The optimization of traffic congestions in big cities: the role of the motor vehicle restriction mechanism

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Abstract. In large cities, the traffic congestion has become an important issue that hinders urban economic development. The motor vehicle restriction policy is an important means for big cities to reduce traffic congestions, and is also used by many large cities around the world. According to the practical experience in Beijing, this paper makes the survey to analyze the impact of restrictive policies on residents' travel choices and takes travel habits into consideration, to provide an urban traffic congestion solution. This paper argues that the restriction policy as an effective way to optimize the traffic in large cities by reducing the proportion of motor vehicle travel choice by 33.2%. In addition, travel habits as a conductive mechanism play the key role in solution of urban traffic congestions.

1. Introduction
Many cities treat the vehicle restriction as one of the important policies for traffic congestion and have implemented for a long period. Although considerable literature discussed the Incentive effect of the charging policies, there are no sufficient studies on the authority-oriented policies, especially on the one-day-a-week driving restriction policy. Whereas, there are plenty of dissenting voices opposing this policy. In contrast, many cities in China implemented the similar policies after Beijing’s implementation of the one-day-a-week driving restriction policy. This policy also become a ‘preference’ selection for governing the traffic congestion. This article uses the questionnaire and disaggregate modeling to analyze effectiveness of the residents’ trip choices under Governments’ restriction policy, taking Beijing as the sample. The purpose is to conclude the restriction policies’ effect on the residents’ motor-vehicle travelling and reduce traffic congestions.

The main arguments are concentrated on the measurement and calculating of the policy’s effect. Most scholars agree that the policies have short-term effectiveness. However, long-term effectiveness would be counteracted by residents’ evasive behavior (strategy behavior) (Gallego et al. [1], 2011, Cantillo et al. 2014[2]). Eskeland & Feyzioglu (1995)[3] and Davis(2008)[4] used time series regression and RD design method separately to do the empirical study of Mexico City, suggesting that the one-day-a-week driving restriction policy in Mexico City would intensify the traffic congestion and air pollution due to the residents would avoid the restriction by purchasing second car with more emission. Grange & Troncoso(2011)[5] found that the restriction policy in San Diego only caused a reduction in traffic flow by 5.5% only, far below the expectations. And the residents did not choose to travel by public transport travel in response to that policy. It is also believed that travel with breaking the limit rules and strategic avoidance is also the main cause of this phenomenon.

The study of the Beijing one-day-a-week driving restriction policy is also of concerning in the near future. Based on the data of Beijing urban transportation platform, the article takes “4” as the research
object, and concludes that the tail number restriction policy can significantly improve the traffic conditions, especially for the traffic conditions at night peaks (Sun, et al, 2014[6]; Yang, J., et al, 2018[7]), but there are also some research concluding that Beijing's limit policies have no significant impact on individual driving decisions. There are about 47.8% of restricted cars that do not comply with the restrictions. The commuters who are far away from city center (the subway station) are the main rule destroyers (Wang, L., J. Xu and P. Qin, 2018[8]), and other scholars have studied the impact of distortion of the labor supply (VBViard and S Fu, 2015[9]) and reduction of fertility (A. Liu, .A., et al., 2018[10]).

2. Beijing’s experience in implementing the one-day-a-week driving restriction policy

From the traffic conditions of the first two years of the 2006 and 2007 Olympic Games, road traffic congestion is very serious. In 2007, it reached an annual average of 7.7 congestion index (which is a serious congestion). Therefore, during the Olympic Games, Beijing implemented a motor vehicle traffic restriction for single and double numbers (from July 1 to September 20). After the Olympic Games, the traffic pressure increased rapidly. On September 27, 2009, the municipal government issued the “Measures for the Implementation of Traffic Management”, requiring that the city’s motor vehicles be restricted by the tail number for one day per week from October 10, and this opened the prelude to the traffic demand management of the "tail number limit". Since the end of 2009, the government has carried out traffic control for up to 10 years and has become a long-term policy factor affecting the travel of residents.

According to the published one-day-a-week driving restriction policy, the two numbers will be restricted in a rotation of four-months. Not only that, on October 22, 2010, Beijing imposed stricter restrictive measures on the purchase of small private cars (Beijing Municipal Government Order No. 227), announcing that from now on, the vehicle will be allocated monthly and the license plate number is 20,000 per month. At the same time, restrictive measures (document No. 18) were also adopted for vehicles entering Beijing, requiring non-Beijing-based motor vehicles cannot enter the Fifth-Ring Road during peak hours (7-9 pm, 17 pm 20:00) during the working day. In 2014, the long-term entry into the Beijing permission policy has been abolished, and the short-term 3-5 days entry into the Beijing permission policy has been implemented, and it has become stricter. As a result, a comprehensive motor vehicle traffic demand management policy system centered on the “one-day-a-week driving restriction policy” and supported by “restriction of purchase” and “outside-based vehicle restriction” has been gradually formed.

3. Hypothesis, Variables and data processing

3.1 Basic Hypothesis

The authority-oriented policy reflects a distinctly different feature that is mandatory to be divided into a limited day and a non-limited day, so it leads to a lower demand for motor travel, which is the direct result of the limit day, because it does not directly cause the change of traveler’s time value and travel costs. The key to the effectiveness of this policy is whether it can guide a way of travel that meets social needs. An interpretable logic is whether there is an inductive effect of the restricted day on the non-limited daily traffic behavior. Most travelers have their own fixed way of travel in the commuting, business, leisure and other travels. This inherent way of travel is a process of repetitive selection of past travel modes. Once selected, it is difficult to change.

| Type               | Hypothesis                                                                 | Numbers    |
|--------------------|-----------------------------------------------------------------------------|------------|
| The total effect   | One-day-a-week driving restriction policy can significantly reduce the choice probability of residents' motor vehicle travel mode. | hypothesis 1|
| Transfer Mechanism | In the relationship between the one-day-a-week driving restriction policy and the motor vehicle travel choice, travel habits have a mediating effect. | hypothesis 2.1|
|                    | The one-day-a-week driving restriction policy has a significant inducement on the formation of residents' travel habits. | hypothesis 2.2|
3.2 Variables, indicator selection and data processing
The choice of travel mode comes from various factors. In addition to personal characteristics (gender, age, occupation, income), travel purpose and distance, policy induction is an important shock variable. Whether it is effective or not, the key different policy types are trade-offs for the interests of the travellers (incentive compatibility). Thus, we use gender, age, occupation and Education to describe a person’s personal characteristics; use family monthly income to describe family attributes; use travel choice, average travel time and travel habits to describe travel characteristics. And use restriction policy and to numb variables to describe the policy’s effectiveness.

3.3 Data survey, reliability and validity test
A total of 2,096 questionnaires were sent (1096 online surveys and 1000 field surveys), 1961 valid questionnaires were collected (1056 online surveys and 905 field surveys), and 135 questionnaires were abandoned due to incomplete answers.

The reliability of the questionnaire was tested by SPSS. The Cronbach's Alpha value of the questionnaire attitude module total scale was 0.851, and the Cronbach's Alpha value of the limit policy scale reached 0.81, indicating that the overall reliability of the questionnaire was good and with good Internal consistency. In structural validity test aspect, the KMO value was 0.849 (>0.5), and the Bartlett’s spherical test approximated the chi-square value to 17954.814 (p=0.00), which passed the test.

4. Results
The empirical model is based on the Binary Logistic Probability Selection Model (BNL), with resident travel choice as the independent variable, the one-day-a-week driving restriction policy and other characteristic variables as the control variables. The specific empirical steps are: (1) The impact of the restriction policy on residents' travel choices does not introduce other control variables, only considering the resident's characteristic variables (Hypothesis 1). (2) Adding travel habits and considering whether the influence is strengthened when introducing travel habits (hypothesis 2.2); (3) analyzing the influence of the one-day-a-week driving restriction policy on traffic habits, using travel habits as independent variables, and one-day-a-week driving restriction policy as the dependent variable (hypothesis 2.1).

The restriction travel policy has impact on the choice of travel policy, as shown in Table 5. Both of the empirical regression results showed that the one-day-a-week driving restriction policy can effectively reduce the relative probability of private car travel by local residents, which are 33.2% and 22.3% respectively. The higher the degree recognition, the lower the private car travel will be, thereby H1 is verified, that is, the tail limit policy can effectively reduce the probability of residents' private car travel choices, and the group who are in favor of the restriction travel reduces the probability of motor vehicle travel more significant.

From the results of other control variables, income and motor vehicle ownership are significantly positively affecting the travel selection probability without considering travel habits. each level of income increases and each additional vehicle, the probability of motor vehicle travel choice will increase by 25.7% and 49.5% respectively. It indicates that the higher the income level, will result the more the vehicle ownership, the lower the degree of motor vehicle travel probability. However, considering the habits of travel, these control variables are not significant, indicating that when residents have persistent behavioral habits, these control variables have no effect on the choice of residents' travel. The comparison of the regression results between the two groups shows that the choice of residents' travel may have the intermediary effect of persistent habits.

| Table 2. Logit regression of dependent variables and explanatory variables and mediators |
| --- |
| Regression Variable name | Travel Choice (without habits) (1) | Travel Choice (with habits) (2) | Travel Choice (3) |
| | B | Exp(B) | B | Exp(B) | B | Exp(B) |
| Tail number limit | -0.403*** | 0.668 | -0.252 | 0.777 | -0.551*** | 0.576 |
| (0.001) | (0.060) | (0.000) |
Table 1: Variable Coefficients

| Variable                  | Coefficient (SE) | t-value | p-value |
|---------------------------|------------------|---------|---------|
| Monthly Income Level      | 0.229 (0.069)    | 3.34    | 0.001   |
| Commuter departure time   | -0.003 (0.979)   | -0.01   | 0.91    |
| Average daily travel time | -0.002 (0.926)   | -0.01   | 0.92    |
| Gender                    | 0.071 (0.539)    | 0.13    | 0.89    |
| Age                       | -0.046 (0.260)   | -0.17   | 0.87    |
| Education Level           | 0.082 (0.126)    | 0.66    | 0.51    |
| Career                    | 0.082 (0.608)    | 0.13    | 0.89    |
| Constant                  | -1.505 (0.000)   | -9.98   | 0.00    |

*** p<0.01; ** p<0.05; *p<0.1

Model (3) is used to test the mediating effect of travel habits. The restriction policy guides residents to adjust their travel habits, effectively reducing the probability of residents' choice of motor vehicle travel by 42.4%, and the mediating effect is greater than the direct influence effect of 33.2%, and hypothesis 2.1 is proved.

From the perspective of other control variables, two key control variables, which are income level and vehicle ownership, have significant effects on travel habits. It can be considered that after taking into account travel habits, income levels and motor vehicle ownership will not directly affect residents’ travel choices, but residents’ travel choices are influenced by factors such as income levels and vehicle ownership. Similarly, time, distance, gender, age and occupation also significantly affect residents' travel habits to a certain extent. Compared with the results of three models, it is found that these control variables do not directly affect residents' travel choices, it affects that through travel habits. The choice played an indirect inducement. Therefore, the impact of the restriction policy on the choice of residents' travel is realized by a mediating variable that is travel habits, which is influenced by characteristic variables including the restriction policy, which could both affect the residents travel choices. The main effect of travel habits is very significant. Hypothesis 2.1 is proved.

5. Conclusions

As an effective way to optimize traffic congestion, the most fundamental reason why the driving restriction policy has not been adopted for cities is that the tail number restriction policy requires a strong restriction and enforcement system, such as a complete closed-loop chain including “limit number”, “outside-based car limit” and “tail limit”. A strong enforcement system could effectively implement and monitor this policy realization, which determines the size and quantity of the restricted vehicle (the amount of Existing quantity). We mainly examine the logical relationship between Beijing’s one-day-a-week driving restriction policy and residents' travel choices from three aspects: the choice of residents' travel modes, the development of travel habits and their policy evasive behaviors. The results show that one-day-a-week driving restriction policy can directly affect the choice of motor vehicle travel, and it is also conducted through the intermediary variables of residents' travel habits, and the conductive effect is more significant. The optimization of traffic congestion requires reduce the number of motor vehicles on the roads in a long term. And according to the results, travel-restriction policy can change residents' travel habits, form stable policy expectations, guide residents to choose other modes of transportation, and inhibit the development of travel habits of using private car. Thus, limiting the choices of private cars, eventually make a huge difference in the traffic congestion.
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