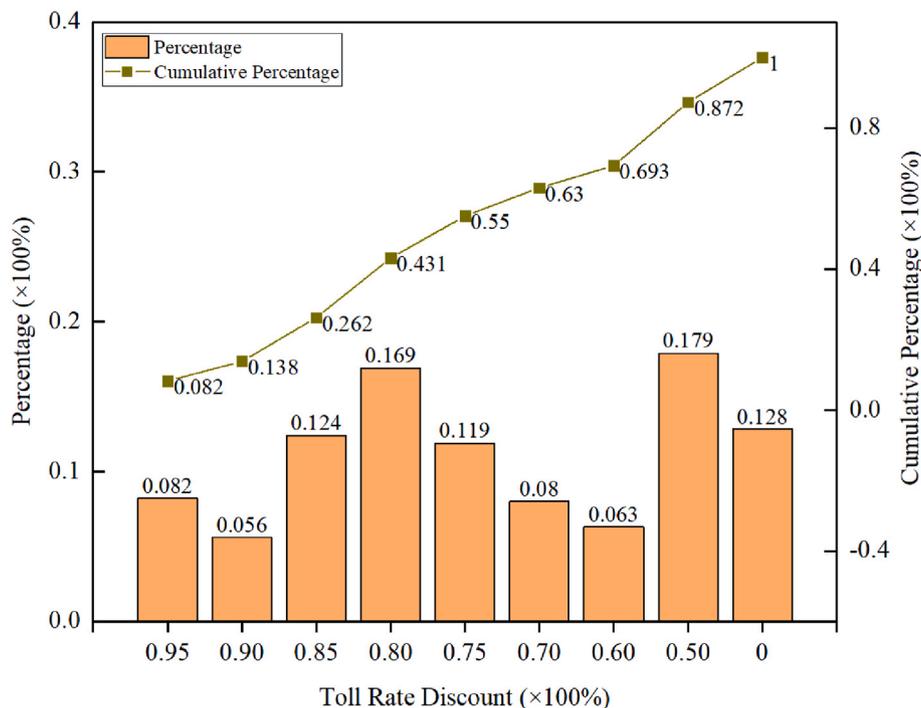
Fig. 3. Percentages of truckers willing to use the freeway corresponding to different toll rate discounts (for truckers on parallel national and provincial roads).

Table 3
Description of latent and observed variables for SEM.

Latent variables	Observed variables	Variable description
(Parallel national and provincial roads)		**Exogenous latent variables**
ξ_1 (PC)	X_1 (Age)	ξ_1: Personal characteristics (PC)
	X_2 (DY)	ξ_2: Economic factors (EF)
ξ_2 (EF)	X_3 (RFT)	**Endogenous latent variables**
	X_4 (Discount)	η_1: Travel characteristics (TC)
	X_5 (ETD)	η_2: Travel choice habits 1 (TH1)
η_1 (TC)	Y_1 (VT)	η_3: Travel choice habits 2 (TH2)
	Y_2 (TW)	η_4: Travel route choice intentions (TCI)
η_2 (TH1)	Y_3 (KM-NP)	**Observed variables describing the exogenous**
	Y_4 (KM-F)	**variables**
	Y_5 (TD)	X_1: Drivers' age (Age)
η_4 (TCI)	Y_7 (TCO)	X_2: Driving years (DY)
	Y_8 (RF)	X_3: Reasonableness of freeway toll (RFT)
	Y_9 (RNP)	X_4: Expected toll rate discount (Discount)
		X_5: Enjoyed the freeway toll discount (ETD)
(Freeway)		**Observed variables describing the endogenous**
ξ_1 (PC)	X_1 (Age)	**variables**
	X_2 (DY)	Y_1: Vehicle type (VT)
η_1 (TC)	Y_1 (VT)	Y_2: Total weight of vehicle and cargo (TW)
	Y_2 (TW)	Y_3: Kilometers driven on parallel national and
η_3 (TH2)	Y_3 (KM-NP)	provincial roads per recent travel (KM-NP)
	Y_4 (KM-F)	Y_4: Kilometers driven on freeways per recent
	Y_5 (TD)	travel (KM-F)
	Y_6 (FP)	Y_5: Travel distance (TD)
η_4 (TCI)	Y_7 (TCO)	Y_6: Fee paid each time in the freeway (FP)
	Y_8 (RF)	Y_7: Travel considerations (TCO)
	Y_9 (RNP)	Y_8: Reasons for choosing freeway (RF)
		Y_9: Reasons for choosing parallel national and
		provincial roads (RNP)

as a mediator, the indirect and total effect of personal characteristics on travel choice habits are also significant (p-value is 0.001 for these two cases). Therefore, the influence of personal characteristics on travel choice habits is a process of partial mediation. Personal characteristics have a significant direct effect on travel choice habits, as well as an indirect effect through travel characteristics.

5.3.2. The SEM of truckers on freeways

As shown in Fig. 5, personal characteristics have a significant positive effect on travel characteristics ($p < 0.001$, the weight is 0.714). Travel characteristics affect travel route choice intentions and habits negatively and positively, respectively ($p < 0.05$, the weight is -0.388; $p < 0.001$, the weight is 0.680). The direct effect of travel choice habits on travel route choice intentions is not significant, and personal characteristics have no significant direct effect on travel route choice intentions and habits. We also analyzed the indirect effect of personal characteristics on travel route choice intentions. Table 10 shows the unstandardized results of the mediation model between personal characteristics and travel route choice intentions.

As shown in Table 10, the direct effect of personal characteristics on travel route choice intentions without mediation factors is not significant ($p = 0.124$). When travel characteristics and habits are included as mediators, the p-value of paths 1, 2, 3, and the total effects are also not significant ($p = 0.09, 0.543, 0.199,$ and 0.520, respectively). Like truckers on parallel national and provincial roads, the result shows that travel route choice intentions are not affected by personal characteristics.

Meanwhile, as shown in Fig. 5, Tables 11 and 12, the direct effect of the travel characteristics on the travel route choice intentions without mediation factors is not significant ($p = 0.095$). When travel choice habits are included as mediators, the indirect and total effects between travel characteristics and travel route choice intentions are still not significant ($p = 0.204$ and 0.160, respectively). Thus, there is no mediation effect in the influence of travel characteristics on travel route choice intentions. Personal characteristics have no significant direct effect on travel choice habits without mediation factors ($p = 0.781$). When travel characteristics are included as mediators, the indirect and total effects are significant ($p < 0.001$ for these cases), indicating a case of completely mediated effects.

5.4. Summary of SEM results

An analysis of the results for truckers on parallel national and provincial roads indicates the following: travel characteristics exert the

Table 4
Parameters of measurement model for truckers on parallel national and provincial roads.

Latent variables	Observed variables	Parameters of significant test				STD. loading	Cronbach's alpha	Composite reliability	Convergent validity (AVE)
		Estimate	S.E.	EST/S.E.	p-value				
PC	Age	1				0.848	0.755	0.850	0.740
	DY	0.724	0.096	7.542	***	0.872			
EF	Discount	1				0.600	0.211	0.670	0.400
	RFT	0.679	0.338	2.011	0.044	0.683			
	ETD	0.417	0.123	3.390	***	0.628			
TC	TW	1				0.886	0.732	0.880	0.780
	VT	2.523	0.127	19.866	***	0.879			
TH1	TD	1				0.550	0.638	0.720	0.470
	KM-F	1.711	0.156	10.968	***	0.750			
	KM-NP	1.017	0.123	8.268	***	0.738			
TCI	TCO	1				0.765			
	RF	0.436	0.146	2.986	0.003	0.470	0.350	0.670	0.420
	RNP	0.782	0.245	3.192	0.001	0.666			

Note: S.E.: Standard error; STD: Standardized; EST: Estimate; ***: p-value <0.001.

Table 5
Parameters of measurement model for truckers on freeways.

Latent variables	Observed variables	Parameters of significant test				STD. loading	Cronbach's alpha	Composite reliability	Convergent validity (AVE)
		Estimate	S.E.	EST/S.E.	p-value				
PC	Age	1				0.865	0.891	0.840	0.730
	DY	0.901	0.071	12.690	***	0.844			
TC	TW	1				0.777			
	VT	2.784	0.177	15.729	***	0.792	0.703	0.760	0.620
	TD	1				0.667			
TH2	KM-F	1.819	0.179	10.162	***	0.841	0.834	0.860	0.610
	KM-NP	1.544	0.191	8.084	***	0.840			
	FP	2.040	0.198	10.303	***	0.758			
TCI	TCO	1				0.804			
	RF	0.756	0.181	4.177	***	0.742	0.629	0.800	0.570
	RNP	0.814	0.197	4.132	***	0.716			

Note: S.E.: Standard error; STD: Standardized; EST: Estimate; ***: p-value <0.001.

Table 6
Discriminant validity analysis for two types of SEMs.

Variables	Convergent validity (AVE)	Discriminant validity (National and provincial roads)				
		PC	EF	TC	TH1	TCI
PC	0.740	**0.860**				
EF	0.400	−0.003	**0.632**			
TC	0.780	0.380	−0.001	**0.883**		
TH1	0.470	0.344	−0.001	0.562	**0.686**	
TCI	0.420	0.144	−0.224	0.245	0.175	**0.648**

Variables	Convergent validity (AVE)	Discriminant validity (Freeway)			
		PC	TC	TH2	TCI
PC	0.730	**0.854**			
TC	0.620	0.716	**0.787**		
TH2	0.610	0.513	0.700	**0.781**	
TCI	0.570	0.061	−0.079	0.052	**0.755**

Note: The bold diagonal is the square root of the average variance extraction (AVE), and the lower triangle is the Pearson correlation.

most significant positive effect on travel route choice intentions; by contrast, economic factors generate the most significant negative effect. Meanwhile, travel characteristics exert the most significant positive effect on travel choice habits; similarly, personal characteristics significantly and positively affect travel characteristics. In addition, personal characteristics exert a significant direct effect on travel choice habits, as well as an indirect effect through travel characteristics.

An analysis of the results for truckers on freeways shows that their travel route choice intentions are only significantly and negatively affected by travel characteristics. Personal characteristics exert a significant positive effect on travel characteristics, and travel

characteristics positively affect travel choice habits. The direct effect of personal characteristics on travel choice habits is not significant, but the indirect effect is significant when travel characteristics are regarded as mediators.

6. Discussion

In order to explore the influencing factors and relationships among factors for travel route choice intentions of truckers on freeways and on parallel national and provincial roads, and analyze the differences in travel preferences between these two types of trucker groups, this study analyzed the relationships among personal characteristics, economic factors, travel characteristics, travel choice habits, and travel route choice intentions by establishing two separate SEMs.

6.1. Impact relationships

The effect of travel characteristics on travel route choice intentions was significant for both freeway truckers and truckers on parallel national and provincial roads, indicating that the two types of truckers would consider the total weight of the vehicle and cargo and vehicle types to determine travel routes. This was also consistent with the findings of Hyodo and Hagino (2010) and Rowell et al. (2014). Personal characteristics, which were represented by age and driving years, had no significant direct or indirect effect on their travel route choice intentions. However, most previous researches about passenger car drivers found that the influence of personal characteristics on travel behavior or route choices was significant (Bunce et al., 2012; Doroudgar et al., 2017; Pojani et al., 2018; Song et al., 2021; Zhu et al., 2022). Thus, significant differences in personal characteristics are present between passenger car
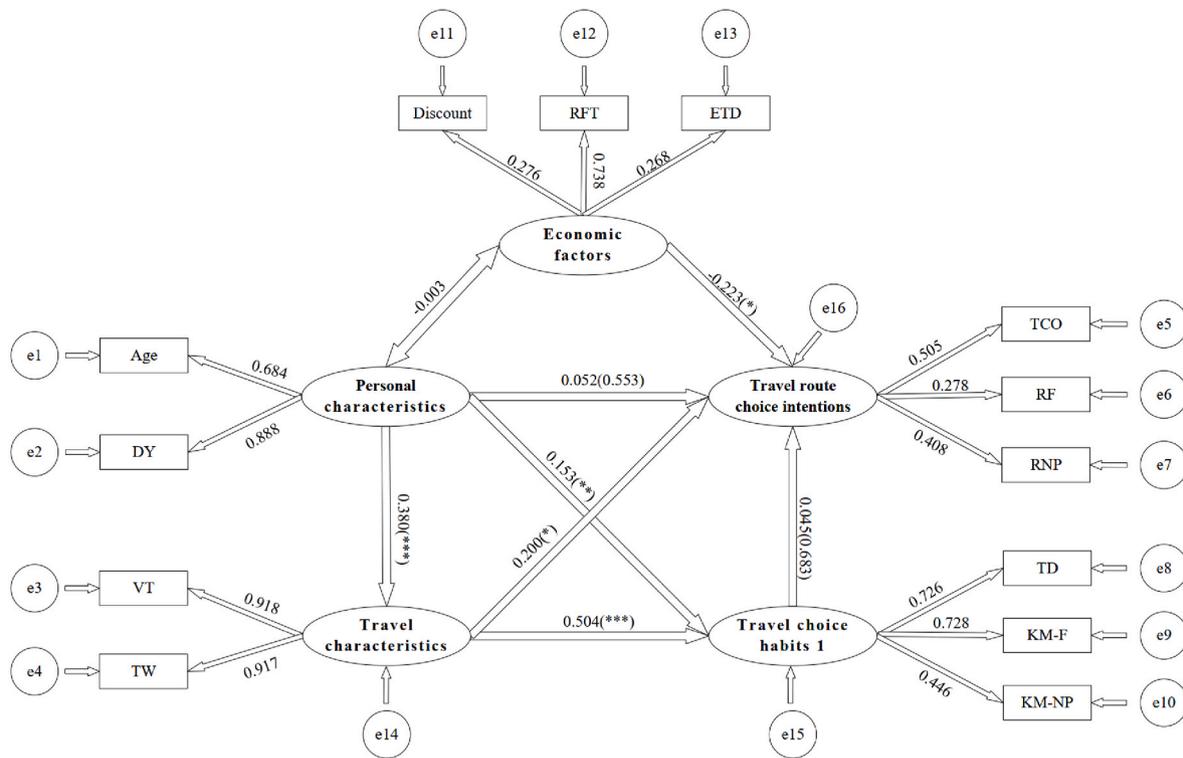
Fig. 4. Standardized path coefficients of the SEM for truckers on parallel national and provincial roads (* for p < 0.05; ** for p < 0.01; *** for p < 0.001).
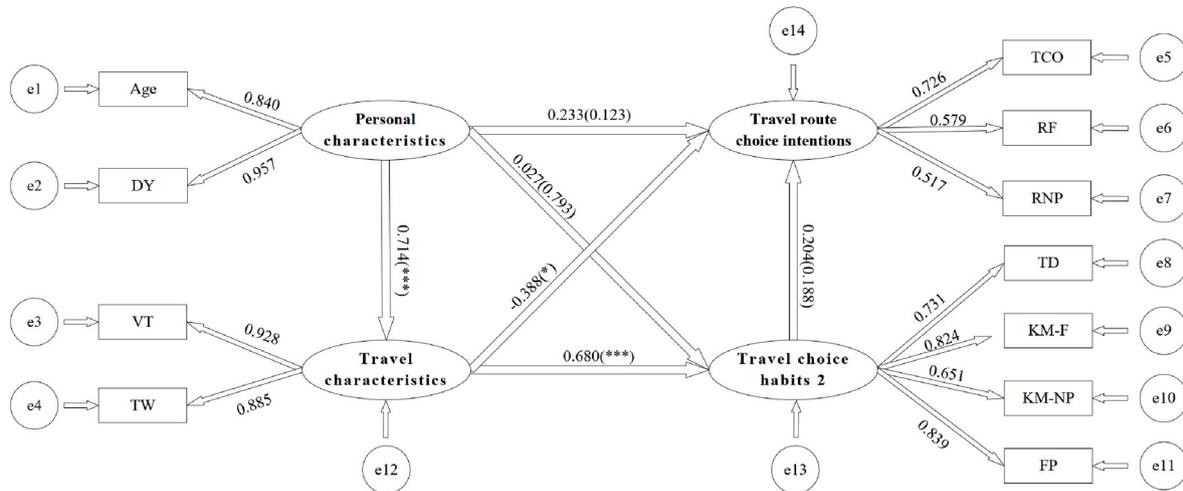

Fig. 5. Standardized path coefficients of the SEM for truckers on freeways (* for p < 0.05; ** for p < 0.01; *** for p < 0.001).

drivers and truckers as well as the purpose of vehicle use (Kockelman Maria & Zhao, 2000). Truckers might not be affected by lack of experience when choosing their travel route. Similarly, the effect of travel choice habits on route choice intentions was also not significant, indicating that truckers' travel route choice intentions would not be influenced obviously by their recent driving conditions. Although some research found that travel choice habits affected travel choice behavior significantly (Chen & Chao, 2011; Eriksson et al., 2008), the different results appearing in our study might be highly related to different tasks and destinations for each type of transportation undertaken by truckers (Fuller et al., 2003). Therefore, truckers exhibited less habitual travel route choice behavior of repeating than private car owners especially commuters.

Jou et al. (2007) found that the effect of freeway tolls on travel route choices was significant and negative. Our study also indicates that

economic factors have a significant negative effect on the travel route choice intentions of truckers on parallel national and provincial roads. The possibility of considering routes with high comfort and short driving time (freeway) would be higher with increasing toll discounts. Coincidentally, based on the analysis of the impact of different freeway toll discounts on the travel willingness of truckers on parallel roads (see Fig. 3), we also found that the number of truckers willing to turn to freeways from parallel roads increased with increasing toll discounts. Therefore, the method of decreasing freeway tolls could be employed to increase traffic volume on freeways without considering the case of other influencing factors. A similar conclusion was also reached in a previous study in which tolls or toll discounts were regarded as an important variable (Sun et al., 2013). For truckers on freeways, the toll was also important according to descriptive analysis, but economic factors were not correlated with their travel route choice intentions after

Table 7

Mediating effects of personal characteristics on travel route choice intentions (unstandardized results).

Path	Product of Coefficients				Bootstrapping 2000 Times 95%CI			
	Estimate	S.E.	EST/S.E.	p-value	Percentile		Bias Corrected	
					Lower 2.5%	Upper 2.5%	Lower 2.5%	Upper 2.5%
Indirect effectrowhead								
1.PC—TC—TCI	0.045	0.029	1.552	0.065	−0.019	0.097	−0.004	0.106
2.PC—TH1—TCI	0.004	0.012	0.333	0.541	−0.021	0.031	−0.015	0.036
3.PC—TC—TH1—TCI	0.005	0.014	0.357	0.631	−0.023	0.035	−0.021	0.038
Total indirect effects	0.054	0.026	2.077	0.024	−0.006	0.102	0.01	0.115
Direct effectrowhead								
PC—TCI	0.031	0.072	0.431	0.617	−0.091	0.191	−0.085	0.201
Total effectrowhead								
Total effects	0.084	0.063	1.333	0.104	−0.026	0.214	−0.016	0.226

Note: S.E.: Standard error; EST: Estimate; Mediating factors: TC, TH1.

Table 8

Mediating effects of travel characteristics on travel route choice intentions (unstandardized results).

Path	Product of Coefficients				Bootstrapping 2000 Times 95%CI			
	Estimate	S.E.	EST/S.E.	p-value	Percentile		Bias Corrected	
					Lower 2.5%	Upper 2.5%	Lower 2.5%	Upper 2.5%
TC—TH1—TCI	0.014	0.040	0.35	Indirect effect 0.646	−0.066	0.092	−0.060	0.102
TC—TCI	0.125	0.075	1.667	Direct effect 0.071	−0.057	0.249	−0.018	0.265
Total effects	0.139	0.061	2.279	Total effect 0.025	−0.023	0.228	0.035	0.256

Note: S.E.: Standard error; EST: Estimate; Mediating factor: TH1.

Table 9

Mediating effects of personal characteristics on travel choice habits (unstandardized results).

Path	Product of Coefficients				Bootstrapping 2000 Times 95%CI			
	Estimate	S.E.	EST/S.E.	p-value	Percentile		Bias Corrected	
					Lower 2.5%	Upper 2.5%	Lower 2.5%	Upper 2.5%
PC—TC—TH1	0.096	0.023	4.134	Indirect effect 0.001	0.055	0.147	0.057	0.148
PC—TH1	0.077	0.032	2.406	Direct effect 0.019	0.012	0.138	0.017	0.141
Total effects	0.174	0.032	5.438	Total effect 0.001	0.112	0.237	0.115	0.239

Note: S.E.: Standard error; EST: Estimate; Mediating factor: TC.

Table 10

Mediating effects of personal characteristics on travel route choice intentions (unstandardized results).

Path	Product of Coefficients				Bootstrapping 2000 Times 95%CI			
	Estimate	S.E.	EST/S.E.	p-value	Percentile		Bias Corrected	
					Lower 2.5%	Upper 2.5%	Lower 2.5%	Upper 2.5%
1.PC—TC—TCI	−0.216	0.139	−1.554	Indirect effect 0.090	−0.519	0.026	−0.507	0.032
2.PC—TH2—TCI	0.004	0.024	0.167	0.543	−0.045	0.057	−0.027	0.078
3.PC—TC—TH2—TCI	0.077	0.075	1.027	0.199	−0.047	0.243	−0.046	0.243
Total indirect effects	−0.134	0.102	−1.314	0.170	−0.354	0.043	−0.344	0.054
PC—TCI	0.182	0.120	1.517	Direct effect 0.124	−0.052	0.419	−0.050	0.423
Total effects	0.048	0.088	0.545	Total effect 0.520	−0.161	0.196	−0.147	0.208

Note: S.E.: Standard error; EST: Estimate; Mediating factors: TC, TH2.

Table 11

Mediating effects of travel characteristics on travel route choice intentions (unstandardized results).

Path	Product of Coefficients				Bootstrapping 2000 Times 95%CI			
	Estimate	S.E.	EST/S.E.	p-value	Percentile		Bias Corrected	
					Lower 2.5%	Upper 2.5%	Lower 2.5%	Upper 2.5%
TC—TH2—TCI	0.148	0.145	1.021	Indirect effect 0.204	−0.089	0.490	−0.089	0.490
TC—TCI	−0.413	0.270	−1.530	Direct effect 0.095	−1.010	0.046	−0.997	0.063
Total effects	−0.265	0.192	−1.380	Total effect 0.160	−0.675	0.077	−0.641	0.105

Note: S.E.: Standard error; EST: Estimate; Mediating factor: TH2.

Table 12
Mediating effects of personal characteristics on travel choice habits (unstandardized results).

Path	Product of Coefficients				Bootstrapping 2000 Times 95%CI			
	Estimate	S.E.	EST/S.E.	p-value	Percentile		Bias Corrected	
					Lower 2.5%	Upper 2.5%	Lower 2.5%	Upper 2.5%
PC—TC—TH2	0.208	0.049	4.245	Indirect effect ***	0.114	0.304	0.123	0.320
PC—TH2	0.012	0.045	0.267	Direct effect 0.781	−0.078	0.106	−0.077	0.107
Total effects	0.220	0.039	5.641	Total effect ***	0.144	0.295	0.152	0.306

Note: S.E.: Standard error; EST: Estimate; Mediating factor: TC; ***: p-value <0.001.

analysis. This situation might occur through a combining effect with some other factors. For example, existing studies demonstrate that the route decisions of truckers are influenced by numerous critical factors, and various trade-offs between factors exist (e.g., the trade-off between travel cost and travel time) (Iraganaboina et al., 2021; Ringhand & Vollrath, 2019; Toledo et al., 2020). These factors compelled truckers to drive on freeways despite their unwillingness to pay toll fees. However, the specific reasons have yet to be further explored, together with the moderating effect of psychological factors.

The indirect impact relationships among factors were explored using the mediation models of two types of SEM. The results of both models showed that the indirect effect of personal characteristics on travel choice habits was significant when travel characteristics were regarded as mediators. This finding indicates that truckers gradually develop their travel choice habits that matched their own characteristics based on their age and driving years, moderated by their travel characteristics. However, the indirect effects between other factors were not significant. These findings regarding the indirect effect address a significant gap in previous studies that pay more attention to the direct effect or interaction relationships among factors.

Apart from analyzing the aforementioned direct and indirect effects, the relationships among personal characteristics, travel characteristics, and travel choice habits were also verified. Both SEMs for truckers on freeways and on parallel national and provincial roads revealed that personal characteristics exerted a significant positive effect on travel characteristics, and travel characteristics positively affected travel choice habits. Some studies also have clarified that age exerted a significant positive effect on travel characteristics (Bosehans et al., 2023; Mohammadi et al., 2021). In addition, the process by which travel characteristics influence travel choice habits has been identified in earlier research. Specifically, cargo service types and vehicle types determine the transport tasks a truck can perform; meanwhile, repetitive tasks can promote the development of travel choice habits over time (e.g., becoming accustomed to perform tasks within a certain distance or region) (Ahmed & Roorda, 2022; Fuller et al., 2003).

6.2. Group differences

Some differences between truckers on freeways and on parallel roads were observed when analyzing the influencing factors and their relationships. The travel characteristics of truckers on freeways had a negative effect on travel route choice intentions, which was different from the truckers on parallel national and provincial roads (shown in Figs. 4 and 5). This result illustrated that with the total transport weight increasing, the possibility of considering the route tolls was added for truckers on freeways, while truckers on parallel roads paid more attention to routes with high comfort and short travel time. This finding explained why the proportion of trucks with total weights between 10 and 40 tones on freeways was higher (accounting for 52.7%), while trucks of less than 10 tones were higher (accounting for 43%) on parallel national and provincial roads. However, as most studies regarded truckers as a homogeneous group, only the conclusion that truckers preferred roads with lower tolls could be found (Arentze et al., 2012; Holguín-veras & Wang, 2011).

In addition, we also found that the direct effect of personal characteristics on travel choice habits was not consistent between truckers on freeways and on their parallel roads (see Tables 7–12). For truckers on freeways, without the mediating effect of travel characteristics (regardless of the total weight of vehicle and cargo and vehicle type), the mileage used to travel on freeways or parallel roads might not be affected by their driving experience. However, for truckers on parallel national and provincial roads, their mileage traveling on freeways or parallel roads was related to their driving experience. According to the descriptive analysis (see Table 2), the proportion of freeway truckers with more than 10 years of driving experience is as high as 50%, which is markedly higher than that of truckers on parallel roads (accounting for 37%). Half of freeway truckers have extensive driving experience; thus, their personal characteristics might not be a significant factor directly influencing their travel choice habits. Similar results were also found in the research on risky driving behavior, indicating that the personal characteristics (e.g., driving experience) of experienced drivers might not be a factor in promoting risky driving behavior (Jovanis et al., 1991; Strathman et al., 2010; Tseng, 2023). However, the research conducted failed to identify any significant differences between groups within a complete sample covering different types of drivers (Knorring et al., 2005).

7. Summaries and conclusions

Based on the SP and RP survey data, two SEMs of truckers on freeways and on parallel national and provincial roads were established in this work. The influence of personal characteristics, travel characteristics, economic factors, and travel choice habits on the travel route choice intentions of truckers were explored, and the findings verified the research hypothesis. Meantime, the differences between the results of the two SEMs were discussed.

The results showed that travel characteristics (i.e., vehicle type and the total weight of the cargo and vehicle) had a significant effect on travel route choice intentions of truckers on freeways and parallel national and provincial roads. The travel route choice intentions of truckers on parallel national and provincial roads were significantly affected by economic factors (i.e., expected toll rate discounts). There was also an interactive relationship among these influencing factors in the SEM of truckers on freeways and their parallel roads, where the effect of personal characteristics (i.e., age and driving years) on travel choice habits was significantly mediated by travel characteristics.

This study provides some insights for guiding the travel route choices of truckers and improving the utilization rate of freeways. The following measures related to influencing factors could be carried out to guide the travel route choices of truckers.

(1) The most important influencing factor for truckers is economical. They will consider choosing a route with shorter driving time and improved comfort when the tolls meet their expectations. Therefore, it is expectable that truckers on parallel national and provincial roads can be transferred to freeways by providing preferential economic measures on freeways.

(2) In order to enhance the attractiveness of the freeway in terms of economic factors, it is appropriate and necessary to give trucks reasonable and precise preference measures, such as formulating a variety of toll rate discount levels according to vehicle types or mileage.

(3) While taking economic measures to transfer trucks on parallel national and provincial roads into freeways, it is necessary to stabilize the existing traffic volume of trucks on freeways. Some supporting measures, including reasonably increasing the number of special lanes and steadily increasing the speed limit for trucks, can be applied to shorten the driving time and improve the operation efficiency and comfort.

This study mainly investigated the influencing factors and their relationship with travel route choice intentions by using a questionnaire in Guangxi, China. However, the results for the SEM model might not be universally applicable because of limitations in data volume and differences in populations within different regions. Therefore, the study results require further verification with more SP and RP survey data in many other provinces or cities to enhance its general applicability. In addition to subjective investigations and theoretical modeling, testing the precision of our findings by obtaining objective travel behavior data (e.g., position data from Global Position System or Electronic Toll Collection data) associated with the truckers is necessary. Two models were constructed to analyze the differences between the relationships among factors influencing the travel route choice intentions of truckers on freeways and on parallel roads. A unified heterogeneity recognition model can be valuable in identifying potential differences between the two groups of truckers. Indeed, conducting research is crucial in predicting travel route choice intentions based on the results of factor or relationship identifying models.

CRediT authorship contribution statement

Ning Zhang: Data curation, Software, Writing – original draft. **Yiping Wu:** Conceptualization, Methodology, Supervision, Project administration. **Jian Rong:** Writing – review & editing, Resources. **Juan Shao:** Investigation, Visualization. **Jiayuan Chen:** Data curation, Formal analysis. **Chenjing Zhou:** Writing – review & editing, Validation.

Declaration of competing interest

The authors declare no potential conflicts of interest regarding the research, authorship, or publication of this article.

Acknowledgments

References

Adurthi, N. M., Bari, C. S., Navandar, Y. V., & Dhamaniya, A. (2022). A study on user acceptable road pricing policy for toll roads: A case of eethakota, India. *Transportation Research Procedia, 62*, 656–663. https://doi.org/10.1016/j.trpro.2022.02.081

Agrawal, S., & Peeta, S. (2021). Hybrid route choice model incorporating latent cognitive effects of real-time travel information using physiological data. *Transportation Research Part F: Traffic Psychology and Behaviour, 81*, 223–239. https://doi.org/10.1016/j.trf.2021.05.021

Ahmed, U., & Roorda, M. J. (2022). Modelling carrier type and vehicle type choice of small and medium size firms. *Transportation Research Part E, 160*, Article 102655. https://doi.org/10.1016/j.tre.2022.102655

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*, 179–211.

Alizadeh, H., Farooq, B., Morency, C., & Saunier, N. (2019). Frequent versus occasional drivers : A hybrid route choice model. *Transportation Research Part F Psychol. Behav., 64*, 171–183. https://doi.org/10.1016/j.trf.2019.05.009

Arentze, T., Feng, T., Timmermans, H., & Robroeks, J. (2012). *Context-dependent influence of road attributes and pricing policies on route choice behavior of truck drivers : Results of a conjoint choice experiment.* https://doi.org/10.1007/s11116-012-9391-z

Bacero, R. S., Rith, M., & Fillone, A. M. (2022). Truckers' perceptions on truck regulations and policies in a developing country: A case study of metro manila, Philippines. *Case Stud. Transp. Policy.* https://doi.org/10.1016/j.cstp.2022.02.003

Bachoo, S., Bhagwanjee, A., & Govender, K. (2013). The influence of anger, impulsivity, sensation seeking and driver attitudes on risky driving behaviour among post-graduate university students in Durban, South Africa. *Accident Analysis & Prevention, 55*, 67–76. https://doi.org/10.1016/j.aap.2013.02.021

Bamberg, S., Ajzen, I., & Schmidt, P. (2003). Choice of travel mode in the theory of planned behavior: The roles of past behavior, habit, and reasoned action. *Basic and Applied Social Psychology, 25*, 175–187. https://doi.org/10.1207/S15324834BASP2503_01

Bamberg, S., & Schmidt, P. (2003). Incentives, morality, or habit? Predicting students' car use for university routes with the models of ajzen, schwartz, and triandis. *Environment and Behavior, 35*, 264–285. https://doi.org/10.1177/0013916502250134

Basu, N., Haque, M. M., King, M., Kamruzzaman, M., & Oviedo-Trespalacios, O. (2021). A systematic review of the factors associated with pedestrian route choice. *Transport Reviews, 0*, 1–23. https://doi.org/10.1080/01441647.2021.2000064

Bekhor, S., & Albert, G. (2014). Accounting for sensation seeking in route choice behavior with travel time information. *Transportation Research Part F: Traffic Psychology and Behaviour, 22*, 39–49. https://doi.org/10.1016/j.trf.2013.10.009

Ben-Akiva, M., & Lerman, S. R. (2018). *Discrete choice analysis: Theory and application to travel demand.* Transportation Studies.

Ben-Akiva, M. E., Lerman, S. R., & Lerman, S. R. (1985). *Discrete choice analysis: Theory and application to travel demand.* MIT press.

Ben-Elia, E., Di Pace, R., Bifulco, G. N., & Shiftan, Y. (2013). The impact of travel information's accuracy on route-choice. *Transportation Research Part C: Emerging Technologies, 26*, 146–159. https://doi.org/10.1016/j.trc.2012.07.001

Ben-Elia, E., Erev, I., & Shiftan, Y. (2008). The combined effect of information and experience on drivers' route-choice behavior. *Transportation, 35*, 165–177. https://doi.org/10.1007/s11116-007-9143-7

Bosehans, G., Bell, M., Thorpe, N., & Dissanayake, D. (2023). Something for every one? - an investigation of people's intention to use different types of shared electric vehicle. *Travel Behav. Soc., 30*, 178–191. https://doi.org/10.1016/j.tbs.2022.09.004

Bouscasse, H., Joly, I., & Bonnel, P. (2018). How does environmental concern influence mode choice habits? A mediation analysis. *Transportation Research Part D: Transport and Environment, 59*, 205–222. https://doi.org/10.1016/j.trd.2018.01.007

Bunce, D., Young, M. S., Blane, A., & Khugputh, P. (2012). Age and inconsistency in driving performance. *Accident Analysis & Prevention, 49*, 293–299. https://doi.org/10.1016/j.aap.2012.01.001

Burgdorf, C., & Eisenkopf, A. (2018). Effects of road tolls for intercity buses on travel activities and the choice of means of transport in German long-distance passenger transport. *Research in Transportation Economics, 72*, 92–105. https://doi.org/10.1016/j.retrec.2018.03.005

Byrne, B. M. (2001). Structural equation modeling: Perspectives on the present and the future. *International Journal of Testing, 1*, 327–334. https://doi.org/10.1080/15305058.2001.9669479

Chen, C. F., & Chao, W. H. (2011). Habitual or reasoned? Using the theory of planned behavior, technology acceptance model, and habit to examine switching intentions toward public transit. *Transportation Research Part F: Traffic Psychology and Behaviour, 14*, 128–137. https://doi.org/10.1016/j.trf.2010.11.006

Cheng, L., Chen, X., Yang, S., Wu, J., & Yang, M. (2019). Structural equation models to analyze activity participation , trip generation , and mode choice of low-income commuters. *Transp. Lett., 7867*, 1–9. https://doi.org/10.1080/19427867.2017.1364460

Cherry, C. R., & Adelakun, A. A. (2012). Truck driver perceptions and preferences: Congestion and conflict,managed lanes, andtolls. *Transport Policy, 24*, 1–9. https://doi.org/10.1016/j.tranpol.2012.07.012

Choocharukul, K. (2008). Effects of attitudes and socioeconomic and travel characteristics on stated route diversion: Structural equation modeling approach of road users in Bangkok, Thailand. *Transportation Research Record, 35*–42. https://doi.org/10.3141/2048-05

Chorus, C. G. (2010). A new model of random regret minimization. *European Journal of Transport and Infrastructure Research, 10.*

Chorus, C. G., Arentze, T. A., & Timmermans, H. J. P. (2007). Travelers ' need for information in traffic and transit : Results from a web. *Surveyor, 11*, 57–67. https://doi.org/10.1080/15472450701293841

Di, X., & Liu, H. X. (2016). Boundedly rational route choice behavior: A review of models and methodologies. *Transportation Research Part B: Methodological, 85*, 142–179. https://doi.org/10.1016/j.trb.2016.01.002

Doroudgar, S., Chuang, H. M., Perry, P. J., Thomas, K., Bohnert, K., & Canedo, J. (2017). Driving performance comparing older versus younger drivers. *Traffic Injury Prevention, 18*, 41–46. https://doi.org/10.1080/15389588.2016.1194980

Eriksson, L., Garvill, J., & Nordlund, A. M. (2008). Interrupting habitual car use: The importance of car habit strength and moral motivation for personal car use reduction. *Transportation Research Part F: Traffic Psychology and Behaviour, 11*, 10–23. https://doi.org/10.1016/j.trf.2007.05.004

Fan, J., Lu, Y., & Luo, W. (2019). Valuing domestic transport infrastructure: A view from the route choice of exporters. *The Review of Economics and Statistics*, 1–46.

Fuller, T., Rockliffe, N., Wigan, M., Tsolakis, D., & Thoresen, T. (2003). *Economic evaluation of road investment proposals: Valuing travel time savings for freight.* Edinburgh Napier University.

Gan, H., & Ye, X. (2014). Leave the expressway or not? Impact of dynamic information. *J. Mod. Transp., 22*, 96–103. https://doi.org/10.1007/s40534-014-0043-1

Gardner, B. (2009). Modelling motivation and habit in stable travel mode contexts. *Transportation Research Part F: Traffic Psychology and Behaviour, 12*, 68–76. https://doi.org/10.1016/j.trf.2008.08.001

Goldbach, C., Kayar, D., Pitz, T., & Sickmann, J. (2019). Transferring decisions to an algorithm : A simple route choice experiment. *Transportation Research Part F Psychol. Behav., 65*, 402–417. https://doi.org/10.1016/j.trf.2019.08.011

Gomez, J., Papanikolaou, A., & Vassallo, J. M. (2017). Users' perceptions and willingness to pay in interurban toll roads: Identifying differences across regions from a nationwide survey in Spain. *Transportation, 44*, 449–474. https://doi.org/10.1007/s11116-015-9662-6

Gruner, S., & Vollrath, M. (2021). Challenges for obtaining a system-optimal traffic distribution by giving route advice due to the biased memory of congestion. *Transportation Research Procedia, 52*, 396–403. https://doi.org/10.1016/j.trpro.2021.01.046

Hagenauer, J., & Helbich, M. (2017). A comparative study of machine learning classifiers for modeling travel mode choice. *Expert Systems with Applications, 78*, 273–282. https://doi.org/10.1016/j.eswa.2017.01.057

Han, H., Al-Ansi, A., Chua, B. L., Tariq, B., Radic, A., & Park, S. H. (2020). The post-coronavirus world in the international tourism industry: Application of the theory of planned behavior to safer destination choices in the case of us outbound tourism. *International Journal of Environmental Research and Public Health, 17*, 1–15. https://doi.org/10.3390/ijerph17186485

Han, F., Xie, R., & Lai, M. (2018). Traffic density, congestion externalities, and urbanization in China. *Spatial Economic Analysis, 13*, 400–421. https://doi.org/10.1080/17421772.2018.1459045

Hao, J., Zhang, L., Ji, X., & Tang, J. (2020). Modeling and analyzing of family intention for the customized student routes: A case study in China. *Phys. A Stat. Mech. its Appl., 542*, Article 123399. https://doi.org/10.1016/j.physa.2019.123399

Hassan, H. M., & Abdel-Aty, M. A. (2011). Analysis of drivers' behavior under reduced visibility conditions using a Structural Equation Modeling approach. *Transportation Research Part F: Traffic Psychology and Behaviour, 14*, 614–625. https://doi.org/10.1016/j.trf.2011.07.002

He, S. Y., & Thøgersen, J. (2017). The impact of attitudes and perceptions on travel mode choice and car ownership in a Chinese megacity: The case of Guangzhou. *Research in Transportation Economics, 62*, 57–67. https://doi.org/10.1016/j.retrec.2017.03.004

Holguín-veras, J., & Wang, Q. (2011). Behavioral investigation on the factors that determine adoption of an electronic toll collection system. *Freight carriers, 19*, 593–605. https://doi.org/10.1016/j.trc.2010.09.010

Hyodo, T., & Hagino, Y. (2010). Modeling truck route choice behavior by traffic electronic application data. Present. In *Transp. res. Board SHRP 2 symp. Innov. Freight demand model. Data*.

Institute, B. T. (2021). *Beijing transport development annual report*.

Institute, S.U. and R.C. and T.D.R.. (2022). *Sixth comprehensive traffic survey*.

Iraganaboina, N. C., Bhowmik, T., Yasmin, S., Eluru, N., & Abdel-Aty, M. A. (2021). Evaluating the influence of information provision (when and how) on route choice preferences of road users in Greater Orlando: Application of a regret minimization approach. *Transportation Research Part C: Emerging Technologies, 122*, Article 102923. https://doi.org/10.1016/j.trc.2020.102923

Jain, D., & Tiwari, G. (2020). Gender and income based variability in travel choices in Vishakhapatnam, India. *Transportation Research Procedia, 48*, 2870–2890. https://doi.org/10.1016/j.trpro.2020.08.232

Javid, M. A., Okamura, T., Nakamura, F., & Rui, W. (2013). Analysis and modeling of commuters' perception to radio traffic information in Lahore, Pakistan. In *20th ITS world congress tokyo*.

Jou, R. C., & Chen, K. H. (2013). An application of cumulative prospect theory to freeway drivers' route choice behaviours. *Transportation Research Part A Policy Pract., 49*, 123–131. https://doi.org/10.1016/j.tra.2013.01.011

Jou, R. C., Lam, S. H., He, R., & Wu, P. H. (2007). Acceptance tendencies and commuters' behavior under different road pricing schemes. *Transportmetrica, 3*, 213–230. https://doi.org/10.1080/18128600708685674

Jou, R. C., & Yeh, Y. C. (2013). Freeway passenger car drivers' travel choice behaviour in a distance-based toll system. *Transport Policy, 27*, 11–19. https://doi.org/10.1016/j.tranpol.2012.12.005

Jovanis, P. P., Schofer, J. L., Prevedouros, P., & Tsunokawa, K. (1991). *Analysis of bus transit accidents: Empirical, methodological, and policy issues*.

Kennedy, E. H., Beckley, T. M., McFarlane, B. L., & Nadeau, S. (2009). Why we don't "walk the talk": Understanding the environmental values/behaviour gap in Canada. *Human Ecology Review, 16*, 151–160.

Khoo, H. L., & Asitha, K. S. (2016). User requirements and route choice response to smart phone traffic applications (apps). *Travel Behav. Soc., 3*, 59–70. https://doi.org/10.1016/j.tbs.2015.08.004

Kiatkawsin, K., & Han, H. (2017). Young travelers' intention to behave pro-environmentally: Merging the value-belief-norm theory and the expectancy theory. *Tourism Management, 59*, 76–88. https://doi.org/10.1016/j.tourman.2016.06.018

Knorring, J. H., He, R., & Kornhauser, A. L. (2005). Analysis of route choice decisions by long-haul truck drivers. *Transportation Research Record*, 46–60. https://doi.org/10.3141/1923-06

Kockelman Maria, K., & Zhao, Y. (2000). Behavioral distinctions : The use of light-duty trucks and passenger cars. *J. Transport. Stat.*, 47–60. https://doi.org/10.21949/1501635

Koushik, A. N. P., Manoj, M., & Nezamuddin, N. (2020). Machine learning applications in activity-travel behaviour research: A review. *Transport Reviews, 40*, 288–311. https://doi.org/10.1080/01441647.2019.1704307

Lanzini, P., & Khan, S. A. (2017). Shedding light on the psychological and behavioral determinants of travel mode choice: A meta-analysis. *Transportation Research Part F: Traffic Psychology and Behaviour, 48*, 13–27. https://doi.org/10.1016/j.trf.2017.04.020

Lee, J. Y., Chung, J. H., & Son, B. (2008). Analysis of traffic accident size for Korean highway using structural equation models. *Accident Analysis & Prevention, 40*, 1955–1963. https://doi.org/10.1016/j.aap.2008.08.006

Liu, D., Du, H., Southworth, F., & Ma, S. (2017). The influence of social-psychological factors on the intention to choose low-carbon travel modes in Tianjin, China. *Transportation Research Part A Policy Pract., 105*, 42–53. https://doi.org/10.1016/j.tra.2017.08.004

Liu, X. H., Zhang, D. G., Yan, H. R., Cui, Y. Y., & Chen, L. (2019). A new algorithm of the best path selection based on machine learning. *IEEE Access, 7*, 126913–126928. https://doi.org/10.1109/ACCESS.2019.2939423

Lizana, M., Tudela, A., & Tapia, A. (2021). Analysing the influence of attitude and habit on bicycle commuting. *Transportation Research Part F: Traffic Psychology and Behaviour, 82*, 70–83. https://doi.org/10.1016/j.trf.2021.07.015

Mai, T., Bastin, F., & Frejinger, E. (2017). On the similarities between random regret minimization and mother logit: The case of recursive route choice models. *J. Choice Model., 23*, 21–33. https://doi.org/10.1016/j.jocm.2017.03.002

May, A. D., Koh, A., Blackledge, D., & Fioretto, M. (2010). Overcoming the barriers to implementing urban road user charging schemes. *Eur. Transp. Res. Rev., 2*, 53–68. https://doi.org/10.1007/s12544-010-0026-1

Moghaddam, Z. R., Jeihani, M., Peeta, S., & Banerjee, S. (2019). Comprehending the roles of traveler perception of travel time reliability on route choice behavior. *Travel Behav. Soc., 16*, 13–22. https://doi.org/10.1016/j.tbs.2019.03.002

Mohammadi, A., Kermanshah, M., & Moeinaddini, A. (2021). Investigation of safety attitude on passenger vehicle type choice : An integrated choice and latent variable (ICLV) approach. *IATSS Research, 45*, 336–346. https://doi.org/10.1016/j.iatssr.2021.02.003

Newsom, J. T. (2012). Some clarifications and recommendations on fit indices. *USP, 655*, 123–133.

Pojani, E., Van Acker, V., & Pojani, D. (2018). Cars as a status symbol: Youth attitudes toward sustainable transport in a post-socialist city. *Transportation Research Part F: Traffic Psychology and Behaviour, 58*, 210–227. https://doi.org/10.1016/j.trf.2018.06.003

Ringhand, M., & Vollrath, M. (2019). Effect of complex traffic situations on route choice behaviour and driver stress in residential areas. *Transportation Research Part F: Traffic Psychology and Behaviour, 60*, 274–287. https://doi.org/10.1016/j.trf.2018.10.023

Romero, F., Gomez, J., Paez, A., & Vassallo, J. M. (2020). Toll roads vs. Public transportation: A study on the acceptance of congestion-calming measures in madrid. *Transportation Research Part A Policy Pract., 142*, 319–342. https://doi.org/10.1016/j.tra.2020.11.001

Rowell, M., Gagliano, A., & Goodchild, A. (2014). Identifying truck route choice priorities: The implications for travel models. *Transp. Lett., 6*, 98–106. https://doi.org/10.1179/1942787514Y.0000000015

Simon, H. A. (1978). Rationality as process and as product of thought. *The American Economic Review, 68*, 1–16.

Song, X., Yin, Y., Cao, H., Zhao, S., Li, M., & Yi, B. (2021). The mediating effect of driver characteristics on risky driving behaviors moderated by gender, and the classification model of driver's driving risk. *Accident Analysis & Prevention, 153*. https://doi.org/10.1016/j.aap.2021.106038

de Souza, F. L. U., Larranaga, A. M., Palma, D., & Pitombo, C. S. (2021). Modeling travel mode choice and characterizing freight transport in a Brazilian context. *Transp. Lett., 00*, 1–14. https://doi.org/10.1080/19427867.2021.1976011

Strathman, J. G., Wachana, P., & Callas, S. (2010). Analysis of bus collision and non-collision incidents using transit ITS and other archived operations data. *Journal of Safety Research, 41*, 137–144. https://doi.org/10.1016/j.jsr.2010.02.003

Sun, Y., Toledo, T., Rosa, K., Ben-Akiva, M. E., Flanagan, K., Sanchez, R., & Spissu, E. (2013). Route choice characteristics for truckers. *Transportation Research Record*, 115–121. https://doi.org/10.3141/2354-12

Toledo, T., Atasoy, B., Jing, P., Ding-Mastera, J., Santos, J. O., & Ben-Akiva, M. (2020). Intercity truck route choices incorporating toll road alternatives using enhanced GPS data. *Transp. A Transp. Sci., 16*, 654–675. https://doi.org/10.1080/23249935.2020.1722284

Tseng, C. (2023). Social-demographics, driving experience and yearly driving distance in relation to a tour bus driver's at-fault accident risk. *JTMA, 33*, 910–915. https://doi.org/10.1016/j.tourman.2011.09.011

Walker, J. L. (2001). *Extended discrete choice models: Integrated framework, flexible error Structures,and latent variables*.

Wijnen, K., Janssens, W., De Pelsmacker, P., & Van Kenhove, P. (2002). *Marktonderzoek met SPSS: Statistische verwerking en interpretatie*. Garant.

Zhang, H., Lu, Y., Shi, F., & Zhu, D. T. (2012). Overloaded vehicle choice behavior analysis based on nested logit model. *Jiaotong Yunshu Xitong Gongcheng Yu Xinxi/ Journal Transp. Syst. Eng. Inf. Technol., 12*, 113–118. https://doi.org/10.1016/s1570-6672(11)60238-9

Zhao, P., & Gao, Y. (2022). Public transit travel choice in the post COVID-19 pandemic era: An application of the extended Theory of Planned behavior. *Travel Behav. Soc., 28*, 181–195. https://doi.org/10.1016/j.tbs.2022.04.002

Zhou, X., Wang, M., & Li, D. (2019). Bike-sharing or taxi ? Modeling the choices of travel mode in chicago using machine learning. *Journal of Transport Geography, 79*, Article 102479. https://doi.org/10.1016/j.jtrangeo.2019.102479

Zhu, Y., Jiang, M., & Yamamoto, T. (2022). Analysis on the driving behavior of old drivers by driving recorder GPS trajectory data. *Asian Transp. Stud., 8*, Article 100063. https://doi.org/10.1016/j.eastsj.2022.100063

Zudhy Irawan, M., Fajarindra Belgiawan, P., & Basuki Joewono, T. (2022). Investigating the effects of individual attitudes and social norms on students' intention to use motorcycles – an integrated choice and latent variable model. *Travel Behav. Soc., 28*, 50–58. https://doi.org/10.1016/j.tbs.2022.02.009