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Incorporating attitudinal aspects in roadway pricing analysis☆

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ABSTRACT

The impacts of behavioral attitudes are rarely explored when it comes to roadway pricing strategies. The existing literature mainly focuses on observed traveler or trip characteristics and is less likely to capture latent preferences or heterogeneity of roadway users. Motivated to address this knowledge gap, the study herein puts an effort to examine how underlying behavioral attitudes will affect drivers' choices in utilizing managed lane facilities. Based on the data from the South Florida Expressway Stated Preference Survey, factor analysis was conducted based on ten attitudinal statements, and four latent attitudinal factors were identified: willingness to pay, willingness to shift travel schedule, utility (cost/time) sensitivity, and congestion tolerance. In order to assess managed lane's utility for drivers, two sets of multinomial logit (MNL) models were developed using combined revealed preference (RP) and stated preference (SP) data, with and without these attitudinal factors. Results indicated significant contribution of attitudinal parameters in the model, both in terms of coefficients and model performance. The factors were further used in a cluster analysis which identified major segments of roadway users. Such market segmentation is expected to provide valuable insights in capturing travelers' behavior while accounting for attitudinal aspects, which could enhance transportation planning efforts and policy making procedures.

1. Introduction

Observed trip attributes and individual characteristics such as trip purpose, trip length, income, gender, and age are usually the major focuses of roadway pricing studies as influential factors. Due to the multidimensional subtle complexities in choice behavior, choice analysis requires adequate attention towards both observed and unobserved characteristics. While attitudinal attributes hold the potential to represent unobserved characteristics of the traveler, they have rarely been incorporated in roadway pricing analysis.

Attitudinal aspects of travel behavior are originally derived from a psychological theory, known as theory of planned behavior (TPB). According to Ajzen (2001), intensions to perform actions of different kinds can be predicted with high accuracy based on attitudes toward those actions. Therefore, incorporation of attitudinal characteristics in travel behavior analysis is expected to provide the opportunity to increase the explanatory power of the models and reveal the intentions.

This paper intends to analyze and evaluate the impacts of attitudinal parameters on drivers' propensity toward using managed lanes (MLs). As a relatively new concept of roadway pricing (introduced about two decades ago), MLs offer roadway users some appealing features, including shorter travel times and higher levels of travel time reliability (Burris et al., 2015). In particular, the literature suggests that travelers favor MLs over increasing or placing of tolls on expressways (Greene and Smith, 2010). With increasing emphasis on MLs strategies in the US, it is critical to understand the behavior changes and underlying causalities in responding to MLs, in order to evaluate the program impacts and effectiveness.

Many studies have examined user sensitivity in response to travel time, travel time reliability, and toll cost. In most cases, the sensitivity was estimated without considering the attitudinal aspects of individuals. Only few studies focused on exploring the propensity of ML usage based on unobserved characteristics. Devarasetty et al. (2013) and Larsen and Burris (2014) considered several psychometric measures as the explanatory variables of ML usage, but the measures were found insignificant. Thus, previous efforts on addressing attitude were not sufficient. Given this context, this study aims to incorporate attitudinal variables (as indices of latent preferences) into roadway pricing analysis. The study will investigate the extent of influence for the attitudinal factors on the likelihood of using MLs, if there is any.

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2. Literature review

The literature in attitudinal applications in transportation planning can be broadly grouped into three categories – a) employed attitudinal factors as a set of explanatory variables, b) considered attitudes as an instrumental variable for market segmentation, and c) incorporated attitudes as latent variables in hybrid choice models (HCM) to make the model more realistic (Bolduc et al., 2008; Johansson et al., 2006, Kamargianni and Polydoropoulu, 2013). Although HCM is the most powerful behavioral modelling technique used to analyze attitudes/perceptions, the focus of this paper is to capture the influence of attitudinal factors on the propensity of ML usage which can be addressed using simple forms of logistic models.

The role of traveler attitudes and perceptions is often analyzed in mode choice contexts. Kuppam et al. (1999) analyzed 40 attitudinal variables in order to capture the latent preferences of respondents toward any specific mode. They developed three multinomial logit models – model included only demographic and socio-economic variables, model included only attitudinal factors, and model included both type of variables. Likelihood ratio test of model results implied that contributions of attitudinal variables were nearly twice compared with the contribution of demographic variables. Namgung and Akar (2014) examined the influence of 39 attitudinal factors on public transportation (transit) usage. They developed two binary logit models – with and without consideration of attitudinal variables. Results indicated that the inclusion of attitudinal factors in the model will lead to a significant increase in the model's statistical power. Van et al. (2014) analyzed 31 attitudinal responses from six Asian countries in a mode choice context with three options – car, public transport, and other modes (walking/motorbike/bicycle etc.). Attitudinal variables were incorporated into seven multinomial logit models – one combined model and six models for six countries. They identified barrier attitudes of using public transportation, and found that behavioral intention of using cars was strongly related to attitudes.

For analysis purpose, studies often require large amount of attitude information. In general, attitudinal responses were collected in a Likert scale or bi-polar adjective scale. The level of Likert scale varied across the studies from four levels, five levels (Khalilikhah et al., 2016), seven levels, to ten levels. To manage the large number of attitudinal variables, the most popular statistical technique to regroup homogeneous variables is factor analysis. The major objective of factor analysis is data reduction, where the main challenge is to identify the minimum number of factors that can explain most of the variances. The major criteria for selecting the number of factors include Eigen value (> 1), minimum factor loadings, Cattell scree plot method (elbow point), and percentage of variance explained by the factors.

Based on the criteria, Kuppam et al. (1999) reduced 40 attitudinal variables into 8 meaningful factors, Van et al. (2014) found 3 distinct factors from 31 attitudinal statements, Shiftan et al. (2008) reduced 38 attitudinal variables into 7 meaningful factors, Chao et al. (2013) extracted 6 factors from 36 service attributes, Beirao and Cabral (2008) transformed 35 attitudinal questions into 8 factors, and Anable (2005) identified 17 meaningful factors from 105 attitudinal statements. No uniform requirements of minimum factor loading and the percentage of variances explained were observed in the studies. For example, Van et al. (2014) considered 0.4 and Chao et al. (2013) considered 0.5 as minimum factor loadings, whereas Kuppam et al. (1999) accepted lower factor loadings (0.29). The 'sign' of factor loading may be negative also. Similarly, Van et al. (2014)'s study explained 52.6% of the variances, whereas Chao et al. (2013)'s model explained 66.70% of the total variance.

Another application of attitudinal data in transportation planning is market segmentation analysis. Some studies applied attitudinal data to identify distinct markets, mainly in public transportation usage. The process involved two stages – reduction of attitudinal dimension by either factor analysis or structural equation modelling (SEM), and assigns each observation to a corresponding factor through cluster analysis.

Attitudes were found to be influential in several behavioral aspects of transportation applications, including the perception regarding public transportation features, consciousness on vehicle emission reduction, assessment of a new transportation alternative, obligation to time saving and flexibility, and sensitivities to costs and stress (Parkany et al., 2005). Regarding roadway pricing, there are not enough empirical evidences on application of attitudinal data for travel behavior analysis. Some studies partially focused on quantifying the impact of attitudes on willingness to pay (WTP) estimation. For example, Abou-Zeid et al. (2010) and Lowery et al. (2011) quantified attitudinal impact on value of time (VOT), but ignored the attitudinal impact on reliability (VOR).

In some cases, researchers claimed to address attitudes in analyzing roadway pricing behavior, but they actually failed to separate the concept of 'attitudes' from 'preferences'. Rather than analyzing latent characteristics, they were more focused with observed characteristics. Therefore, WTP were influenced mainly by observed characteristics, such as income, age, trip purpose, time of day, trip distance, and thereby did not reflect latent preferences. For instance, Li et al. (2002) identified potential ML users based on trip purpose, gender, age group, and income attributes. They did not consider any latent characteristics of the respondents, rather assumed observed characteristics as attitudes. Similarly, Zmud et al. (2015) developed binary logit models for tolled facilities, but attitudes were only incorporated in survey design and respondent recruitment stage. In another study, Lowery et al. (2011) found that respondents in a suburban area who sensed congestion in upcoming years were more interested to use ML. However, sense of congestion is more like a perception rather than a behavioral attitude.

Based on a study in Edinburg (UK), Allen et al. (2006) showed that even a well prepared congestion pricing scheme can be rejected if the scheme failed to accommodate different attitudinal aspects of its potential users. Thereby, attitudinal aspects of behavioral modelling is reasonable and worth exploring from transportation planning perspectives. In light of the above discussion, it can be inferred that many studies were conducted on estimating the impacts of attitudinal factors in the broad area of travel behavior analysis. A significant number of efforts were also given on estimating roadway pricing parameters, such as VOT and VOR (Carrion and Levinson, 2012). However, a distinct gap in the literature can be observed regarding the contribution of attitudinal factors on VOT and VOR estimation.

3. Data sources

The data used in this study came from the South Florida Expressway Stated Preference Survey, which was conducted by Resource System Group between November 16 and December 15, 2011 (Resource System Group, 2012). The survey targeted drivers on three major corridors, including I-75, I-95, and SR 826. At the time of this study, express lanes already existed on I-95 between the SR 112 interchange in the south and the Golden Glades interchange in the north, while new express lane projects were being proposed for the other two corridors.

A total of 2041 respondents were surveyed (including 1060 from I-95, 521 from I-75, and 460 from SR 826). Among the 1060 I-95 travelers, 513 were eligible for the ML (eligibility was determined by the entry and exit points of the trips). Each respondent faced eight SP scenarios. The final cleaned dataset had 513 RP responses and 16,327 SP responses. Some screen captures of the survey are depicted in Fig. 1.

Each SP scenario offered five different choice alternatives, including general purpose (GP) lane, managed lane (ML) in peak hour, managed lane before the peak period (ML2), managed lane after the peak period (ML3), and managed lane with additional passengers (ML4). Scenarios were customized based on individuals' travel information. Accordingly,