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RESEARCH PAPER

# A Review of Latent Variable on Urban Travel Behavior

**CHEN Jian[1, 2] GAN Mi[*3]**

1. Chongqing Key Lab of Traffic System & Safety in Mountain Cities, Chongqing Jiaotong University, Chongqing 400074, China
2. School of Traffic and Transportation, Chongqing Jiaotong University, Chongqing 400074, China
3. School of Transportation and Logistics, Southwest Jiaotong University, Chengdu 600031, China

**Abstract**: Latent variable method is an effective way to improve the prediction accuracy of travel behavior. And a new perspective to travel behavior research is provided by latent variable. In order to solve the problems about lack of cognition and application of latent variable of travel behavior, the characteristics of existing travel behavior modeling method are analyzed based on social psychology. And the necessity of research on the latent variable is proposed. The connotation, application field and model building of latent variable on urban travel behavior are systemized. Three core problems are defined, which are identification, validation and calculation. It is reviewed and studied the opportunity, difficulty and challenge of travel behavior integrated model covering the latent variables. The relevance between measure method of latent variable and SP/RP survey is revealed. And then the model test standard is summarized. Finally the development trend of latent variable research and the direction of our efforts are proposed.

**Key words**: traffic engineering; travel behavior; latent variables; integrated model; structural equation model

## 1 Introduction

The study of urban travel behavior is a significant basic theory for traffic engineering. Urban traffic development strategy, planning as well as rationality and accuracy of its policy-making directly depend on accurate analysis and through understanding of urban residents' travel habits. Many problems arise with our rapid social & economic development and urbanization, such as severe urban traffic congestion, lower traffic safe reliability, more energy consumption etc., moreover, newly-constructed urban railway system and BRT make the traffic environment diversified and complicated. Therefore, it is quite difficult to meet the accuracy and meticulousness, if we only consider the traditional travel behavior analysis model and method, which are based on observable observed variables. Recently, the study of latent variables in urban travel behavior becomes a hot point among international researches. However, there are still many key issues to be solved. It's the premise and key to systematically and comprehensively summarize the exiting achievement at home and abroad, and propose the possible research orientation for enhancing the urban traffic travel behavior research.

Travel behavior is a special commodity purchasing, and its essence is consumer choice behavior. According to consumer choice behavior theory, consumers' satisfaction (personal perceptions) to each alternative and the importance (personal attitude) of each alternative to the consumer will influence their preference to the alternatives, but personal perceptions and attitude cannot be measured directly[1], and sometimes, these choices are not completely rational, even possibly depending on their habit or emotion. Therefore, travel choice can be influenced by factors both observable and unobservable. However, during the current urban travel behavior study, both traditional 'four-stage method' and activities-based travel behavior analysis method focus on external influencing factors('four-stage method' is based on relations between SED (social, economic, and demographical, SED) and traffic system, while the activities-based travel behavior analysis method pays attention to relationship among daily activities and trips), and ignore the latent variables in external influences and travelers' psychological factors, which can't be directly observed and measured. This leads to lower accuracy and persuasion of the model so that the results are not that precise to real travel behaviors, which can't indicate higher prediction accuracy or scientifically objective nature of

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*Corresponding author. E-mail: migan@home.swjtu.edu.cn

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urban travel behavior. Correlational studies show that, latent variables do have impact on travel behaviors, such as travelers' attitude and cognition, and the said impact has been tried to add in traffic demand analysis model to improve the prediction accuracy and precision [2].

## 2 Analysis Method and Model for Travel Behavior

(1) Trip-based analysis model.

Currently, the trip-based 'four-stage method' model is used for travel behavior analysis. In 1970s, along with the proposal of random utility theory and discrete choice model, the 'four-stage method' began to focus on disaggregate model instead of aggregate model, moreover, its theory and technology were dramatically enhanced and developed. Scholars like Koppelman, McFadden and Wilson adopted disaggregate model to analyze the characteristics, such as travel mode choice and trip purpose[3-5], and then, Koppelman, Hensher, Schwanen [6-8] as well as national specialists Hongzhi Guan, Ming Yang and Tianran Zhang further improved and completed this disaggregate travel mode choice behavior model[9-11]. But the 'four-stage method' still has limits: model building based on each independent analyzing step (phase), lacking of systematical and internal coherence; not including kinds of relationships (such as time-space, interpersonal relationship or mode choice); or short of micro analysis on travel behavior characteristics.

(2) Activity-based analysis model.

Recently, 'four-stage method' suitable for medium and long term planning can't meet new research demands, as short term planning and management demands increase for urban traffic system. Therefore, activity-based travel behavior analysis method attracts more and more attention from domestic and overseas researchers, which originated from the 1970s. In 1983, a traffic research team, from University of Oxford, initiated a comprehensive research on activities and travel behavior, and took individual behavior into consideration under space-time limit to discuss and analyze the travel characteristics [12]. Damm, Golob and Kitamura provided overall discourses on theoretical method of activity-based travel behavior analysis[13-15], mainly including econometric model and hybrid simulation model. Mahmassani, Zhicai JUAN focused on the research of econometric model[16, 17], and Chandra, Ryuichi, Bowman, Zhicai JUAN, Yang ZHAO conducted useful exploration on the latter model[18-22].

(3) Analysis model based on big data platform and behavior experience.

With revolution and rising of modern IT, traffic travel behavior under this data environment and travel-behavior-based analysis become the hot point in this field. Scholars including Zongtao DUAN from the view of big data, proposed the atomic service computing platform based on distributing mobile traffic information, and formed a new-type traffic information service synergistic system[23]. Study from Tianliang LIU and etc. indicated that traffic information of friends circle in social networking services can influence individual travel choice, and different information exchange rate leads to differences in system global optimality[24]. 240 volunteers attended the experimental analysis of Y-shaped traffic networks with multiple bottlenecks launched by Terry[25]. Seltenand etc. selected 18 students in University of Bonn as subjects for rout selection behavior experiment [26].

These summaries indicate that:

(1) Big achievement on relationship between external factors (SED, activity) and trip has been reached, however, definition of latent-variable-based travel behavior influencing factors, travel behavior inner mechanism and travelers' choice-making process are not involved, because it can be quite simple or very complicated for travelers to make decisions, and this is an 'unknown area' to study;

(2) How to explore the inner mechanism behind travel behavior by quantifying latent variables is a scientific issue, as travelers' choice depends on many subjective factors, which can't be observed or measured directly.

## 3 Latent variables in traffic travel behavior

Latent variables are usually used for theoretical framework or unobserved variables, such as personality characteristics, emotions, social status and etc. Latent variables have different meanings in different fields. For traffic engineering disciplines, latent variables can involve service reliability, environmental perception, and potential preference of travel modes. Spear man adopted factor analysis method for human intelligence testing[27], which is regarded as the first study of latent variables. And latent variables are widely applied in many aspects, such as social sciences (Theodore, Mezzeti) [28, 29], psychology (Fabriga, Bollen)[30, 31], market & economics research (Ashok, Ebbes) [32, 33].

Generally speaking, traffic travel behavior model only considers directly-observed variables, like travel mode characteristics (travel time, fee and etc.) and travelers' personal socio-economic characteristics (age, gender, education background, income and etc.). However, relevant studies indicate that, travelers' perception on travel environment, conveniences and safety can also greatly influence their choice-makings.

It diversified traditional traffic travel behavior research to introduce latent variables, Train, McFadden, Ben-Akivafirstly applied this into traffic field[34, 35], and built the original discrete choice model framework for travel mode, involving latent vairalbes. After that, scholars like Mitra, Leeand analyzed the relationship between potential safety measures during traffic planning and road accident scale[36, 37], and Gopinath, Morikawa, Walker, Yáñez, Politisadded the influence of travel attitude and perception during