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Urban commuters' valuation of travel time reliability based on stated preference survey: A case study of Beijing

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ABSTRACT

Regarding travel mode choices, urban commuters always consider not only travel time but also travel time reliability of different modes. In this study, schedule delays were used for measuring travel reliability. The trip scheduling model and binary logit model were used to estimate the value of travel time reliability. First, by considering the impacts of the income level and time constraint, the trip scheduling models were developed. Then, data for model calibration was collected through street-interview survey based on the stated preference (SP) approach. Finally, the model was calibrated using the collected data and the commuters' value of travel time reliability were estimated. On the basis of the model results, the influence of income level and time constraint on the value of travel time reliability was analyzed. The results revealed that the value of travel time reliability differed significantly for different income and time constraint levels, and transportation modes. The developed models for travel time reliability analysis can be applied to supporting the travel cost analysis in the future.

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1. Introduction

Urban transportation demand has increased rapidly over recent years in China. The high growth rate of economic development and the increase of motorized mobility have led to severe traffic congestion during peak hours in Beijing, causing unreliable travel times for surface transportation in urban areas. For commuters, different transportation modes are available, but their reliability is unpredictable. Consequently, travel time reliability has a substantial impact on commuters' mode choice behavior. Therefore, it is essential to analyze the valuation of travel time reliability to understand the relationship between travel costs and mode choice decisions more clearly. The commuting transportation during morning peak is analyzed. During morning peak, commuters will face a strong pressure to arrive at work on time. While for afternoon peak, travel destinations may be home, shop, or entertainment location. Commuters will not face a strong time pressure. Therefore, travel time reliability will be regarded more critical during morning peak.

To analyze commuters' willingness to choose the travel schemes with the different reliabilities, the SP survey was conducted and the hypothetical situations were designed to evaluate their potential effects on individual commuters' choices. An SP survey can cover a wider range of attributes and conditions to more strongly support the development of the model.

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In this study, trip scheduling models were developed for both public and car transportation. On the basis of commuters' characteristics in Beijing, income level and time constraints were considered as the explanatory variables to estimate the value of travel time reliability. Quantitative values for the commuters' value of travel time reliability were derived based on the model results.

2. Literature review

Travel time reliability refers to the variations in travel time that cannot be predicted. Many researchers have defined travel time reliability differently. A commonly used definition of travel time reliability is the probability that travelers successfully complete a trip within the expected period of time (Asakura and Kashiwadani, 1991). Wigan et al. (2000) stated that reliability is the portion of a designated delivery that is late. Cambridge Systematics (2001) defined travel time reliability as a measure of the expected range in travel time, and provided a quantitative measure of the predictability of travel time. To estimate the value of travel time reliability and analyze it quantitatively, several statistical models have been established. Among the relevant studies, three common methods have been used to measure the value of travel time reliability.

In the first method, the value of travel time reliability is measured using a mean-variance model (Jackson and Jucker, 1982). Variability is considered a source of disutility, and time variability can be expressed by the variance of travel time. In the mean-variance model, utility is defined as a function of the mean travel time and variance. The mean-variance model was expanded upon by Senna (1994) on the basis of expected utility theory. Senna's model consists of the expected travel time, standard deviation of travel time, and cost. Valuation of travel time reliability is defined as travelers' willingness to pay for the cost of reducing variability.

Regarding the second method, Small (1982) proposed the trip scheduling model for analyzing travelers' departure time choices that satisfied on-time arrival. He defined schedule delay as the difference between the preferred arrival time and the actual arrival time. The scheduling model is an alternative approach to measuring travel time reliability that considers the consequences of unreliable travel time. The method to estimate the value of travel time, *SDE* and *SDL* was also proposed in his study. Noland and Small (1995) improved the trip scheduling model by adding the factor of the possibility of being late. Bates et al. (2001) proposed that the scheduling method is suitable for valuating travel time reliability in the passenger car context because of the continual adjustment of car driver's departure time. The ability of public transportation travelers to adjust their departure time is limited by the existence of a timetable offering discrete time choices for departure. Hollander and Small (2006) empirically estimated two models in the context of bus transportation, and proposed that, in addition to the mean travel time, variability was more accurately explained in the scheduling model.

Regarding the third method, the mean lateness model was proposed for measuring the value of reliability, and became the standard approach for analyzing reliability for rail transportation passengers in the United Kingdom (ATOC, 2002). In the model, travel unreliability is measured by the mean lateness of departure or arrival, while the mean earliness is not considered.

Under different traffic conditions, the value of travel time reliability may have significant differences. Therefore, to quantitatively analyze the value of travel time reliability, proper influencing factors should be considered. In this study, except for the travel time and cost, income level and time constraints were considered in the trip scheduling model. On the basis of survey data from Beijing, the value of travel time reliability was derived.

3. Methodology

In Beijing, commuting generally occurs during morning and evening peak hours in commuter corridors. This has a significant effect on the urban transportation system. In addition, commuting traffic constitutes a large proportion of total travels (Zhuge et al., 2012). Currently, public (including bus and subway) and car transportation (including taxi) are the two main modes. The users of these modes account for 90.8% of all travelers (Xia, 2013). Therefore, the reliability of the public transportation and car modes are considered in the model establishment. To achieve a clearer understanding of commuting behavior, home-to-work trips during morning peak hours were analyzed because arriving at work on time represents a major time constraint.

3.1. Analysis of influencing factors

The influencing factors were analyzed first. When commuters have different travel options, they consider various influencing factors such as travel mode, cost, time, and reliability (Asensio and Matas, 2008). The factors that can affect the commuters' travel options are summarized in Fig. 1.

3.2. Model development

To evaluate travel time reliability, the trip scheduling model was applied as the basic model, which proposed by Small first (Small, 1982). The schedule delay (*SD*) was used to establish the model. It expressed the difference between the pre-

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