Exploring the impacts of online car-hailing service on individuals’ travel behavior

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Abstract. Online car-hailing is growing rapidly in popularity worldwide and provides a new travel mode to the urban residents. However, every coin has two sides, it does increase urban mobility while cause some new problems, such as safety concern and privacy issues. Therefore, it is urgent to facilitate the benefits of online car-hailing and avoid the negative impacts at the same time. With this consideration, this paper aims to provide a better understanding of the travel behavior induced by online car-hailing and the modes transfer to it. We apply Hierarchical Tree-based Regression (HTBR) to explore the influencing factors of the inducement and transferring mode, using the data collected by a web-based survey published on DiDi app. The results show that the passengers’ demand for car-sharing is the most significant factor to attract more traversers to use online car-hailing and car ownership mainly influence transferring mode. Finally, we provide some practical suggestions for the city operators.

1. Introduction
In recent years, the booming development of online car-hailing has brought new choices to urban transportation with the development of the Internet and the popularity of mobile terminals. The emergence of app-based, on-demand ride services has provoked spirited debates over their role in urban transport. Therefore, as the hotspot issues in the current society, it is necessary to study the impacts of online car-hailing service on urban cities in order to promote positive impacts and reduce negative impacts. Specifically, the characteristics of online car-hailing users who are induced to travel and the modes transfer to it should be found.

Comprehensive studies have been carried out in many developed countries (USA, Europe, Korea, etc.) [1-4] on the issues of characteristics of car-sharing and the environmental influence. However, previous findings in developed countries did not pay attention to the inducement and transferring mode by online car-hailing and significantly underrepresented the impacts in China. As thus, this study tries to investigate this issue by developing a methodology to understand the impacts of online car-hailing on travel behavior.

The rapid expansion of online car-hailing services has fundamentally changed the way people choose travel mode from point A to point B [5], and this may affect the optimization of the urban transportation. Recently, extensive researches have begun to pay attention to the role of online car-hailing service playing in urban city. In general, online car-hailing services have supplemented the public transportation, optimized traffic resource allocation [6]. The information symmetry of car-hailing platform facilitates accurately matching the demand and supply, greatly reducing the waste of transportation resources. Lishan Sun et al. analyzed and evaluated the effect of shared transportation on alleviating or solving traffic and environmental issues in mega-cities from five perspectives to affirm the positive effect of
shared transportation on solving the traffic and environmental problems in mega-cities [7].

However, the online car-hailing may also be a double-edged sword. In addition to the positive effects mentioned above, there will be negative effects. Some studies pointed out that considering the availability of car-hailing, it may cause more frequent car uses, which is negative to the urban traffic and city environment [8]. Tian Wu said that only 43% of online car-hailing services in China were to substitute private vehicle travels in 2015. Increased gasoline consumption induced by online car-hailing services will contribute to urban air quality and human health problems which are already serious social concerns in Chinese cities [9]. Lisa Rayle et al. investigated and obtained traffic information about online car-hailing in San Francisco, compared survey data with bus travel data, and analyzed the impacts of using taxi software on bus travel. The results showed that taxi software will attract more travelers and reduce their dependence on bus [10]. Tom Wenzel et al. found that commuting and between-ride “deadheading” account for 19% and 26% of online car-hailing VMT (vehicles miles traveled) and it increased energy use by an estimated 41–90% compared to baseline, pre-TNC, personal travel [11]. We can know that researches in the past mainly focused on the positive impacts and the environmental impacts. However, there are fewer papers studying the negative impacts and the researches on induced travel and transferring mode are just explanatory analysis.

This study aims to study DiDi chuxing, which is the biggest online car-hailing service company in China. We want to examine DiDi users' characteristics of inducement and figure out the transferring from other modes to online car-hailing based on a web-based traffic survey in three first-tier cities in China, which is critical for planners to manage online car-hailing service. Specifically, using the method of Hierarchical Tree-based Regression (HTBR), we can systematically analyze the impacts of online car-hailing on the urban traffic. Future research should build on this exploratory study to further understand impacts of online car-hailing on labor, social equity, the environment, and public policy.

2. Methods

To collect data on online car-hailing users and trips, we conducted a web-based travel survey. Compared to other types of surveys, the web-based questionnaires are convenient for respondents and can reach out to broader respondents with few geographical restrictions [12]. We cooperated with DiDi chuxing and the survey was first conducted on DiDi chuxing app for about 10 days from the 13th of October to the 23th of October, 2017, covering the first-tier cities including Beijing, Shanghai and Shenzhen, which similarly featured at the urbanization level, resident income level, economic and social development, online car-hailing popularity and traffic pattern.

In order to obtain information about inducement behavior and transfer mode pattern in China after the appearance of online car-hailing, we designed 2 questions in the questionnaire. For the last DiDi chuxing trip, if there is no DiDi chuxing, will you cancel this trip? For the last DiDi trip, if there is no DiDi, what kind of travel mode will be used?

The first question is designed to investigate the inducement by online car-hailing. If respondents cancel their trips it represents that their travel behavior is induced by online car-hailing. The second question continues to analyze which modes those who do not cancel their trips will choose. The alternative modes can be interpreted as the original modes those respondents chose before the appearance of online car-hailing. So, from the second question we can get the mode transferring by online car-hailing. Combining two questions above, we can describe the impacts of online car-hailing on urban transportation system. To explore the factors associated with online car-hailing users' travel behavior, the explanatory variables mainly include online car-hailing users’ socio-demographic characteristics, such as age, gender, education, occupation, annual family income, car ownership, etc. Also, online car-hailing service characteristics are included, such as most commonly used DiDi service, DiDi travel frequency, the main use of DiDi, DiDi using time and DiDi service satisfaction.

3. Descriptive analysis

3.1 Inducement
Finally, a total of 10588 responses were collected. There are 10517 valid responses that can be used to analyze after filtering out incomplete, incorrect and inaccurate data. Figure 1 shows that for the last DiDi trip, if there are no DiDi, 11.28% of respondents will cancel their trip and 88.72% of respondents will not. It means there are 11.28% of respondents are induced by DiDi chuxing.

Figure 1. The statistical pie chart of inducement

3.2 Transferring mode
Figure 2 shows that among the 88.72% of respondents who will not cancel, 35.95% of respondents will use green modes including slow traffic, bus and metro. 47.56% of respondents will use taxi and other modes, and 5.20% of respondents will use cars. It means that DiDi chuxing mainly substitute taxi, followed by public transportation.

Compared to private cars, the public transportation is high intensive mode and slow traffic does not occupy road resources. So, the transferring from green modes to online car-hailing is negative. On the other hand, transferring from private cars to online car-hailing should be encouraged. We will focus on these two transferring modes.

4. Influencing factors result
Two HTBR models are constructed to characterize the importance and ordering of different levels of influencing factors of inducement (HTBR Model #1) and transferring mode (HTBR Model #2). The HTBR analysis in this study was carried out using the IBM SPSS21.0 software package. The specifications for tree construction include: the maximum tree depth is set as 3 levels; the significance values for splitting nodes and merging categories are set as 0.05. The minimum number of cases for parent nodes is set as 200 and the minimum number of cases for child nodes is set as 100 in this model.

4.1 Inducement
The results of HTBR model 1 are displayed in Figure 3. The final tree structure for inducement involves five splitting variables, including Education, Most commonly used DiDi service, DiDi satisfaction, Gender and Main use of DiDi.

The first level of the tree shows that the most important classification factor for inducement is education. The first optimum split in node 0 is according to educational background, which classifies inducement into three subgroups: with low education, 20.9% of respondents will be induced, which is higher than junior college degree (12.3%), undergraduate degree (9.8%), postgraduate degree and above (6.7%). The results of inducement are ultimately in line with the different educational background.

In the second level of the tree, DiDi satisfaction further splits the inducement in lower education, undergraduate, postgraduate and above into child groups. Most commonly used DiDi service divides
junior college into child groups. For respondents in lower education stage, if respondents are very satisfied with DiDi service, 28.5% of the proportion will be induced; for respondents in undergraduate stage, if respondents are very satisfied with DiDi service, 18.2% of the proportion will be induced; for respondents in postgraduate stage, if respondents are very satisfied with DiDi service, 14.7% of the proportion will be induced, which is higher than the group that respondents are satisfied/basically satisfied/not satisfied with DiDi service (17.8%, 8.4%, 5.5%). For respondents in junior college stage, most commonly used DiDi service divides it into three subgroups. If respondents most commonly use shunfengche (car-sharing), 21.1% of the proportion will be induced, which is higher than kuaiche (12.1%), DiDi taxi or zhuanche (7.3%).

The general trend is that people who are very satisfied with the DiDi service, who commonly use shunfengche (car-sharing) have a greater probability to be induced.

In the third level of the tree, main use of DiDi splits the node 6 into two subgroups and gender splits the node 10 into two subgroups. The terminal node 17 and node 18 indicate that for people with undergraduate degree and are very satisfied with DiDi service, if the purpose of DiDi is commuting, 21.9% of the proportion will be induced, which is much higher than that of non-commuting (14.6%). The terminal node 21 and node 22 indicate that if respondents are male, 6.9% of the proportion will be induced, which is higher than that of female (4.2%).

It shows that people who mainly use DiDi for commuting propose have a greater probability to be induced by DiDi.

4.2 Transferring mode

Then, we analyzed the influencing factors of transferring mode outside the inducement. Figure 4 shows the results of HTBR model 2, which are applied for transferring mode classification. The final tree structure for transferring mode is dependent on five variables, including Car ownership, Occupation, Age, Annual family income, Main use of DiDi and DiDi using time.

The first level of the tree shows that the most important classification factor for transferring mode is car ownership. It classifies the transferring mode into two sub-groups. For people have cars, 37.5% of respondents will transfer from green modes, 8.3% of respondents will transfer from cars and 54.2% will transfer from taxi and other modes. For people do not have cars, transferring from green modes accounts for 46.5%, transferring from cars accounts for 1.2% and transferring from taxi and other modes accounts for 52.3%. There are clear pattern about transferring mode. People have cars are more likely to transfer from cars and less likely to transfer from green modes.
In the second level of the tree, occupation leads to further splits at node 1 into child groups. Age divides node 2 into child groups. For respondents have cars, if respondents with educational occupation, 53.6% of the proportion will transfer from green modes and 5.5% will transfer from cars; if respondents are general staff, 40.7% will transfer from green modes and 6.3% will transfer from cars; if respondents are leadership or middle and senior manager, 30.8% will transfer from green modes and 11.2% will transfer from cars; if respondents with medical or unsteady occupation, 34.0% will transfer from green modes and 8.4% will transfer from cars; The probabilities of transferring from green modes are ultimately in line with the age.

The general trend is that people who are younger, with educational occupation or people who are general staff have a greater probability to transfer from green modes. People who are leadership or middle and senior manager and people with medical or unsteady occupation are more likely to transfer from cars.

In the third level of the tree, annual family income splits the node 4, 5 and 6 into two subgroups, main use of DiDi splits the node 7 into two subgroups, DiDi using time splits the node 8 into two subgroups. The general trend is that people have low or medium income are more likely to transfer from green modes and people have high income are more likely to transfer from cars. The terminal node 18 and node 19 indicate that for 25-34 years old people who do not have cars, if the purpose of DiDi is commuting, 49.1% of the proportion will transfer from green modes, which is much higher than that of non-commuting (42.8%). The terminal node 20 and node 21 indicate that for 18-24 years old people who do not have cars, if respondents use DiDi at peak hours, 67.8% of the proportion will transfer from green modes, which is higher than that of off-peak hours or random time (4.2%).

It shows that people who have low or medium income, mainly use DiDi for commuting propose and use DiDi at peak hours have a greater probability to transfer from green modes. People who have high income are more likely to transfer from cars.

5. Conclusion
This study aims to investigate the impacts of online car-hailing on urban transportation system based on a traffic survey conducting by DiDi chuxing in three first-tier cities, Beijing, Shanghai, and Shenzhen. The study examines the characteristic of online car-hailing users in order to analyze the inducement pattern and transferring mode by online car-hailing service.

The inducement by online car-hailing service is the major concern to the society. Fig 1 shows that 11.28% of the online car-hailing users are induced. So, online car-hailing service really stimulates people to generate new traffic to urban city. According to the survey in San Francisco, 8% of the users are
induced [10]. Online car-hailing service induces more travels in China. Compared to the mega city in America, in first-tier cities in China, the development of public transportation started late and there are more communities with poor road network, poor transport access, immature taxi market, and rare parking space supply. This is what the operators need to improve. The inducement is ultimately in line with the different educational background. It seems that people with lower educational degree may generate the potential traffic to urban transport. For the satisfaction of online car-hailing service, the trend is that people who are very satisfied with the online car-hailing service are highly adherent to it, and are more likely to be induced. It reminds us that the quality of service is an important indicator of urban transport services. People who commonly use shunfengche (car-sharing) have a greater possibility to be induced because shunfengche (car-sharing) is a unique mode and has low substitutability among travel modes while kuache, zhuancher, DiDi taxi has the similar pattern with taxis.

Another issue we try to study is the transferring mode by online car-hailing service. Although online car-hailing and taxis serve a similar market demand and the two types of services covered similar areas and trip lengths [10]. The survey results suggest that other than taxi, more than half of the online car-hailing trips transfer from green modes and cars. Figure 2 indicates that green modes account for 35.95%, including slow traffic, bus and metro. Cars account for 5.20%. Taxi and other modes account for 47.56%. The transferring from cars to online car-hailing service should be encouraged and the transferring from green modes to online car-hailing service are negative and need to be noticed. Not surprisingly, car ownership determines the original modes so people have cars are more likely to transfer from cars. People with lower income have a greater probability to transfer from green modes while high income group are more likely to transfer from cars. This is due to the inconsistency in consumption levels. Using online car-hailing service at peak hours or for commuting purpose tend to transfer from green modes shows that the experience for green modes in commuting hours are bad so the online car-hailing service can attract these people.

The survey reveals several meaningful results. First, the passengers’ demand for shunfengche (car-sharing) is an important reason for the inducement by online car-hailing service and car ownership is the key point for transferring mode. Second, People pay more attention to the satisfaction of travel modes. Third, people who travel for commuting purpose are more inclined to be induced or transfer from green modes by online car-hailing. Furthermore, other than taxis, green modes are mainly replaced by online car-hailing.

Future research work is recommended in exploring the impacts of origins, destinations and travel distance to determine the area with low-quality transportation and lacking in parking lots. Also, it is worth to study the relationship between travel distance and transferring mode, which is important to enhance the quality of public transportation service. These related studies can help the city operators to better manage the city and control urban traffic.

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