URBAN MOTOR VEHICLE LIMITING POLICY BASED ON SYSTEM DYNAMICS

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Abstract: The governance of urban traffic jam is a hot topic in the process of urban development in China. From the perspective of system dynamics, this paper point out that the urban motor vehicle limiting policy used to control traffic jam needs a strong public transport system, and if there is no convenient public transport system, the limiting policy only has short-term effect. This paper also put forward some relevant countermeasures at last.

1 INTRODUCTION

The most typical feature of the city is aggregation. With the popularization of motor vehicles especially private cars, almost all the major cities in China are facing the pressure of traffic jam. Many urban roads lost their function in rush hours and become a parking lot. According to the statistics of Beijing Traffic Management Bureau, traffic congestion in Beijing caused a social cost of about 40 million every day and 14.6 billion every year. It follows that, traffic jam is not a simple transport problem, but an economic problem even political issue. So it's high time to improve the traffic situation in Beijing.

Beijing implemented motor vehicle limiting policy during the 2008 Olympic Games, and motor vehicle was limited to travel by the tail number of their license plate, odd days odd number and even-numbered days even number. After the Olympics, in order to consolidate the effect of the policy, this provision continued, but the limiting extent was weaker. There is no doubt that the limiting policy can bring much positive effect, but the negative effect caused by the policy is obvious too. However, after the special period, whether this policy is necessary to continue caused great controversy in the whole society. Discuss the relation between urban traffic jam and the limiting policy, and find measures to alleviate urban traffic jams are of great significance.

China's current research on limiting policy is still less, Shanshan Han (2009) analyzed the limiting policy and some problems followed from the perspective of supply and demand, and made some recommendations accordingly. Pan Zhang (2010) analyzed personal and social impacts of this policy based on the cost-benefit theory of public economy, and a number of recommendations were also brought out. The current study is mostly qualitative analysis, and lack of quantitative models and data support. This research analyzed the main causal feedback loop between traffic jams and the limiting policy in Beijing with the use of system dynamics, and established a system dynamics model. The model was simulated through VENSIM (the special software of system dynamics) on the basis of historical statistics and the specific circumstances of Beijing. This paper analyzed the effects of the limiting policy through simulation, and put forward some relevant proposals.

2 SYSTEM DYNAMICS MODEL OF THE LIMITING POLICY

System Dynamics (SD) was founded by Forrester (a professor of Massachusetts Institute of Technology) in 1960s. This approach focuses on the structure and

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feedback mechanisms within the system, and is good at dealing with long-period, higher-order, nonlinear, multi- variables, and more complex feedback system problems. Urban development problem is part of social complex system and is suitable to use system dynamics.

2.1 Determination of System Boundary

The behaviour analysis is based on the interaction of elements within the system, and System dynamics assumes that changes in the external environment will not affect the nature of the system behaviour. Urban transport system is a complex socio-economic system, this paper only consider the impact limiting policy have on urban traffic jam. In this paper, we use the travel quantity of urban vehicles to measure the extent of urban traffic jam, assuming that the larger the travel quantity is the more congested urban traffic is. City vehicles including private cars, official cars, buses, taxis and other types of cars, each type's inventory, growth rate, travel quantity will have an impact on urban traffic conditions.

The limiting policy is aimed at alleviate the existing traffic pressure to some extent. In ideal condition, the limiting policy can reduce the travel quantity of urban vehicles, so as to ease urban traffic jam. However, the limiting policy only reduced the number of motor vehicles on the road every day, and the demand for private cars had not changed. People still need to work and go out every day, and the use of private cars is limited, so there will be other options.

The first way is to choose public transport such as buses, taxis as substitution to private cars, which is the original intention of the policy. However, this requires higher availability of public transport, which including the number of buses, the arrangement of time, route, site and so on. The second method is to buy a second car with different license plate tail number. In this way, people can enjoy the previous convenience without breaking the rules. So our model took the service quality of public transport and the proportion of buying a second private car into consideration.

Based on the above analysis and the purpose of this paper, we ultimately determine the scope of the research system, including the inventory of urban private cars, official cars, buses, and other motor vehicles (including taxis, school buses, police cars, fire engines, etc), the availability of public transport, the total number of urban vehicle, the limiting policy, the travel quantity of urban motor vehicle, the growth rate of motor vehicle (growth rate of private cars, official vehicles), the proportion of purchasing a second private car and so on. As the inventory and growth rate of buses and other motor vehicles is small, we did not consider the growth rate of buses and other motor vehicle.

2.2 The Establishment of System Model

Causal interactions within the system determine the function and behaviour of the system. Urban vehicles including private cars, official cars, buses, taxis and so on, each type's inventory, growth rate and the implementation of the limiting policy would affect the travel quantity of urban motor vehicle, and then had an impact on urban traffic conditions.

According to the analysis of the causal relationships between each factor, as is shown in figure 1,we use VENSIM, the special software of system dynamics to establish a model of the impact limiting policy have on urban traffic jams.

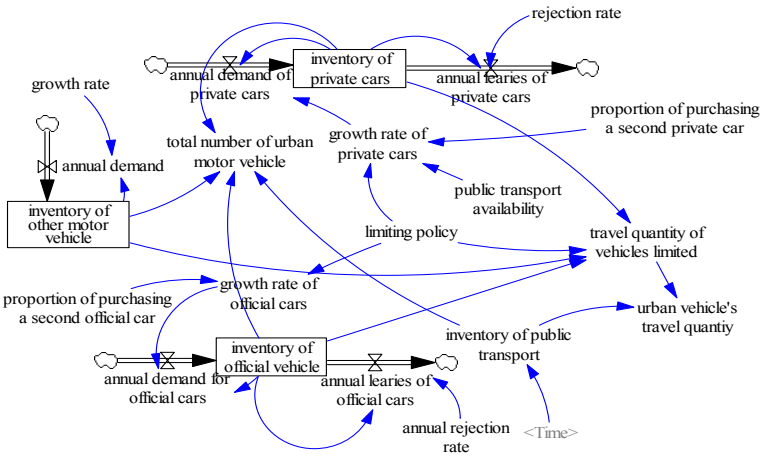

Figure 1: The stock flow chart of limiting policy's impact on urban traffic jams.

2.3 Model Equation and Parameter Settings

System dynamics model includes level equations, rate equations, auxiliary equations, parametric equations and initial value equations. The model can be simulated after entering equations to the stock flow diagram of the system. This model took the data of Beijing from 2004 to 2008 as model parameters and data of 2009 as model test value.

According to "Beijing Statistical Yearbook", statistics Beijing Traffic Management provided and other relevant information, we set the initial value of the model and some related parameters. Some of the model equations are as follows:

$$P = 0.0667 \quad (1)$$

$$Qt = Ip + Ql \quad (2)$$

$$T = Io + Ip + Ic + Iv \quad (3)$$

$$Io = INTEG (Do - Lo, 32) \quad (4)$$

$$Lo = Io * P \quad (5)$$

$$Do = Io * Ro \quad (6)$$

$$Iv = INTEG (Ad, 50) \quad (7)$$

$$Lp = Ip * P \quad (8)$$

$$Ip = INTEG (Dp - Lp, 129.8) \quad (9)$$

$$Dp = Ip * Rp \quad (10)$$

$$Ql = IF\ THEN\ ELSE (L = 1, (Iv + Ip + Io) * \quad (11)$$

$$It = 2004 \quad (12)$$

$$Ft = 2020 \quad (13)$$

Among the above equations, P refers to rejection rate, Qt refers to urban vehicle's travel quantity, Ip refers to inventory of public transport, Ql refers to travel quantity of vehicles limited, T refers to total number of urban motor vehicle, Io refers to Inventory of official cars, Ic refers to inventory of private cars, Iv refers to inventory of other motor vehicle, Do refers to annual demand for official cars, Lo refers to annual learies of official cars, Ro refers to growth rate of official cars, Ad refers to annual demand, Dp refers to annual demand of private cars, Lp refers to annual learies of private cars, Rp refers to growth rate of private cars, L refers to limiting policy, It refers to initial time, Ft refers to final time.

3 MODEL SIMULATION AND ANALYSIS

In this paper, we used VENSIM to simulate the model, studying the impact urban motor vehicle limiting policy had on urban traffic conditions. The simulation time is from 2004 to 2020, the simulation step is 1 year. By changing relevant parameters, we could analyze different influence degree the limiting policy had on traffic jams under different conditions, thereby sought to improve urban traffic condition in effective way.

The large travel quantity of private cars is the main cause of urban traffic jams. After the implementation of limiting policy, people who previously travel by private cars will have two options: choose public transport instead of private cars or buy a second car with different license plate tail number. This paper conducted a simulation on these two conditions.

3.1 Choose Public Transport

People limited by the limiting policy will choose public transport instead of private cars if the public transport is convenient enough , and no one would buy a second or third car on account for the limiting policy. Urban motor vehicle's travel quantity before and after the implementation of the policy is shown in Figure 2:

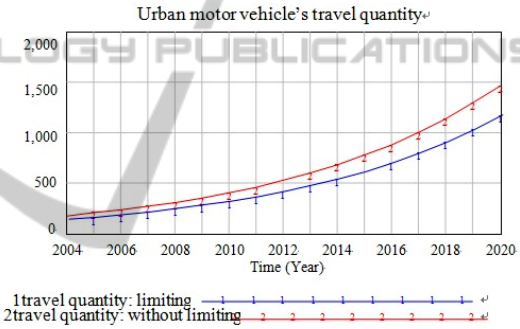

Figure 2: Urban motor vehicle's travel quantity before and after the policy (choose public transport).

As is shown in the figure, in ideal condition, most people will choose public transport instead of private cars after the implementation of the policy. So the limiting policy can reduce urban motor vehicle's travel quantity and play a role in the mitigation of urban traffic jams. However, this is based on an efficient public transport system.

3.2 The Purchase of a Second Car

After the implementation of the limiting policy, many families choose to buy a second car because the current public transport service is still not so convenient. The rapid growth of motor vehicle is slowly offset the positive effects of the limiting policy. The purchase of a second car will weaken the impact of the policy, and the impact of the policy will be different with different purchase rate of a second car. Unable to determine how many people will buy a second car, so sensitivity analysis is

made. Urban motor vehicle's travel quantity before and after the implementation of the policy when there are 3% people buy a second car is shown in Figure 3.

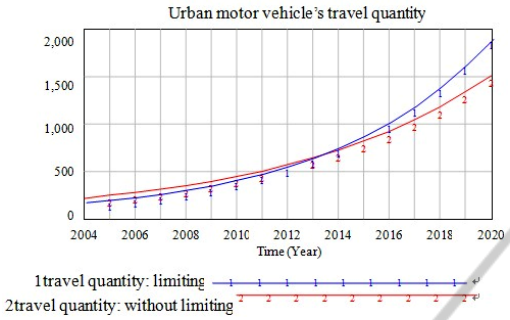

Figure 3: Urban motor vehicle's travel quantity before and after the policy (3% buy a second car).

As is shown in the figure, when there are 3% people buy a second car, the limiting policy can reduce urban motor vehicle's travel quantity in the short term. But in the long run, urban motor vehicle's inventory will be greatly increased because the purchasing of a second car. As the base number of limiting is much bigger, the limiting policy even would have opposite effect, leading urban motor vehicle's travel quantity much greater.

Increase the proportion of second car's purchasing through sensitivity analysis, urban motor vehicle's travel quantity before and after the implementation of the policy when there are 6.25% people buy a second car is shown in Figure 4.

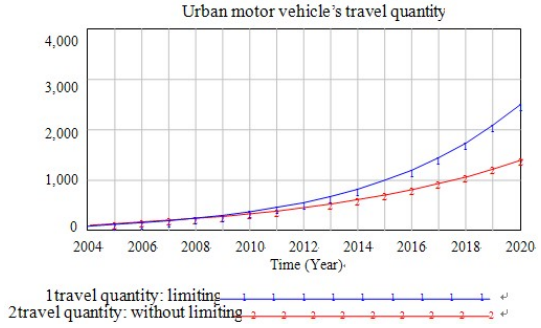

Figure 4: Urban motor vehicle's travel quantity before and after the policy (6.25% buy a second car).

Through the simulation of the model we can find that when the proportion of purchasing a second car is small, the limiting policy can play a role in the short term, but when the purchasing ratio becomes large enough, the role of the policy will gradually disappear. And in the long run, the positive effects of the limiting policy will gradually be offset by the rapid growth of motor vehicles.

4 CONCLUSIONS

The governance of urban traffic jam is a hot topic in the process of urban development in China, and many cities implemented limiting policy to ease traffic jams. This paper established a model of the impact limiting policy had on urban traffic jams. Through the simulation of the model with VENSIM, we got the conclusion that the limiting policy need the support of a strong public transport system , people constricted will choose public transport instead of private cars only when the public transport is convenient enough, thereby ease urban traffic jams. However, many families choose to buy a second car because the current public transport service is still not so convenient. On this occasion, the limiting policy only has short-term effect. In the long run, especially when the purchasing ratio becomes large enough, urban motor vehicle's inventory will be greatly increased. As the base number of limiting is much bigger, the limiting policy even would have opposite effect. Therefore, simply limiting is not a scientific way and can not fundamentally solve the problem of urban traffic jams. In the long run, the development of public transport can effectively ease urban traffic jams.

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