Benefits and Risks of the Driving Restriction Policy: A Case Study of Xi’an, China

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ABSTRACT With the deterioration of air pollution and traffic congestion especially in urban areas, the policy restricting cars operating on the road is deemed as an effective strategy to mitigate the negative impacts. After implementing the driving restriction policy (DRP), some benefits were yielded albeit a few problems appeared. It is desirable to assess the benefits and risks of the DRP and thus propose measures to maintain the benefits. A revealed preference (RP) survey was conducted in the field and via the internet. There are 585 valid samples collected, which were classified by socioeconomic factors, and the corresponding reactions were analyzed and compared. The correlation analysis was used to identify significant and independent demographic/characteristic variables. The results show that most travelers perceive benefits from reducing car ownership and have positive views on DRP. However, others would negatively react to the DRP, which is mainly manifested by buying another car, driving during non-restricted hours and traveling against regulations. Furthermore, socio-demographic characteristics show a relatively high correlation with travel mode choice. Automobile is favorable to middle-aged travelers with upper-middle income. Family characteristics (i.e. household structure, pick up children and cars ownership) are also important inducing travelers to use private cars. These findings will be helpful for formulating the DRP to yield greater benefits after implementation.

INDEX TERMS Driving restriction policy, mode choice, descriptive statistical analysis, correlation analysis, benefits, risks.

I. INTRODUCTION The driving restriction policy (DRP) has been deemed as an effective means to limit the number of cars traveling on the road, which is also regarded as a simple and quick approach to shift travelers’ choice from automobile to other transportation modes [1]. The vision of transportation authorities was manifested in the goal of DRP, which aims to improve mobility and safety as well as to mitigate environmental impact such as air pollution by decreasing the number of cars running on the road during weekdays. Besides DRP, other traffic demand management (TDM) strategies have been adopted, such as increasing parking fees [2] and fuel taxes [3], imposing congestion charges [4], [5] and offering incentives for using public transportation modes [6]. Compared with congestion charging and increasing fuel tax policy, the DRP was recognized as a strategy with higher acceptance [7] and immediate effects [8], which is deemed as an integral part of the solution to ease the impact of traffic congestion.

The DRP was first implemented abroad, such as Santiago [9], Mexico City [10], [11], and it has been widely implemented in China in recent years (i.e. Beijing [12]), which is shown in Fig 1.

Beijing implemented the odd-even license plate restriction (OER) for easing congestion during the Olympic Games in 2008. Since 2011, the DRP became popular in China to reduce travel delay and ease environmental and other traffic-related impacts. However, the benefits and risks associated with the DRP vary in different cities because of the hike of economic and industrial development. Yi et al. [15]
analyzed the PM 2.5 concentration in 11 cities and found that the causes of haze pollution vary geographically. For a city under highly developed economic settings with low air pollution (such as Beijing), the DRP would be effective to mitigate haze.

The location convenience plays a critical role for us to select Xi’an as the study city. Unlike Beijing, Xi’an is under moderate economic settings with heavy air pollution and traffic congestion. The effects of DRP brought to this city would be different from those with Beijing. It is desirable to investigate the differences, and we hope the outcomes could be beneficial to the cities with similar characteristics to Xi’an in developing the DRP.

Xi’an is a medium-size city in China with population around 10 million. The increase of the road capacity is behind the growth of demand. The air pollution caused by vehicle emissions has aroused public concerns. A study indicated that the number of vehicles in Xi’an had exceeded 3.3 million in 2018, in which the number of private cars was yielded 2.8 million. According to annual report on transportation development in Xi’an in 2018, the residents traveling with buses and trains account for 24.5% and 10.9%, respectively. However, the traffic condition is still very congested. Thus, the DRP was adopted, and the implementation and improvement process are shown in TABLE 1.

The initial purpose of implementing the DRP was to improve the air quality, especially in winter. The initial DRP was applied to city-wide all weekday for 3 months. During this period of time, the driving restricted measures varied according to the level of pollution alert (e.g., for level III alert, the ODR needs to be implemented; for level I alert, the OER is implemented). Note that the DRP did not apply to the bus, taxis, green energy vehicles and special vehicles (e.g. ambulance, fire trucks). In the early stage of the implementation of the DRP, the traffic police just gave the admonishment to drivers who violated the regulations. The fine of 200 yuan with 3 points would be charged to those who violate the regulations from November 15, 2016. After implementing the DRP, the emission of four main pollutants from motor vehicles decreased by 17.5%, about 590 tons in 2016.

The resulting benefit after implementing DRP greatly encouraged the government to adapt to similar policies with less restrictions. From November 20, 2017 to March 15, 2018, the DRP was implemented and applied to two numbers (the last digit of the tag number) with shorter period of time per
day (7:00 a.m. to 8:00 p.m.) again, which aimed not only to improve air quality but also to ease traffic congestion. Further, the restricted area is smaller. Considering the increase of transit ridership after implementation of DRP, transit agencies increased the service frequency in peak hours to fully meet the demand. The degree of congestion decreased by 13.1%. Nearly 440,000 vehicle trips per day were reduced, in which 47,000 vehicle trips were reduced during the peak hours (Major Cities of China Transport Report, 2017).

The economic development had fueled strong motivation to stimulate vehicle ownership, resulting in serious traffic congestion. A periodical DPR in a form of ODR was initiated in 2018.

Although the DRP has been deemed as an effective solution to ease congestion and pollution, the public resistance, mainly from residents who own cars, to the policy was concerned by decision makers. We hope the outcomes of this study could identify the source of the problem and suggest solution to ease the tension. First of all, the drivers’ perceived benefits and risks of DRP are evaluated, considering available transportation systems as alternated modes. Secondly, the characteristics of travelers who tend to use less environmentally friendly mode are obvious. Finally, suggestions may be summarized to assist the DRP implementation. Note that the survey results derived in this study not only provide suggestions to Xi’an City to improve the effectiveness of the DRP but also serve as references for other cities planning to promote the DRP.

The rest of this paper is organized as follows. Section 2 discusses the previous studies related to DRP. Section 3 describes the process of data collection and the theory of correlation analysis. In Section 4, the survey results are discussed and analyzed. Finally, conclusions and policy implication are presented in Section 5.

II. LITERATURE REVIEW

Some scholars supported the DRP because they believed that the DRP could improve environmental pollution and ease traffic congestion. According to the daily environmental related data, Viard and Fu [16] found that the air pollution decreased by 21% when the DPR was imposed in Beijing from 2007 to 2009. Yuan et al. [17] found that the DRP is beneficial to reducing ozone. Zhang et al. [1] found that the DRP is very effective to shift people from automobile to public transit and ease traffic congestion. While analyzing the Beijing household travel survey data, Gu et al. [18] found that the DRP has an impact on easing road congestion by reducing private car travel frequency and mileage. Furthermore, Wang et al. [19] found that excluding electric vehicles from regulations of the DRP or the purchasing restriction policy (PRP) could earn the support from the public. Later, Li et al. [20] found that the implementation of DRP and PRP is more effective to promote the use/ownership of electric vehicles than government subsidization.

Several studies indicated drawbacks in the process of implementing DRP. Ye [14] analyzed the air pollutant monitoring data in Lanzhou City and found that the air quality was not improved after implementing DRP. It may be caused by travelers purchasing or renting alternative vehicles. Liu et al. [21] found that the DRP alone could not effectively motivate travelers to use public transport. In addition, the high-income group was reluctant to use public transportation unless the public transportation services were effectively improved. Wang et al. [22] indicated that commuters whose origin or destination was far from the center of Beijing City or subway station are common violators. Eskeland and Feyzioglu [23] found that the car ownership gradually increased in Mexico City after implementing DRP because residents would buy a second car with a different tag number. These unfavorable situations have a negative impact on the benefits of the policy.

Some studies show that there are positive and negative impacts co-existing after the implementation of DRP. Yao et al. [24] argued that the implementation of the DRP improved travel speed in the morning peak in Hangzhou because some commuters could justify their departure time to avoid the restricted time period of DRP. Based on the data collected in Langfang City, Liu et al. [25] found that traffic volume decreased slightly after altering DRP strategy from the ODR to the OER, but the congestion was not significantly improved as expected. It is said that the travel speed was improved in the short-term because of the implementation of the DRP, which would stimulate travel on weekends [7]. After analyzing six cities where the DRP are implemented, Zhang et al. [1] found that implementing the DRP could increase ridership of public transport modes by 5-25%. However, implementing the DRP and PRP simultaneously could increase ridership of public transport modes by 20-30%. Although the DPR can reduce the car ownership on the road directly, many travelers still have taken some measures to the DRP. For instance, they would buy another car with different ending number of license plates. It would be bad for policy. Based on the findings of the studies by Zhang et al. [1] and Li et al. [20], DRP could stimulate the demand of electric and non-electric car ownership. Huang et al. [26] found that the DRP could achieve the expected goal of reducing pollution in the short term in Lanzhou, but it was ineffective in the long-run.

In summary, the findings of various previous studies to the DRP vary as summarized in TABLE 2. Most of the studies only investigated the benefits (i.e. air pollution or traffic congestion), and yet compared the cost-benefit ratio from various aspects. Secondly, previous studies have used actual observed data (i.e. air quality data and traffic flow data) to evaluate the benefits of the DRP. While these are accurate, it also ignored the individual traveler’s the psychological factors impact on the policy. Private car owners, as the main participants in the DRP, are a subject that cannot be ignored in the study. Lastly, the findings from previous studies are quite different. Due to the variation of residents’ cognition to the DRP and regional culture, the perception and attitude to the policy, as well as
TABLE 2. Comparison of research on the effects of the DRP.

| Benefit | Environment | Congestion |
|---------|-------------|------------|
| Travel behavior, would affect the expected performance after implementation the DRP. | Viard and Fu (2015) [16], Yuan et al. (2018) [17], Zhao et al. (2017) [27], Gu et al. (2017) [18], Li et al. (2019) [20], Mohan et al. (2017) [28] | Grange and Troncoso (2011) [9], Guerra and Millard-Ball (2017) [10], Liu et al. (2016) [21], Wang et al. (2014) [22], Eskeland and Feizygolu (1997) [23] |

III. METHODOLOGY AND DATA

This section presents the contents and characteristics of the dataset of the research, the instruments used in collecting data, the procedures of the sampling process. The SPSS version 25 and Origin 2017 are applied to analyze the survey data and present its results respectively.

A. SURVEY DESIGN

To obtain relevant data from travelers to DRP, a revealed preference (RP) survey was designed and conducted to collect travelers’ responses to DRP and their personal information in Xi’an. The purpose of the RP survey was to understand the respondents’ choice and preference under specific conditions.

Since the benefits and risks associated with the DRP are mainly reflected by mode choice, traveler’s behavioral responses (including non-compliance travel [22] and alternated travel modes [7]) were accordingly adopted as survey items in the third and fourth parts of the questionnaire. In addition, we added the mode choice before and after implementing the DRP. Moreover, the theory of planned behavior holds that attitudes and subjective norms have a certain effect on behaviors [39]. Several studies have applied the theory mentioned above and emphasized the importance of travelers’ attitude [7], [21]. Thus, the attitudes of travelers and people around them towards the policy were included in the questionnaire. The perception of travelers can affect their attitude toward policies [7], which refers to the perception on the effect of DRP and the perception of public transport service. Thus, we allocated them in the second part of the questionnaire, together with the attitude as the respondents’ cognition of the policy. Many studies explored people’s green travel behaviors from the perspective of group heterogeneity, suggesting that gender, income and education have significant effects on travelers’ travel patterns [41]. With this in mind, questions designed to acquire travelers’ socio-demographic and economic characteristics were included.

Hence, the survey was conducted and discussed in four sections, which mainly collects relevant data including travelers’ socio-demographic and economic characteristics, travelers’ cognition and attitude towards DRP, travelers’ behavioral response and alternated travel modes. After completing the questionnaire design, the preliminary survey was first conducted, focusing on private car owners. There were 43 pre-survey samples. Through the feedback of the interviewees, the questionnaire measurement items were justified by defining unclear key words, removing/merging some questions co-related to each other, and shortening the length of some questions. The time consumed by answering each questionnaire was less than 5 minutes. The final questionnaire was formed and shown in TABLE 3.

In TABLE 3, Section 1 reveals the travelers’ socio-demographic and economic characteristics, which includes six questions, namely travelers’ gender, age, monthly income, household structure, whether need to pick up children or not, and car ownership. Travelers’ gender is classified into male and female. Travelers’ age is classified into five groups: “less than 25”, “26-35”, “36-45”, “46-60”, and “61 above”. Travelers’ monthly income is classified into four groups: “less than 5,000”, “5,001-8,000”, “8,001-15,000”, and “15,001 above”. Household structure is divided into three categories: single family, couple family,
and multi-person family. Whether need to pick up children is classified into “no” and “yes”. Car ownership is classified into one car and two or more cars.

Section 2 describes the travelers’ cognition and attitude towards the DRP, which includes four questions. First is the perception of DRP’s benefits on air pollution/traffic congestion. Second is the confidence in the long-term benefits of DRP. Third is the perception of public transportation service in Xi’an. Fourth is the attitude towards DRP (you / the people around you). All the questions in this section are measured on a 5-point Likert scale, which made it easier for respondents to express their own positions and opinions clearly.

Section 3 is traveler’s behavioral response to the DRP, which includes two questions. One is the behaviors of dealing with DRP, including seven alternatives in the questionnaire. The other is the frequency of non-compliance travel for travelers, which is also measured by a 5-point Likert scale.

Section 4 describes the changes in traveler’s mode choice under the influence of the DRP, which provides four alternatives, such as private car, taxi, public transport, and non-motorized modes.

B. PROCEDURE

This survey was conducted both online and on-site, aiming at obtaining samples which are more comprehensive. The advantage of online survey is that samples are collected quickly and widely. At the same time, the interviewees of the online survey need to use the Internet, which indicates that these people are well-educated and would get a better understanding of the items. In offline surveys, open-ended questions can be applied to observe the responses and obtain relatively accurate information. In addition, the offline survey is complementary to the samples of the online survey.

The online survey was conducted by Questioning Star, which provided a platform to release questionnaires. And we set the preconditions, which could specify the scope of the survey. The online survey was carried out from March 14 to April 14, 2019, and a total of 400 samples were collected.

The on-site survey was conducted in Xi’an through on-the-spot roadside interviews. Three representative types of urban area, such as residential area (kindergartens and supermarkets around), educational area (universities and schools), and business area (main roads and parking lots around), were selected to conduct the survey, which means that reliable and comprehensive samples could be obtained. 200 survey samples were obtained. The sample collection is presented in TABLE 4. After excluding the samples which were not filled integrally (e.g. missing the personal information) or filled by people who don’t satisfy the requirements of the survey (owning one car at least), a total of 19 invalid questionnaires were screened.

| TABLE 4. Survey sites and survey samples. |
|-------------------------------------------|
| Survey form      | Survey area            | Sample size | Valid samples | Effective rate |
| Online survey    | Internet               | 404         | 400           | 99.0%          |
| On-site survey   | Residential areas      | 74          | 67            | 90.5%          |
|                  | Educational areas      | 59          | 56            | 94.9%          |
|                  | Business area          | 67          | 62            | 92.5%          |
| Total            |                        | 604         | 585           | 96.9%          |

C. SURVEY PARTICIPANTS

The sampling frame for this study comprise: (i) Xi’an residents who are restricted by the DRP come from different families; (ii) have travel demand; (iii) have the driving ability and at least a private car.

To ensure proper sample size denoted as \( n \) applied in the statistics analysis, Equation (1) is applied [31].

\[
 n = \frac{z^2 \times p(1-p)}{e^2}
\]

where \( z \) is a statistic and when the confidence is 95%, and \( z = 1.96; p \) is the probability of holding a positive attitude towards the restriction policy, which is set as 59%; \( e \) is the error term, and 5% is selected in this paper.

According to the Equation 1, the minimum sample size was calculated to be 372. 585 valid samples were finally obtained, which is over the minimum sample size. The socio-demographic characteristics of the respondents are shown in Fig. 3.

From Fig. 3, it can be seen that 63% of respondents are male. The proportion of respondents below 35 and over 35 years old are close to the same. In terms of monthly income, the distribution is relatively balanced except for the population over 15,000 Yuan. Household structure are generally complex, multi-person families account for 76% of the total. The proportion of families who need to pick up their children is similar to that of those who don’t. Most of the respondents had only one private car, accounting for 82%.

Overusing the private cars is the main cause of traffic congestion in urban area, and these groups are also the main constraint object of the DRP. Hence, it is very important to find out the travel characteristics of these groups and take action accordingly for transportation authorities. To make the sample more representative and research the influence of personal and family characteristics on travel mode, the respondents are classified into 8 groups, as shown in TABLE 5. “Age” is classified into two categories: “young” and “middle-aged”. “Young” means below 35 years old and “middle-aged” means over 35 years old. For “Monthly Income”, “lower income” means less than 5,000 Yuan per month and “upper-middle income” means earning more than 5,000 Yuan per month.
Similarly, according to the car ownership of each family and whether need to pick up the children or not, the respondents are classified into 4 types of families as shown in TABLE 6. Since each respondent comes from different family, this classification can also be considered a classification of four family types.

**D. CORRELATION ANALYSIS**

We applied a correlation analysis to check whether there is a correlation, statistically significant, between the respondent demographic/characteristic variables and all survey items are contained in TABLE 7. Spearman’s rank correlation coefficient is suitable for analyzing the dataset that does not follow a normal distribution or not have a linear relationship between the variables [32]. Spearman’s rank coefficient was derived using their ranks, instead of the two values themselves, and has a real number ranging from $-1$ to $1$. If the coefficient is bigger than 0, it means that the correlation between the two variables for comparison is positive; that is, if one variable increases, the other variable also increase. If the coefficient is 0, these two variables have no correlation. If the coefficient is smaller than 0, it can be interpreted that they have negative correlation; that is, if one variable increases, the other variable would decrease. The correlation coefficient denoted as $\rho$ is defined as formula (2):

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)} \quad (2)$$

where $d_i = x_i - y_i$ is representing the difference between the two equalities assigned to $i$. The $x_i$ is the rank of the $i$-th data element of variable $X$, $y_i$ is the rank of the $i$-th data element of variable $Y$, and $n$ is the total number of the samples.

The use of formula (2) allows the computation of Spearman’s rank correlation coefficient and p-value. As mentioned before, Spearman’s rank correlation coefficient shows how the two variables for comparison are correlated. The degree of correlation according to the correlation coefficient values can be interpreted as shown in TABLE 7.

**IV. RESULTS AND DISCUSSIONS**

**A. BENEFITS PERCEPTION AND CONFIDENCE OF THE DRP**

According to the first two questions in Part Two, the benefits perception and confidence of the policy are shown in Fig. 4. Judging from Fig. 4 (a), 72% of the respondents think that the DPR is helpful to improve the traffic congestion and 61% support the DRP because they believe that it has an impact on alleviating air pollution. However, there are more people supporting that the DPR’s effect on alleviating the air pollution is
not obvious than the people who consider the DPR is no use in improving traffic congestion, nearly 10%. It shows that the main benefit that most of the respondents can clearly feel is the effects on alleviating the air pollution and traffic congestion in the city. Whereas 27.8% of the respondents are still uncertain about the effect on easing traffic congestion, and 39.1% of the respondents hold negative attitude on the effects of easing air pollution. On the whole, the benefit of the DPR’s effect on easing the traffic congestion that respondents can perceive is strong (mean: 3.72), while they have a relatively weak perception of the DPR’s benefits on alleviating the air pollution (mean: 3.34). Therefore, respondents’ perception of the benefits of the policy needs to be improved.

When the respondents were asked about their views on the long-term benefits of the DRP (Fig. 4, b), that is, the confidence in the policy, the number of supporting respondents has decreased. In detail, it was obvious in part of easing traffic congestion, down 13%. But the reduction in air pollution was relatively small, with only 5%. Although the extent of decline is slightly different, the final proportion is similar. So, we can draw a conclusion that the respondents have less confidence in the long-term benefits than that at present. The downward trend implies the risk of the DRP in the future.

According to the above results, most respondents can feel the benefits produced by the policy, especially the effects of easing traffic congestion, but the attitude of alleviating air pollution was negative. It reveals that automotive exhaust emission is only one source of air pollution. Xu et al. [33] found that factors, such as population density, energy consumption, the proportion of secondary industry in GDP, and car ownership, could increase regional air pollution to different degrees. So, it is not enough to improve the air quality by implementing the DRP. The government needs to control all kinds of source of pollution comprehensively. Nonetheless, Xu et al. [33] also used regression analysis to conclude that vehicle emissions have a significant impact on AQI and are on the rise nationwide. So, the government needs to make great efforts to publicize the hazards of automobile exhaust and increase their confidence in the DPR.

Travelers’ perception and confidence of the DRP’s benefits are the basis for forming attitudes towards the policy [34], [35]. Schmöcker et al. [36] indicated that travelers’ attitudes towards TDM policies were influenced by emotional factors, such as benefits perception and policy cognition. And the theory of planned behavior believes that human behavior is influenced by attitudes, which further has an important impact on the benefits of the policy. Thus, according to the Q4 in the Part Two of the survey, the attitudes of Xi’an travelers towards the DRP are analyzed, as shown in Fig. 5.

Fig. 5 depicts that 58.9% of the respondents are optimistic about the DRP, and a quarter of respondents are neutral to the policy. On the whole, due to the large proportion of people who hold a neutral attitude towards the policy, the scale of people who support the policy is not as large as expected. It is speculated that the people who choose the neutral attitude do not feel the benefits obviously or the DPR make their travel inconvenient. The travelers’ attitude, as an imperative factor influencing travel mode [7], also plays an important role in determining the benefits and risks of the policy. By contrast, those who support the DRP are more likely to make some choices in line with the DPR. Hence, understanding the views of neutral people, publicizing the benefits of the policy to them in a targeted way, and enhancing the support of travelers for the policy are the ways to protect the benefits of the policy.

Improving the respondents’ attitudes towards the DRP is an important measure to protect the benefits of it. Therefore, in the following part, the factors influencing attitudes are discussed to develop measures to improve the benefits of DRP. Combined with Q2 and Q4 in the Part Two of the survey,
the relationship between attitude and confidence is cross-analyzed, as shown in Fig. 6 (a). And the relationship between the attitudes of the respondents and those of the people around them was cross-analyzed, as shown in Fig. 6 (b).

Fig. 6 (a) shows that travelers’ confidence in the DRP is an indirect reflection of the policy support. Among those who have more confidence in the policy, more than 70% of the respondents are supportive to the policy. And in the middle of the people who have no confidence in the policy, the proportion of them declined largely. For these people, the incomprehension of the DPR and the hazards of automotive exhaust emissions may cause them to have the choice. So, in their mind, the DPR brings more inconvenience than the benefits.

In addition, Fig. 6 (b) shows the respondents’ views on the DRP were highly consistent with those of the people around them. More than 80% of respondents are also optimistic about it when people around them support the policy. This phenomenon reflects people’s herd mentality and group pressure. That is to say, people’s perception and attitude towards things are affected by social pressure, which further affects their behavior. A study on green buying behavior of consumers showed that group pressure and self-perceived benefits can affect green buying intention [37].

Therefore, the following Suggestions are given for the above two factors. On the one hand, travelers need to improve their confidence in the DRP. The government should regularly publish relevant data on air quality and traffic congestion after the implementation of DRP and compare them with those before the implementation of DRP, so as to increase travelers’ perception and confidence in the restrictions. On the other hand, the social atmosphere of green travel needs to be created. It is a good choice to publicize the harm of motor vehicles and the significance of implementing the DRP in the urban area. And certain incentives can be given to private car owners who do not drive.

### B. TRAVELER’S RESPONSE TO THE DRP

Traveler’s behavior can directly bring benefits or risks to the DRP. According to the data obtained from Q5 in the Part Two of the survey, the different coping behaviors on restricted days is analyzed and shown in Fig. 7.

From Fig. 7, it indicates that the DRP has a positive effect on changing travel mode and promoting travelers to choose public transport instead of private cars. Choosing public transport, taxi, carpooling and non-motorized traffic are the more positive behaviors, accounting for 69.8%, where nearly 50% of them are willing to travel by public transport on the restricted day, 19.2% prefer to take taxi or carpooling to deal with the travelling inconvenience, and 3.1% would like to choose non-motorized traffic such as bicycles and walking. Moreover, 8.7% choose to travel during the non-restricted hours by making their departure earlier or later, which can also relieve urban roads congestion during the rush hours slightly.

Most of respondents are willing to take positive actions to deal with the travelling inconvenience. However, different positive coping behaviors have different willingness to be chosen. Most travelers prefer to choose public transport as commuting modes on restricted days because of its low-cost and low-pollution. Whereas people choosing taxi and carpooling as the travel mode have considerable income or are far away from the bus and subway stations. So, the transportation authorities should attach the importance to the public transport service and the layout of public transport stations, so as to create better conditions for people who want to use low-carbon travel mode.

Meanwhile, the implementation of the DRP also brings about risks, which is mainly reflected in that some private car owners begin to find ways to circumvent the constraints. This is the negative behavior dealing with the DRP, and 30.2% of the respondents chose it in the survey. Given the survey results, 15.2% of the travelers want to avoid the DRP by buying another car. In those travelers, 46.1% of them would buy electronic vehicles and others would buy fossil-fueled cars. This behavior not only activate the car sales market, promoting the economic development of the industry and increasing government revenue, but will directly influence the car ownership of Xi’an, further aggravating the problem of parking space shortage, traffic congestion and air pollution. Obviously, this behavior of travelers would weaken the power of the DPR and caused more harm than good, which is also the biggest risk of the DRP. In addition, 8.7% of respondents choose to travel during the non-restricted hours, which is not conducive to reducing automotive exhaust emissions. However, the travelers having more than one private car can drive another car on the restricted day, which makes them out.
In terms of greenhouse gas emissions, the fossil-fueled vehicles are about three times as much as the new energy vehicles [38]. In order to deal with travelers buying another car to evade the restriction, both implementing the PRP and encouraging the purchase of new energy automobiles are the measures taken by the government, so as to reduce risks brought by the increase of vehicle emissions to the DRP.

At present, although buying a fuel-powered car is still the majority’s choice, there is no denying that electric vehicles have also become the choice of some people (Fig. 7, right panel). Under the background of the DRP, as electric vehicles are not restricted by the DRP and PRP, people are encouraged to purchase electric vehicles. But the technologies of electric vehicles are not mature, the expenditure of purchase and maintenance of electric cars are higher than that of gas-powered ones. Besides, there are also disadvantages such as charging slowly, charging inconveniently and short driving range, which make them still unable to replace fuel cars as the first choice. All the issues that we have discussed above are the key points to carry out the green travel.

Non-compliance travel on restricted days is also a negative behavior to deal with the DRP. If many people break the rules routinely, the DRP will be at great risk. Based on the Q6 in the Part Two of the survey, the frequency of non-compliance travel on restricted days is analyzed and presented in Fig. 8.

In Fig. 8, 85.6% of the respondents think that they will not violate the rules (absolutely not 56.4%, hardly 29.2%), which indicates that the policy has strong constrained force in the mind of travelers. The non-compliance rate in this study is lower than 47.8% found in a previous study in Beijing [22]. The public transport in Beijing is more crowded, making it easier for people to travel against the DRP. On the other hand, the high non-compliance rate pushes the government to impose heavier penalties on non-compliance travel. We can reach an idea that the DPR would alter the traveler’s travel habit and further promote the traveler to choose public transport on restricted days, which is beneficial to easing urban congestion and reducing air pollution on restricted days. This is consistent with the research conclusions of Zhang et al. [1] and Gu et al. [18]. However, 27.5% of people still choose the private cars, the possible reason is that they might have more than one car or adjust their travel time to avoid the DPR.

As for the policy effects on forming the habit of taking public transport on non-restricted days, we haven’t found yet, as shown in Fig. 9 right panel. On non-restricted days after the implementation of the DRP, 82% of the respondents who have chosen private cars for travel previously still use private cars, while only 10.3% of the respondents...
change to public transport. 23.8% of the respondents who chose public transport previously choose private cars on non-restricted days. Similarly, some respondents who chose taxis and non-motorized traffic previously choose private cars on non-restricted days. It indicates that the policy do have the effects on alleviating the road congestion to a certain extent, ensuring the smooth traffic in the morning and evening peak hours, and guiding more people to travel by private cars on non-restricted days, which is consistent with the conclusion drawn by Eskeland and Feyzioglu [23] and Yang et al. [39] that the DRP will stimulate travelers to use private cars on non-restricted days.

In order to maximize the benefits of the DRP, the government facing the current risks urgently needs to put forward better measures to protect the benefits of the policy and carry out different measures for different groups. The respondents were divided into several groups according to the Part One of the survey. Combined with the Q7 in the Part Two of the survey, the travel modes of different groups in different DRP periods are compared, which presented in Fig. 10.

It can be found from the analysis of the traveler’s common travel modes before the implement of DPR (Fig. 10, a) that most travelers who often use private cars in daily life are middle-aged men with upper-middle income, middle-aged men with lower income, middle-aged women with upper-middle income and young women with upper-middle income (in descending order).

Most of the people who often use private cars are middle-aged men. Besides, regardless of their income, private cars are the first choice for this group to choose. The reasons that cause this phenomenon are a lot. First of all, middle-aged men usually have worked for many years, which may give them a higher status in society. They need to choose a travel mode to match it, thus they tend to choose private cars to travel around. In addition, due to the need of participation in some social activities and entertaining clients at work, they have to use the private cars to bring them better travel experience which can play an auxiliary role in the progress of their daily work. Moreover, considering the psychological characteristics of middle-aged men, the fatigue caused by long-term hard work makes them have more pursuits in life quality, so they are more willing to choose private cars as their daily travelling tools. And this group usually has a large number of families, they have the duty to take care of their parents and children, private cars will provide them with great convenience in the respect.

Nearly half of the women with upper-middle income also use private cars frequently. No matter young or middle-aged women, they tend to improve their life quality when they have a decent income. Using private cars is an expression. Since most women are responsible for housework and picking up the children from school and traveling by private cars not only save the time but also make them feel comfortable.

As depicted in the figure, both young people and middle-aged women with lower income are the main groups that take public transport daily. Because young people with lower incomes are facing the economic pressure of forming the family and housing problem. So, the economic public transport would be the first choice for them.

After the implementation of the DRP, the proportion of people who use private cars has significantly decreased in these 8 groups, while the proportion of people who use public transport and taxi has increased through analyzing the travel modes of different groups on the restricted day (Fig. 10, b). This shows that it is of good benefit to control the car ownership on the road. As for the change of travel mode on
restricted days, people with better economic condition would choose the taxi to replace the private cars on the restricted day. Instead, the lower-income groups tend to take public transport.

Fig. 10 (c) shows that, after the implementation of the DPR, the proportion of private cars use on non-restricted days is larger than it before the implementation of the DPR, but the change is subtle, which is as expected. The use of private cars of young men and women with upper-middle income is increased by 14.3% and 11.3% respectively after the implementation of the DPR. It indicates that the restriction will stimulate people to use private cars on non-restricted days, which would offset the benefits of the restriction in this way.

Similarly, whether need to pick up children from school or not and the car ownership in the household are selected as family characteristics, and their influence on travel mode in different DRP periods is also analyzed, as shown in Fig. 11.

In Fig. 11, picking up children from school and owning more than one car in a family would prompt travelers to choose private cars. Since there is more than one private car in a household, travelers use them subconsciously and form travel habits. For the people who need to pick up children, they tend to play a high value on the comfort and safety of children, which cannot be satisfied by public transport. The families with the above two factors, are more like to choose private cars as daily travel tools, reaching 69.2%. On the contrary, the families without any one of the factors above have less demand for private cars, so the probability of using private cars is relatively small. It can be clearly seen from Fig. 11 above that the use of private car and public transport show an increasing and decreasing trend respectively with the change of two-family attributes.

On the restricted day, the number of travelers using private cars in four types of family has declined to varying degrees. It’s worth noting that the percentage of travelers who don’t need to pick up children and have more than one car has the biggest fallen, reaching 31.5%, while the number of travelers who need to pick up their children and have only one car decreased the least, which reflects that the comfort and the convenience of travelling are the momentous factors affecting the benefits of policy. Travelers who have more than one car and need to pick up children are still the biggest group of using private cars. This is consistent with the conclusion drawn by Mayil et al., who analyzed the mode choice considering different family characteristic with multinomial logit models. It indicates that with the increase of families needing to pick up children, the percentage of travelers who usually travel by cars rises significantly, while the rates of other travel modes decrease [41]. Similarly, compared with the number of travelers using private cars before implementing the policy, the number rose slightly on non-restricted days.

Moreover, the location of public transport stations, the comfort of travelling and the punctuality are also the key factors affecting coping behavior on the restricted day. Combined with Q3 and Q7 in the Part Two of the survey, the influence of perceived public transport service on travel modes under the background of the implementation of the DRP is explored, as shown in Fig. 12.

From Fig. 12, it can be seen that the respondents who think public transport service is good are easier to choose the public transport to commute, regardless of daily travel or travel on the restricted day. Under the influence of the DPR, the proportion of people who take public transport on restricted days has increased, but it is also obvious that the number of respondents who think that public transportation service is good has increased more dramatically, from 44.3% to 70.7%.
More than 60% of the respondents who think public transport service are bad prefer to choose private cars. Wang et al. analyzed the violated behaviors to DRP by nested logit model, suggesting that poor service (e.g. overcrowding in public transportation systems), which worsens the traveling experience of travelers, could be the reason for the increase of passengers’ non-compliance with DRP [22]. Therefore, improving the quality of public transport service is an option of guiding people to reduce the use of private cars, which can protect the long-term benefits of the DRP. If public transport is deemed attractive enough in terms of comfort, travel time or availability, commuters will show higher support for the DRP [21].

D. CORRELATIONAL ANALYSES

Spearman’s Rho correlations between the respondent demographic/characteristic variables and all survey items are contained in TABLE 8. In general, it can be seen that most of the correlations in TABLE 8 are weak. Nonetheless this section will present an overview of the main findings from the correlational analysis, with a focus on statistically significant correlations.

1) GENDER
Results showed that females (vs. males) tended to choose greener travel modes on the restricted days. But males expressed higher levels of noncompliance to the DRP.

2) AGE
Younger respondents tended to (a) express better perception of DRP on air, (b) express higher levels of confidence for long-term effects of DRP on air, (c) express a greater willingness to choose greener travel modes (e.g. bus and bicycle).

3) INCOME
Respondents’ level of income revealed a pattern of correlations with survey items that was a little bit different to that of age, described previously. That is, those with higher levels of income tended to perform non-compliance behaviors. What’s more, those with lower income would like to choose greener travel modes when they are not constrained by DRP.

4) HOUSEHOLD STRUCTURE
Results showed that simple household structure (vs. multi-person household structure) tended to choose greener travel modes when they are not constrained by DRP.

5) PICK UP CHILDREN
Whether or not respondents need to pick up children showed that those who have no need to pick up children tended to choose more environmental-friendly travel modes during both restricted days and non-restricted days.

6) CAR OWNERSHIP
Respondents’ car ownership showed mixed correlations with the survey items. The respondents who had less private car tended to (a) express better perception of DRP on air, (b) express higher levels of confidence for long-term effects of DRP on air, (c) express a greater willingness to choose greener travel modes (e.g. bus and bicycle).
(b) choose greener travel modes during both restricted days and non-restricted days.

V. CONCLUSIONS AND POLICY IMPLICATIONS

A. THE BENEFITS OF THE DRP

Travelers, in general, expressed positive impression on the DRP because the associated benefits in easing traffic congestion and improving the air quality are recognized, yet they have weak confidence in the long-term benefits. Building up the confidence of the travelers and helping them respond to the policy with positive behaviors is the key to ensure the long-term benefits of the policy.

The most intuitive benefit of implementing the DRP is to help the government achieve its vision of easing urban traffic congestion. That is to manage the urban traffic demand, control travelers’ demand for private cars, and guide them to use public transport.

Furthermore, there are many potential benefits. The implementation of the DPR could decrease the fuel consumption and reduce the automotive exhaust emissions of private cars, finally realize energy conservation and emission reduction. What’s more, the electric vehicles aren’t constrained by the DPR and PRP, which tempt people to purchase them. Wang et al. [19] have similar results in their study. Li et al. [20] also mentioned that if the DRP and PRP are lifted, more than 95% of Shanghai consumers will postpone or even cancel the plan of purchasing the electric vehicles. So, with the government’s efforts on promoting electric vehicles and encouraging green travel, the policy also has the benefits of activating the market of electric vehicles, which will bring long-term good to the air in the future. Finally, no driving one day a week can help commuters to increase outdoor exercise and keep healthy.

B. THE RISKS OF THE DRP

In this paper, we consider that travelers with more than one private car can travel by private car without restriction on restricted days. Furthermore, 15% of private car owners want to avoid the restriction by purchasing another car. It indicates that the implementation of the DRP has incentive effect on purchasing a second car, which is in line with some previous findings [21], [22]. Both of these actions would have a negative influence on the policy benefits, just like weakening the effect on easing urban road congestion and air pollution, and reducing the actual benefits, which in turn leaves the travelers to the low confidence in the policy. This is the biggest risk that the DPR is faced. And the study shows that the DRP could stimulate travelers to use private cars on non-restricted days, which has offsetting effect on vehicles that are restricted on the road and will also worsen the benefits.

It is necessary to guide the travelers who want to buy a car to purchase an electric car and carry out the PDP in time to protect the benefits of the DRP and establish the travelers’ confidence. The implementation of incentive policies related to electric vehicles can largely increase individuals’ purchasing intention, thereby enlarging the market share of electric vehicles [1]. The government can still notice people to buy electric cars through government subsidies, reducing purchase tax and parking concessions. If the DRP and PRP are not implemented together, the effect of the policy would be incomplete, and it’s unfair to the travelers who can only afford one car. And this will do no good to the implementation of the DPR.

C. THE CHOICE OF TRAVEL MODES UNDER THE DRP

The mode choice of travelers varies according to the personality traits and family characteristics. Whether the DRP is implemented or not, the car ownership and the need of picking up children showed a higher correlation with travel modes than other survey items. Travelers with more than one private car tended to choose the private cars to pick up their children, which is not environmentally friendly. However, during the unrestricted period, the income and family structure also showed a relatively stronger correlation with the travel mode. On the contrary, people with low income or having simple family structure are more likely to choose the environmentally friendly transport. Therefore, we can draw a conclusion that the implementation of the DRP could counteract the impact of income and family structure on travelers’ mode choices, but it doesn’t work on the car ownership and the need of picking up children. In addition, the implementation of the DRP has increased the relevance of gender to travelers’ mode choice, and women are more willing to use environmentally friendly transport on the restricted day.

The conclusion above can provide accurate direction for policy improvement. On the one hand, the travelers that use private cars frequently are taken as the main target group to propagandize the DRP. Policymakers should attach importance to the publicity of the risks of refusing the DPR and bring up the travelers’ sensitivity and responsibility to urban traffic and environmental problems. Moreover, the authorities can make the tasks of taking public transport for relevant person, or require companies and enterprises to provide public transport subsidy for their middle-aged employees using bus or subway as a means of commuting, which can guide them to travel in a low-carbon way and develop the habit of taking public transport. On the other hand, the lower-income young people and lower-income middle-aged women are the main users of public transport, and the population of them is quite large, which is not matching the scale of the public transportation, especially during morning and evening rush hours. Considering that public transport is the main substitute for private cars on restricted days and the public transport service can affect willingness to choose it, the authorities should strengthen the development of public transport to make it meet the needs of the travelers on rush hours.

In addition, the study indicates that owning more than one private car and the need of picking up children from school are the family factors that have an influence on the use of private cars. For these two factors, the government can impose special restrictions on those kinds of people or enact
D. IMPLICATIONS AND LIMITATIONS

While this study illustrated the benefits and risks of the DRP by analyzing travelers’ attitudes towards the policy and travel behaviors, there are still some limitations, which need to be improved in future studies. Firstly, data collection is conducted in the form of questionnaire, which is obtained through the memories and self-perception of the respondents. It may differ from the actual situation. Secondly, our survey is just a case study of Xi’an, and the results are beneficial to those cities, with similar characteristics to Xi’an, interesting in implementing DRP. Finally, this paper only conducts descriptive statistical analysis and correlation analysis to analyze the benefits and risks of the DRP. And regression analysis would be used to analyze the changes of travelers’ mode choices after implementing the DRP and further verify the accuracy of the conclusions in the future study. Nevertheless, after collecting and analyzing a large number of survey samples, this paper concludes the benefits and risks of the policy from different perspectives and provides detailed and comprehensive countermeasures.

Since the number of residents driving on non-restricted days increased compared with that before the implementation of DRP, it is proved that the policy is only an emergency measure to alleviate urban environment and road congestion once again [39]. And the effect of the policy may not be significant in the long run [26]. In order to ensure the effectiveness of the DRP in the future, the following suggestions are proposed according to our research. Firstly, under the implementation of the DRP, the ridership of public transportation modes would inevitably increase, which may affect the quality of service. Thus, the government should allocate more resources (e.g., budget, equipment, and labor) to transit suppliers to react the demand change before the implementation of DRP. This study shows that the effect of passengers’ perception transit service is certain to the decision of mode choice. Therefore, improving the service quality (e.g., comfort and convenience) of public transportation would be critical actions, such as building expanding infrastructure, introducing advanced feeder modes with the mobility as a service for seamless connection. Secondly, there are nearly 40% of respondents who disagree with (or not recognized) the effect of DRP on environmental impact (e.g. air pollution) as well as public health based on the survey outcomes, which is discouraging while promoting the DRP. It is necessary to publicize the benefits of the DRP to enhance the travelers’ perception, so that the maximum effectiveness of the policy could be expected. Finally, external conditions should be improved for assisting the DRP implementation. For instance, an incentive may be offered to metro card users. So that the metro card ownership increases, and more passengers shift to transit could be expected. And we could also encourage people to work at home at least one day per week. And school buses service is needed to be improved for children to ease the traffic congestion caused by picking up children during rush hours.

To sum up, from the perspective of the travelers and the government, although the developing prospect of the DRP is positive, there are still remaining severe risks and problems to be solved. In an era of rapid development of economy and technology, the DPR is according with the concepts of green travel, energy conservation and emission reduction, and this trait will make the policy have great significance and potential feasibility.

REFERENCES

[1] L. Zhang, R. Long, and H. Chen, “Do car restriction policies effectively promote the development of public transport?” World Develop., vol. 119, pp. 100–110, Jul. 2019.

[2] L. Zou, Y. Pang, and M. Dai, “Research on public transit choice for Shenzhen inhabitant trip under the influence of parking charge,” Mod. Transp. Technol., vol. 12, no. 1, pp. 41–43, 77, Feb. 2015.

[3] F. Liu, Y. Cao, and J. Zhou, The Strategy of Urban Motor Vehicle Ownership Control and Rational Usage. 1st ed. Beijing, China: Beijing Jiaotong Univ. Press, 2018, pp. 70–75.

[4] G. Schuitema, L. Steg, and S. Forward, “Explaining differences in acceptability before and acceptance after the implementation of a congestion charge in Stockholm,” Transp. Res. A, Policy Pract., vol. 44, no. 2, pp. 99–109, Feb. 2010.

[5] G. Sun and Z. Yuan, “On public will towards traffic congestion charges in Chengdu: A planned behavioral theory approach,” J. Changsha Univ. Sci. Technol., vol. 11, no. 3, pp. 6–12, Sep. 2014.

[6] Q. Tang and X. Hu, “Triggering behavior changes with information and incentives: An active traffic and demand management-oriented review,” Adv. Transp. Policy Planning, vol. 3, pp. 209–250, 2019.

[7] N. Jia, Y. Zhang, Z. He, and G. Li, “Commuters’ acceptance of and behavior reactions to license plate restriction policy: A case study of Tianjin, China,” Transp. Res. D, Transp. Environ., vol. 52, pp. 428–440, May 2016.

[8] G. Li, “Empirical and simulation research on urban driving restriction policy,” Ph.D. dissertation, Manage. Sci. and Eng., Tianjin univ., Tianjin, China, 2016.

[9] L. de Grange and R. Troncoso, “Impacts of vehicle restrictions on urban transport flows: The case of Santiago, Chile,” Transp. Policy, pp. 862–869, Jul. 2011.

[10] J. Guerra and A. Millard-Ball, “Getting around a license-plate ban: Behavioral responses to Mexico City’s driving restriction,” Transp. Res. D, Transp. Environ., vol. 55, pp. 113–126, Aug. 2017.

[11] L. W. Davis, “The effect of driving restrictions on air quality in Mexico city,” J. Political Economy, vol. 116, no. 1, pp. 38–81, Feb. 2008.

[12] Y. Wang, J. Hao, M. B. McElroy, J. W. Munger, H. Ma, D. Chen, and C. P. Nielsen, “Ozone air quality during the 2008 Beijing Olympics: Effectiveness of emission restrictions,” Atmos. Chem. Phys., vol. 9, no. 14, pp. 5237–5251, 2009.

[13] X. Lu, “Effectiveness of government enforcement in driving restrictions: A case in Beijing, China,” Environ. Econ. Policy Stud., vol. 18, pp. 63–92, Mar. 2016.

[14] J. Ye, “Better safe than sorry? Evidence from Lanzhou’s driving restriction policy,” China Econ. Rev., vol. 45, pp. 1–21, Sep. 2017.

[15] L. Yi, Y. Zhou, and Z. Li, “Analysis of the effects of driving restriction policies in controlling haze pollution,” China Population, Resour. Environ., vol. 28, no. 10, pp. 81–87, May 2018.

[16] V. B. Viard and S. Fu, “The effect of Beijing’s driving restrictions on pollution and economic activity,” J. Public Econ., vol. 125, pp. 98–115, May 2015.

[17] X. Yuan, H. Li, and W. Yang, “Did driving restrictions effectively improve the air quality of Xi’an?”, Statist. Inform. Forum, vol. 33, no. 6, pp. 107–114, Jun. 2018.

[18] Y. Gu, E. Deakin, and Y. Long, “The effects of driving restrictions on travel behavior evidence from Beijing,” J. Urban Econ., vol. 102, pp. 106–122, Nov. 2017.
[19] N. Wang, L. Tang, and H. Pan, “Effectiveness of policy incentives on electric vehicle acceptance in China: A discrete choice analysis,” Transp. Res. A, Policy Pract., vol. 105, pp. 210–218, Nov. 2017.

[20] W. Li, R. Long, H. Chen, F. Chen, X. Zheng, and M. Yang, “Effect of policy incentives on the uptake of electric vehicles in China,” Sustainability, vol. 11, no. 12, pp. 13–33, 2019.

[21] Y. Liu, Z. Hong, and Y. Liu, “Do driving restriction policies effectively motivate commuters to use public transportation?” Energy Policy, vol. 90, pp. 253–261, Mar. 2016.

[22] L. Wang, J. Xu, and P. Qin, “Will a driving restriction policy reduce car trips?—The case study of Beijing, China,” Transp. Res. A, Policy Pract., vol. 67, pp. 279–290, Sep. 2014.

[23] G. Eskeland and T. Feyzioglu, “Rationing can backfire: The ‘day without a car’ in Mexico City,” World Bank Econ. Rev., vol. 11, no. 3, pp. 383–408, 1997.

[24] W. Yao, Y. Ding, F. Xu, and S. Jin, “Analysis of cars’ commuting behavior under license plate restriction policy: A case study in Hangzhou, China,” in Proc. 21st Int. Conf. Intell. Transp. Syst. (ITSC), Nov. 2018, pp. 236–241.

[25] Z. Liu, R. Li, X. Wang, and P. Shang, “Effects of vehicle restriction policies: Analysis using license plate recognition data in langfang, China,” Transp. Res. A, Policy Pract., vol. 118, pp. 89–103, Dec. 2018.

[26] H. Huang, D. Fu, and W. Qi, “Effect of driving restrictions on air quality in lanzhou, China: Analysis integrated with Internet data source,” J. Cleaner Prod., vol. 142, pp. 1013–1020, Jan. 2017.

[27] S. Zhao, Y. Yu, D. Qin, D. Yin, and J. He, “Assessment of long-term and large-scale even-odd license plate controlled plan effects on urban air quality and its implication,” Atmos. Environ., vol. 170, pp. 82–95, Dec. 2017.

[28] D. Mohan, G. Tiwari, R. Goel, and P. Lahkar, “Evaluation of odd–even day traffic restriction experiments in Delhi, India,” Transp. Res. Rec., vol. 2627, no. 1, pp. 9–16, 2017.

[29] D. Tang, H. Ren, S. Zhang, P. Wang, Y. Gao, T. Gan, and X. Liu, “Evaluation of the motor vehicle restriction policy in winter on the air quality in Lanzhou, China,” Environ. Pollut. Control, vol. 5, pp. 567–571, 2019.

[30] B. Choi and A. Pak, “A catalog of biases in questionnaires,” Preventing Chronic Disease, vol. 1, no. 2, pp. 1–13, Jan. 2005.

[31] Z. Ma, C. Shao, Y. Song, and J. Chen, “Driver response to information provided by variable message signs in beijing,” Transp. Res. F, Traffic Psychol. Behav., vol. 26, pp. 199–209, Sep. 2014.

[32] J. H. Kim, “Correlation analysis,” in Environmental Statistics & Data Analysis, Seoul, South Korea: Hannarae, 2018, Ch. 8, pp. 180–202.

[33] W. Xu, J. Sun, Y. Liu, Y. Xiao, Y. Tian, and B. Zhao, “Spatiotemporal variation and socioeconomic drivers of air pollution in China during 2005–2016,” J. Environ Manage., vol. 245, pp. 66–75, Sep. 2019.

[34] A. Grob, “A structural model of environmental attitudes and behaviour,” J. Environ. Psychol., vol. 15, no. 3, pp. 209–220, 1995.

[35] S. Grunert and H. Juhl, “Values, environmental attitudes, and buying of organic foods,” J. Econ. Psychol., vol. 16, no. 1, pp. 39–62, 1995.

[36] J.-D. Schmöcker, P. Pettersson, and S. Fuji, “Comparative analysis of proximal and distal determinants for the acceptance of coercive charging policies in the UK and Japan,” Int. J. Sustain. Transp., vol. 6, no. 3, pp. 156–173, May 2012.

[37] H. Cao, “An empirical analysis of the factors influencing consumers’ green buying behavior,” Statist. Decis., vol. 14, pp. 112–114, Mar. 2018.

[38] L. Jin, Y. Lu, Y. Xie, Y. Lei, and H. Zhang, “Analysis of environmental and economic benefits of new energy vehicles’ full life cycle based on green model,” Resour. Ind., vol. 21, no. 5, pp. 1–8, Oct. 2019.

[39] Y. Yang, G. Li, R. Wang, P. Qiu, and N. Jia, “A study of the impact of vehicle restriction policies on traffic flow: A case study of Tianjin,” J. Transp. Inf. Syst., vol. 34, no. 1, pp. 116–122, 2016.

[40] F. Martin and I. Ajzen, “Belief, attitude, intention and behavior: An introduction to theory and research,” Philosophy Rhetoric, vol. 41, no. 4, pp. 842–844, 1975.

[41] J. Liu and X. Hao, “Incorporating the heterogeneity into travelers’ Green traveling choice model,” J. South China Univ. Technol., vol. 47, no. 7, pp. 99–120, Jun. 2019.

[42] A. Mayil, Q. Lin, Z. Yao, and E. Xi, “Behavior of students’ travel mode choice is based on family structure difference,” J. Chang’ an Univ., vol. 37, no. 6, pp. 113–120, Mar. 2017.