Residents’ action response experiments on different travel modes under the external conditions of a metropolitan environment

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Abstract. The residents’ action response experiments are a complex decision making procedure and a natural science question influenced by multiple indicators and the built environment. It can reflect the urban traffic pattern and resident travel structure at a micro level, which gives us the motivation for better understanding and revealing residents’ behavioral characteristics and influencing factors of different travel modes quantificationally and systematically from the metropolitan environment perspective (novelty). This is of great guiding significance and necessity for the implementation of transportation demand control, optimization of urban traffic system, daily travel decisions of metropolitans, traffic environment, especially in the current application of computer big data analysis techniques. In this paper, we give a discussion and exploration for analyzing the people’s action response problem on different travel modes with external conditions in a metropolitan environment.

1. Introduction
Understanding people’s travel behavior/action response is essential for the planning and governance of transportation systems and environmental impact assessment (fundamental interaction). Among all travel behaviors, travel mode choice (such as walk, cycling, bus, metro, auto, shuttle bus) becomes the most important decision that affects the efficiency of the whole transportation systems. And thus has attracted considerable attentions from researchers and scholars in multiple disciplines including transportation engineering[1-2], geography[3], urban planning and economics[4-5]. Besides, the travel behavior of urban residents is of increasing interest to researchers and planners, and the choices of travel mode for daily mobility/built environment have significant effects on the future development of urban regions due to urban sprawl and structural changes to growing metropolitan areas related to the transportation development[6-8].

2. Random utility maximization
It is a kind of commodity consumption (utility) and the travel mode choice behavior is essentially a consumer’s choice behavior[9]. So in view of the random utility maximization (RUM) theory, different kinds of discrete choice models such as binary logit (BL) model, multinomial logit (MNL) model, nested logit (NL) model, and cross-nested logit (CNL) model are established to describe the mode choice behavior of commuting traffic and daily family activities in the metropolitan area. Combining with data obtained from the investigation, parameter calibration, model testing and forecasting comparison would be conducted to make a more reasonable and scientific explanation for the travel behavior in reality. Using the BL model and dataset in Libya, Miskeen, Alhodairi and
Rahmat (2013) analyzed people’s choices of car and airplane modes for business trips, and their responses to various conditions (reduction in airplane out-of-vehicle travel time) and factors (e.g., gender, education level, nationality, household income, car ownership) were successfully calibrated and validated[10], which would be helpful for decision makers at all levels to allocate wisely resources and improving the transportation environment.

Further, Abane (2011) used an MNL model to discuss the commuting behavior of residents in four metropolitan areas in Ghana[11]. Yao, Sun and Guan (2010) divided travel modes into public transport and private transport, and an NL model of travel choice behavior was established. The regression results demonstrated that some explanatory variables such as age, trip purpose and travel time significantly affected the residents’ choice of travel mode[12]. Zulqarnain, Mark, John and Michael (2017) also developed an NL model to study the behavior of commuters to downtown Pittsburgh who used car, bus, light rail, walking and biking[13]. Additionally, the joint choice of residential location, travel mode and departure time was expressed and compared by CNL and traditional NL models with the Beijing traffic survey data[14].

3. Sociodemographics and built environment

Extensive studies have been carried out to explore what factors significantly affect the travel behavior and mode choices, several show that socio-demographic/socio-economic indicators of households and individuals strongly influence people’s travel mode choice and action response[15-17].

For instance, according to the research of Prillwitz and Barr (2011), female travelers, young and middle-aged travelers, travelers with few private cars, as well as those with high incomes were more willing to travel in environmentally friendly ways[18]. In contrast, Plaut (2005) claimed that younger, higher-income urban residents were more likely to travel by motorized vehicles, and men tended to drive more frequently than women[19]. Chang (2013) found that travel behavior and mode choice patterns differed between age groups. The results illustrated that for the elderly, safety and convenience were the two most noteworthy aspects in travel mode choice[20]. Santos, Maoh, Potoglou and von Brunn (2013) examined the effects of travelers’ incomes and education levels on the demand for public transit, which presented that both of them positively affected the transport mode share patterns[21]. In the Chinese context, higher income, higher job status, and car ownership were associated with greater probabilities of auto use, while female and older residents preferred walking and/or cycling[22-23]. Moreover, trip attributes such as departure time, locations and travel time observably impact the choice behavior as well. Ettema and Timmermans (2003) indicated departure time (or period) had a vital effect on the travel behavior of commuters and older people[24]. Yang, Zheng and Zhu (2013) pointed out that for different travel time (or distances), none of the modes could always have advantages over the others[14], and different travel modes usually had different competitive powers under different scenarios. It can be seen that travel time, departure time, trip purpose (trip information) and gender, age, income, education level, car ownership (residents’ socio-demographic characteristics) are the most frequently examined variables in the mode choice analysis (travel mode choice models).

To sum up, based on the above literature review, it can be found out that although quite a few of the previous studies have explored the causal relationship between some factors and travel mode choice behavior, most of the indexes are limited to a certain aspect (not comprehensive and systematic)[25-27]. And in preceding research[28-29], indexes influencing the choice of travel mode of urban residents can be summarized as: the travelers’ traits, trip characteristics, and transport properties/travel environment. Therefore, factors associated with residents’ travel mode choice/action response in the metropolitan area (external environment) would be divided into four classes, namely, household characteristics, individual attributes, trip information, and trip origins/destinations (ODs) in this work.
4. Panel effects with external environment

Whereas mixed logit (ML) model, evolved and improved from logit models, overcomes two main deficiencies – independence of irrelevant alternatives (IIA) and limitation of random taste variation (LRTV) [30]. Then it can more properly resolve the problem of individual heterogeneity (much closer to the reality) and be used to elaborate and explain choices more reasonably and effectively, particularly when there are continuous variables involved (e.g., time).

On the basis of the 6-week panel gathered in Germany (multi-day travel surveys), empirical evidence was provided on the effects on prediction and validation of different types of correlation and different ways to draw holdout samples. These researchers confirmed that the way holdout samples were extracted affected the validation outcomes and that the best results were obtained when a percentage of individuals with all of their observations were used. The logit model in the presence of taste heterogeneity could produce biased modal shifts, but did not seem to produce relevant effects on environmental impact assessment and analysis [31]. An integrated stated choice study was designed by Guo, Feng and Timmermans (2020) to simulate and estimate the multidimensional choice behavior concerned with residence, job and transportation mode for the commute trip in Shenyang, China, their results of an error component mixed logit model with panel effects indicated that most selected attributes of the residential environment, job profile and transportation mode were significantly related to individual differences in multidimensional choices and the unobserved heterogeneity existed between relocation and transportation mode choice [32]. Gao, Ranjbari and MacKenzie (2019) also employed a stated choice experiment in which respondents chose between driving a personal vehicle or taking ridehailing services to examine the effect on value of travel time and its magnitude [33], the ML modeling (panel data were considered) analysis results indicated that the value of travel time was 13% lower when being driven in ridehailing services than when driving a personal car.

We have also found out applications of ML model (especially with panel data) in terms of the travel mode choices made by urban residents are not so common through a literature search [34-38], and the comparisons with other logit models are even rarer. Hence, on account of the panel data, mathematical models could be established to investigate and explore the residents’ action response problem and influential variables of different travel modes quantitatively, logically and clearly in a metropolitan environment.

5. Discussion

Over the past few years, a stream of new studies has been published on travel mode choice in China [39-42], but our work will distinguish in the three respects from this recent literature. First of all, these studies focus on commuting while mode choices for other travel purposes and the determinants involved remain largely unknown. Next, to our knowledge, the existing literature does not integrately analyze the influence of household and individual attributes, and trip information on travel behavior. Finally, most of these current researches on mode choice in China draw on data from Beijing [41-43] and Shanghai [44], these are China’s main and biggest cities. While like Nanjing is an example of a so-called ‘new first tier’ city (in figure 1), it is relatively smaller in size, and compared with those megacities, there is still a certain gap in urban population activity and the agglomeration of commercial resources. As the majority of future Chinese urban residents will live in these ‘new first tier’ cities, more empirical data on travel behavior in cities like Nanjing are urgently needed to increase understanding of the effects of different transport contexts/modes for travel behavior in China in the future (namely, citizens’ action response experiments).
6. Conclusion
Together, these reasons suggest that specific research is urgently needed into travel behavior and more
detailed into mode choice in China and its determinants. We can comprehensively and thoroughly
analyze the interaction/choice principle of residents’ travel behavior in metropolitan area from four
aspects – household characteristics, individual attributes, trip information, and trip ODs, then explore
and mine the multiple variables remarkably affecting travel mode choices (inclinations). Use
unordered MNL and ML models to conduct an in-depth comparison analysis for travel mode choice
behavior in light of the panel effect (residents’ action response tests). And through the interpretation
of modeling regression results, responses acting among different travel modes and residents’ travel
rules/traits would be expounded orderly.

In the future research, given the conditions of high-speed and large-scale urbanization, we are
willing to conduct dynamic and continuous observations of the survey data in selected cities when we
need to further analyze the characteristics of residents’ travel mode choice behavior in depth.
Moreover, some ‘soft’ variables (e.g., psychological and sociological variables, individualized
attitudes and lifestyle-oriented variables) might become increasingly important in the explanation of
travel behavior and environmental effects (the citizens’ action response issue), and they also could be
covered and investigated in a future study.

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