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Research Article

Research on Traffic Congestion Based on System Dynamics: The Case of Chongqing, China

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With the rapid development of society, urban traffic congestion has gradually become an important social problem that many cities need to solve. For Chongqing, traffic congestion not only affects residents' normal travel but also brings more serious environmental pollution. Aiming at the problem of urban traffic congestion and automobile exhaust pollution, this paper adopts the system dynamics method to establish a model for studying urban traffic congestion system from the perspectives of private cars, trucks, and public transportation. First, we determine city motor vehicle trips as an indicator of the degree of traffic congestion in this paper. Second, we analyze the causal relationship between the growth of private cars, the travel of trucks, public transportation, population, and other factors and then build a model and test the stability of the model. Then, we add some practical policies to the model for policy analysis. Finally, it is concluded that the private car restriction policy is effective in controlling the amount of private car travel, and the purchase restriction policy controls the growth of the number of private cars from the root cause, but the development of public transportation is the most effective treatment measure in the long run.

1. Introduction

With the rapid development of China's economy and the improvement of people's income level, motor vehicles are more needed in all aspects of clothing, food, housing, and transportation. The rapid development of the use of motor vehicles has brought convenience to people and changed the pattern of the entire transportation system. The increasing popularity of online shopping has promoted the development of the logistics industry, which has led to the increasing use of freight cars and increased traffic pressure. In addition, with the convenience of take-away distribution, many delivery staff ride motorcycles to shuttle through the streets and lanes every day, causing a lot of traffic problems. More importantly, economic development promotes the improvement of people's living standards, and the per capita possession of private cars has also continued to increase, which is a major source of road traffic pressure.

When traffic congestion occurs, the vehicle travels very slowly, and the behavior of rapid braking will result in insufficient combustion of fuel oil and a large amount of harmful exhaust gas, which will increase air pollution. And the number of traffic accidents is increasing. Therefore, how to take effective measures to control traffic congestion is an urgent problem to be solved in many cities.

Baidu Maps had released a report called "Research report on urban traffic in China in the third quarter of 2018" in January 2019. It was concluded from the analysis of various data indicators that Chongqing's congestion index was as close as that of Beijing and Harbin. Moreover, in Baidu Map's "fourth quarter of 2018 congestion ranking," Chongqing was one of the "top three," becoming the most congested big city after Beijing and Harbin.

In addition, Baidu Map also divides cities into several categories according to the number of motor vehicles: more than 3 million, more than 2 million, more than 1 million, and less than 1 million. Chongqing ranks second in terms of congestion in cities with more than 3 million categories, second only to Beijing. For Chongqing, traffic congestion is a problem that needs to be improved immediately.

In this paper, we try to find the cause of traffic congestion and further write a model of traffic congestion to find some ways to actually manage. What are the indicators for measuring traffic congestion? How to analyze the factors affecting traffic congestion indicators? These problems are what this article needs to solve.

The structure of this paper is as follows. Section 2 presents the early literature on the study of the causes of traffic congestion and the system dynamics. Section 3 contains the basic construction of the model and some assumptions and premise. Section 4 presents the addition of initial data and the simulation of the model. Section 5 adopts several policies to optimize the results. Finally, Section 6 compares the policies and draws conclusions.

2. Literature Review

Traffic congestion is a qualitative indicator, and its evaluation is subjective in daily life. In academic research, scholars often choose a quantitative indicator instead of qualitative indicator for analysis. Guo et al. [1]selected the road network traffic congestion index, the road network congestion level mileage ratio, the time-based road network congestion level, and the number and distribution of key congestion points to establish a macroindex system for traffic congestion assessment, which can be obtained from actual data.

Based on the study of traffic congestion, the second step is to find out the causes. Many scholars have carried out research studies from the economic, social, and other aspects. The reasons for traffic congestion are analyzed as follows.

Wright and Orenstein think that the main reason for traffic congestion is traffic bottleneck [2]. There are two kinds of traffic bottlenecks: the first is the traffic bottleneck caused by the road itself and the traffic capacity difference caused by the unclear road shape, road width, or road sign. The second reason is the unstable change of road demand. The road supply cannot meet the congestion caused by the change of demand. This type of congestion is caused by uncontrollable weather conditions. Such bottlenecks are few and far between but will lead to even greater congestion. Anthony concluded that traffic congestion was mainly caused by the following problems [3]. First, because of the rapid increase in the number of people, the demand for travel has increased significantly. Secondly, with the increase of the number of motor vehicles, more and more people choose to travel by motor vehicles. Third, occasional severe traffic congestion is caused by the random occurrence of emergency. After explaining the main reasons for the deterioration of infrastructure due to traffic congestion, Diakaki et al. briefly outlined the proposed and implemented control strategies, covering three areas: urban road networks, highway networks, and route guidance [4]. Liu et al. put forward domestic policies for reference according to the experience of "traffic congestion control" in foreign cities [5], such as strengthening the management of traffic road supply and vigorously developing urban public transportation.

Research on traffic congestion management includes those as below. Taylor believes that charging for roads is a way to alleviate traffic problems [6]. McKnight believes that conventional traffic management and improvement of vehicle standards are not particularly effective in the reality of rapidly increasing demand for road use. He also believes that the control of the use and purchase of private cars is the key to effectively control traffic congestion. Coomber et al. proposed different charging methods and prices for parking lots with different functions in the city to alleviate traffic congestion [7]. Muanmas et al. proposed from the perspective of economics that through congestion pricing [8], people can pay the marginal social cost generated when they travel, to internalize the externality of the transportation system and effectively reduce traffic congestion. Fishman et al. studied the mechanism of shared bikes on traffic congestion [9]. Research results showed that bike sharing can not only enhance physical health but also reduce urban traffic congestion and environmental pollution. From the perspective of system dynamics, Heung et al. designed a dynamic programming method to control traffic problems. By installing a local fuzzy logic controller (FLC) at each intersection, a dynamic programming (DP) technology was proposed to derive the green light time at each stage of the traffic light cycle [10].

This paper takes city motor vehicle trips as the index to measure the degree of traffic congestion to simulate and analyze the degree of easing the congestion caused by various policies. System dynamics is a discipline of analyzing and studying information feedback founded by Forrester W of Massachusetts institute of technology in 1956. Its ability to deal with higher order, nonlinear, multiple feedback, complex time-varying system problems and policy simulation has made it widely used in various fields of economic and social development. [11] Modeling steps based on system dynamics are shown in Figure 1. Kaparias and Bell analyzed the successes and pitfalls of London's congestion charging and identified potential future opportunities based on the latest technological developments in the field of cooperative intelligent transportation systems (ITS) [12].

Some literatures also try to find solutions to traffic congestion by using system dynamics method. Wang and Jia analyzed the main factors that affect the demand for private cars [13] and studied the changes of people's demand for private cars after China's entry into WTO. Fan and Yan conducted a simulation analysis of private car ownership in Beijing and compared the impact of existing governance measures on demand [14]. They concluded that actively developing urban public transportation is the most effective way to reduce private cars. Yang et al. [15] selected Beijing city as the research object, established a system dynamics model for analysis, and concluded that controlling the number of motor vehicles is helpful to control traffic congestion. Dang studied that the automobile license plate auction system in Shanghai is effective in reducing the demand for private cars [16]. Jia et al. used system dynamics method to establish traffic congestion pricing management model from the perspective of environmental and social benefits [17]. Through dynamic simulation and comparison, reasonable schemes to alleviate

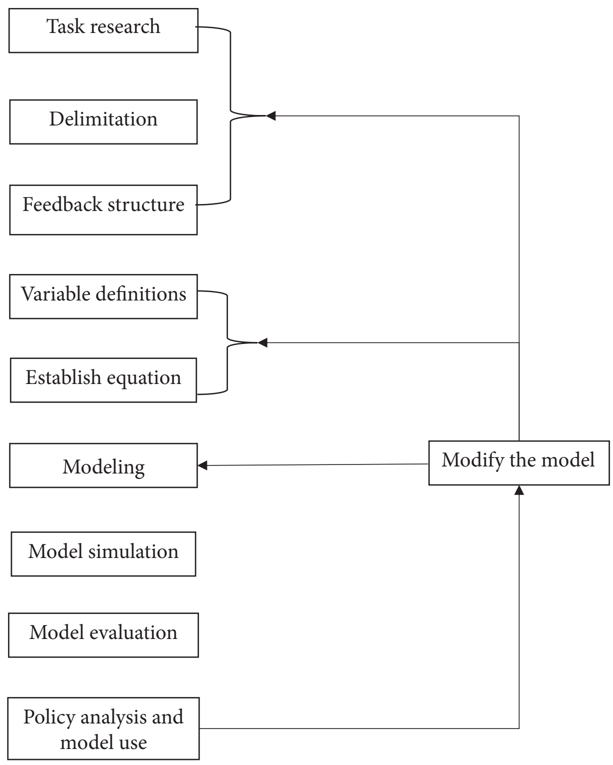

Figure 1: System dynamics modeling process.

traffic congestion and environmental pollution were obtained. Zhang et al. [18] built the system dynamics model of urban green transportation and proposed to improve public transportation and reduce the emission of carbon.

This paper starts from the city motor vehicle trips, considering the travel volume of private cars, buses, trucks, and other motor vehicles and mainly establishes a system from the two perspectives of residents' private car travel and logistics use. Based on the application of system dynamics, this paper uses causal diagram, flowchart, and corresponding data parameters to complete the qualitative analysis and completes the programming with the support of Vensim software. Then, in the simulation, different policy variables are added, and experiments are carried out. Finally, quantitative results of research objects based on time changes can be obtained. Taking Chongqing as an example, the core of this paper is to analyze private car restriction policy, private car purchase restriction policy, and freight car limit policy and estimate the impact of improving the public transport sharing rate. Through the simulation of the above policies, effective suggestions can be put forward to reduce the amount of city motor vehicle travel so as to improve the valuable reference for solving the traffic congestion problem.

3. Model Description

3.1. The Basic Model. At present, there are many indicators for the quantitative analysis of traffic congestion. For example, the congestion ranking of Baidu Map is based on the commuting peak index. This paper mainly measures the city motor vehicle trips to measure congestion.

System dynamics analyzes the interdependent interaction of internal elements of the system and assumes that factors outside the system do not have a significant impact on the elements within the system; therefore, variables that are important to the complex problem being studied are included in the system. Factors that are not significantly related to the problem are excluded from the system.

In order to analyze city motor vehicle travels, this article has established a complex system that not only contains the ownership of private cars, buses, freight cars, and other motor vehicles but also has a close relationship with other aspects of urban population, economy, environment, policy, etc. According to the research purpose of this paper, the analysis factors in the system are finally determined as shown in Table 1.

After determining the boundary of the system, the causal relationship shown in Figure 2 is determined by analyzing the factors. "+" means positive effect and "–" means negative effect. The variables of the city motor vehicle travel system mainly include city's economy (GDP), resident population, urban logistics, private car travel, bus travel, freight car trips, and other motor vehicle trips. By analyzing the relationship between the variables, the causal relationship of the main variables can be established as shown in Figure 2. As the city's economy and population grow, the demand for people to buy vehicles increases. The growth rate of motor vehicle ownership far exceeds the growth rate of urban road area, resulting in greater traffic congestion. The increase in the amount of motor vehicles will emit more exhaust gas, resulting in greater environmental pollution, which in turn will reduce the growth of private cars. This paper attempts to mitigate the implementation of urban policy, such as controlling the growth of private car trips and freight car trips, in order to reduce the number of motor vehicle trips and alleviate traffic congestion. There are some main causal circuits as follows:

City motor vehicle trips ⟶ waste gas pollution ⟶ environmental pollution ⟶ private car growth rate ⟶ private car ownership ⟶ private car travel ⟶ city motor vehicle trips

City motor vehicle trips ⟶ urban motor vehicle ownership ⟶ traffic factor ⟶ private car growth rate ⟶ private car ownership ⟶ private car travel ⟶ city motor vehicle trips

This paper determines the system boundary and establishes a system inventory flow graph based on causality. The causal relationship only illustrates the positive and negative effects between the two variables. In the system dynamics model, the variables are also divided into state variables, rate variables, and so on. To illustrate the relationship that is not illustrated in the causal diagram, to further quantify the entire model, we use Vensim to plot the stock flow (Figure 3). In the policy analysis, after adding various policies, the new SD model is shown in Figure 4.

3.2. Some Formulas

(1) Bus ownership = INTEG (bus ownership ∗ bus growth rate, initial value of bus ownership)

Table 1: Determination of system boundaries.

System category	Specific variables
Residents' travel	Private car ownership Private car travel Private car growth rate Private car scrap rate Bus ownership Bus growth rate Other motor vehicle ownership Other motor vehicle growth rate Related governance policy
Urban logistics	City freight volume Urban freight growth rate Car ownership Freight car trips Urban freight growth Related governance policy
Others	Permanent residents Resident population growth rate Total household registration population Household registration population growth rate Total car purchase price Car tax Fuel cost Fuel cost growth rate Parking fee Total road area of the city Average road area Annual growth rate of urban road area City GDP GDP growth rate NO_2 stock Each vehicle emits NO_2 per year Motor vehicle contribution rate to NO_2 emissions

(2) City motor vehicle trips = bus ownership + other motor vehicle travel + private car travel + freight car travel

(3) Consumer psychological factor = demonstration effect ^0.4 ∗ economic factors ^0.6

(4) Total purchase price = car purchase price + other fees

(5) Income-to-price ratio = per capita GDP/total car purchase price

(6) Total household registration population = total household registration population ∗ household registration population growth rate

(7) Per capita GDP = city GDP/total household registration population

(8) City GDP = INTEG (GDP growth volume, initial GDP value)

(9) Growth rate of private car = traffic factor ^0.15 ∗ economic factor ^0.4 ∗ consumer psychological factor ^0.32 ∗ (1−environmental factor) ^0.13 ∗ degree of consumption satisfaction

(10) Fuel costs = INTEG (fuel cost growth rate ∗ fuel costs, initial value of fuel cost)

(11) Private car ownership = INTEG (annual demand for private cars − annual private cars scrap rate, initial value of private cars)

(12) Annual demand for private cars = private car ownership ∗ growth rate of private cars

(13) Annual scrap number of private cars = private car ownership ∗ private car scrap rate

(14) Permanent residents = INTEG (permanent residents ∗ population growth rate, initial value of permanent residents)

(15) Per capita ownership = private car ownership/resident residents

(16) Other fees = parking fee + fuel fee + car purchase tax

(17) Car tax = purchase price ∗ purchase tax rate

3.3. *Assumption and Notation*

(1) The assumption of the average emission of NO_2 vehicles: taking the vehicle with the emission level of "National Phase IV Motor Vehicle Pollutant Emission Standard" as an example, the emission of light vehicles is about 1.6 l, and the maximum emission of NO_2 cannot exceed 0.08 g/km. If the annual driving distance is 15000 km, NO_2:0.08 kg/km ∗ 15000 km/1000 = 1.2 kg.

(2) The model assumes sustained and stable economic growth.

(3) Urban material flow in the model is replaced by urban freight volume; in the model, NO_2 production was selected as the environmental pollution index. The share rate of public transport is actually the share rate of public transport motorization. Environmental pollution is expressed by the content of NO_2. All growth rates are sequential.

(4) Assume that all growth rates are constant.

(5) Private cars, buses, and trucks are mainly considered in surface traffic volume, while the rest are included in other motor vehicles.

(6) Traffic factors only consider the influence of the average road area of vehicles. Environmental factors are positively correlated with the total number of motor vehicles. Economic factors are expressed as a table function of the ratio of income to car purchase price. The above indexes are obtained by table functions. Consumer psychology is the exponential function of economic factor and demonstrative effect.

(7) The growth rate of private cars is derived from the formula given in [12] and combined with the actual situation of the research object in this paper; it is concluded that the growth rate of private cars = traffic factor ^0.15 ∗ economic factor ^0.4 ∗ consumer psychological factor ^0.32 ∗ (1−environmental pressure)^0.12 ∗ consumer satisfaction degree. The degree of consumption satisfaction is determined

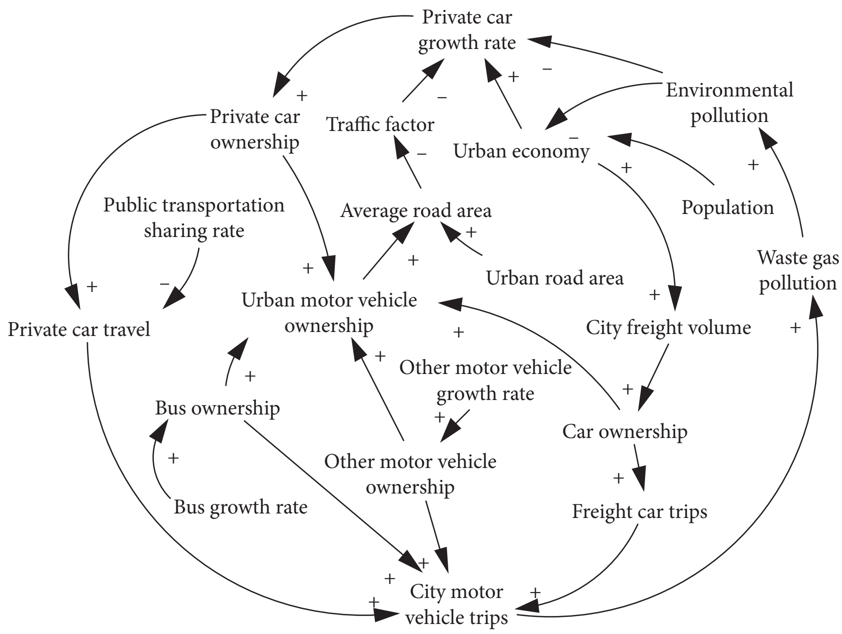

Figure 2: Causal cycle diagram.

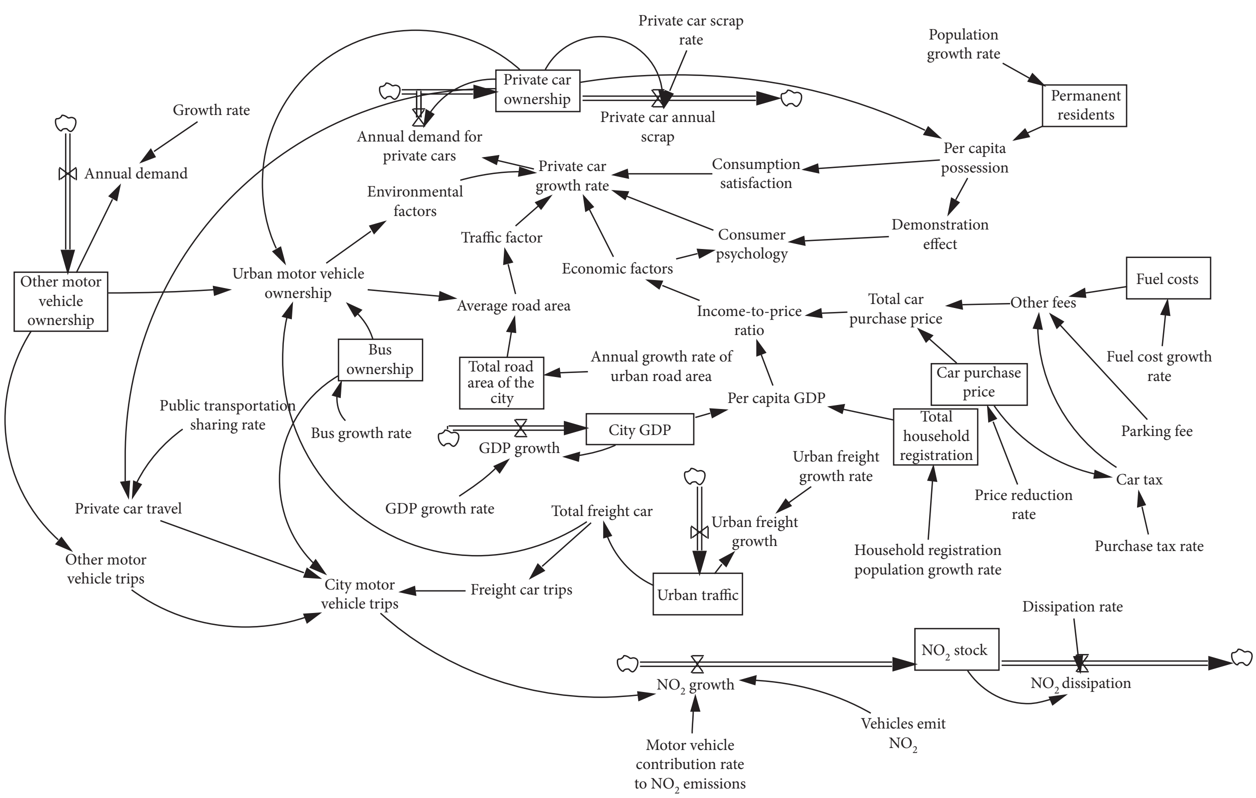

Figure 3: System dynamics diagram (without policy).

by per capita ownership. When per capita ownership is 0, the degree of consumer satisfaction is 0, and people are eager to buy cars. When per capita ownership is above 1, consumers' demand for cars is not high, so the degree of consumer satisfaction tends to be 1.

(8) The assumption of the restriction policy: each restriction of a tail number will reduce the number of vehicle trips by 10%. Similarly, when two tail numbers are restricted, about 20% of private car trips will be reduced. The parity-number limit policy is rotated once every two days, reducing the trip rate by 50%.

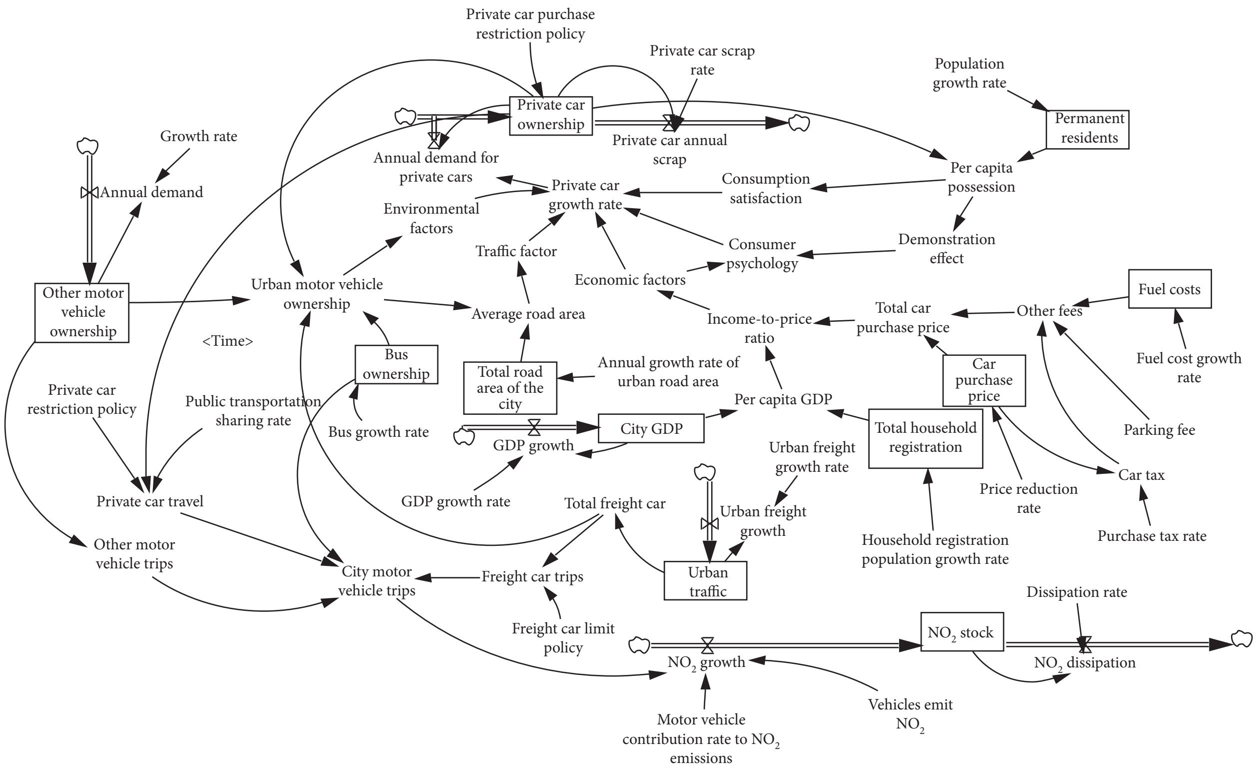

Figure 4: System dynamics diagram (with policy).

(9) The winning rate of private purchase restriction policy is assumed to be 30%.

(10) In the process of operation, the policy of vigorously developing public transportation is translated into the annual increase of public transportation sharing rate, which is shown in the form of table function.

4. Model Simulation

4.1. Parameter Estimation. The parameter estimation methods adopted in this model are as follows:

(1) Adopt the linear fitting method

(2) Quote relevant data of statistical yearbook

(3) Estimate parameter values according to the model's reference behavior characteristics

(4) Methods of expert evaluation and references

Take the logarithm of Chongqing's GDP from 2011 to 2016 and use Excel to get the trend (Figure 5). According to the trend chart, the logarithm of GDP and time basically conforms to the linear relationship, and the determination coefficient is 0.9971, with a high degree of fitting, as follows:

$$y = 0.1126x - 217.13,$$
$$R^2 = 0.9971. \quad (1)$$

The GDP growth rate of Chongqing is 11.26%. Similarly, according to the data of statistical yearbook, logarithmic fitting was carried out for each level variable, and the values were obtained as shown in Table 2.

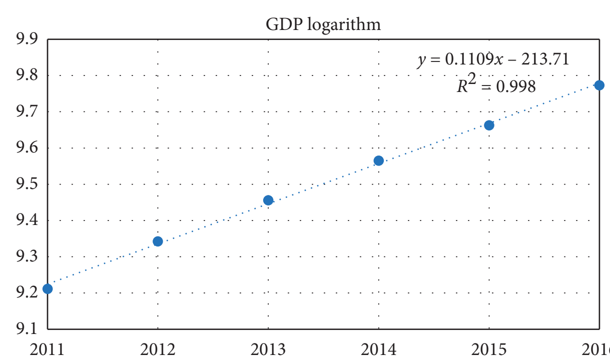

Figure 5: GDP growth rate fitting chart.

Table 2: Setting of constant values of the model.

Variable	Initial value set %
The GDP growth rate	11.26
Permanent population growth rate	0.84
Registered population growth rate	0.35
Fuel rate growth rate	10.17
Bus growth rate	11.83

The initial values of the Chongqing traffic simulation model are shown in Table 3 which refer to the relevant data of Chongqing in China statistical yearbook 2011 [19].

4.2. Model Simulation. Different step sizes of 0.25 (step 2), 0.5 (step 0), and 1 (current) are selected for the system dynamics model, which represent quarter, half year, and

Table 3: Initial values of the model.

Variable (unit)	The initial value
Private car ownership (10,000)	89.89
Bus ownership (vehicle)	8118
Other car holdings (ten thousand)	39.69
Purchase price (yuan)	150000
Per capita GDP (yuan/person)	34500
Total household registration population (10,000)	3392
Permanent residents (10,000)	3048
Total area of the city (ten thousand square kilometers)	17776
Purchase tax rate	0.1
Private car scrap rate	0.11
Total freight car (ten thousand)	26.01
Fuel costs (yuan)	5000
Cargo volume (ten thousand tons)	9.68
NO_2 dissipation rate	0.1
Initial time	2011
Final time	2030
Time step	1
Units for time	Year

year, respectively. The results are shown in Figure 6. According to the trend in the figure, it can be concluded that the system is basically stable, and the operation of the model does not cause morbidity.

This paper takes the 2011–2016 Chongqing Statistical Yearbook data as the initial value and makes a medium and long-term simulation of the development of the number of motor vehicles in Chongqing. In Table 4, the simulation results of some variables in 2017 are compared with the actual statistical values. Compared with the prediction results, the error of each simulation value is small, and all do not exceed 5%. The behavior described by the model is basically consistent with the actual system behavior, and the model is basically effective.

4.3. Trend Forecast. As can be seen from Figure 7, without the use of policy adjustments, travel of all types of motor vehicles will continue to increase. And because private cars are the largest number of all types of motor vehicles and demand growth is growing rapidly, its continuous increase will increase the traffic burden without any control policy. But it can also be seen that the rapid growth of private cars will gradually slow down around 2025. Although the overall trend is still rising, the growth rate has been declining slowly.

Buses can reduce the number of private cars and increase the number of total motor vehicles. However, as the growth of private cars is much faster than the growth of buses, the natural growth rate of buses cannot alleviate the traffic pressure that the growing number of private cars brought.

It can be analyzed that with the increase of city GDP and the increase of per capita income, the consumption level of people is also increasing. As online shopping has become the most commonly shopping method, the demand for logistics has also increased accordingly. In addition to long-distance transportation such as aviation and trains, the number of freight cars is also increasing. The large-scale freight cars are heavy in weight, slow in speed, and low in fuel combustion, which also causes air pollution and traffic pressure.

As shown in Figure 8, the growth rate set by the model decreases with time. The automobile demand may gradually decrease. As a result, the growth rate may continue to decline. However, since the per capita vehicle cannot reach 1 in a short period of time, the consumer satisfaction level will not be zero during the simulation period, so the growth rate will decrease later and then approach a constant so that the number of private cars still grows and traffic stress will not be alleviated.

5. Policy Optimization

5.1. Private Car Restriction Policy. At present, Chongqing has not yet implemented a large-scale limit policy and only implemented the double-number restriction policies on the bridges of the Fujian-Macau Bridge, the Huanghua Garden Bridge, and the Jiahua Bridge. This article mainly refers to three possibilities. Most of the existing domestic limit policies have been implemented to restrict the tail numbers during the weekdays and not to restrict them on weekends. Moreover, buses, taxis, official vehicles, and most freight vehicles are not affected by this policy. Therefore, in this article, it is assumed that the traffic restriction policy only has impact on the travel of private cars.

We set the parameters, fill in the model, and run the simulation three times separately to get the trend (Figure 9).

As can be seen from Figure 9, the restriction policy has a significant effect on reducing the amount of private car travel. In theory, the more restricted the tail numbers, the less the travel and the smaller the traffic burden. However, it can also be seen from the figure that after adopting parity-number restriction policy, the number of motor vehicle trips in cities has been reduced by almost half. With the implementation of the private car restriction policy, the development of public transportation may not keep up with people's travel needs.

5.2. Private Car Purchase Restriction Policy. Chongqing has not yet taken specific measures in terms of restricting the purchase of vehicles. However, in theory, rather than trying to adopt other policies to reduce the number of private cars, it is better to reduce the purchase of vehicles from the root cause. In order to curb the excessive growth of private cars, different restrictions on purchases have been adopted in various places, which are mainly divided into three types: Beijing's random lottery purchase policy, Shanghai's license auction policy, and Guangzhou Auction + Rocking Policy. This paper mainly adopts Beijing's policy to analyze.

In recent years, Beijing has been ranked among the top three in the country, both in terms of the number of motor vehicles and the degree of traffic congestion. On December 23, 2010, Beijing began to implement the policy of determining the private car purchase indicators by lottery.

The specific implementation principle of the lottery policy is a certain number of vehicles is allocated for each period, and the number is assigned before the lottery and drawn. The selected number in the pumping period also has

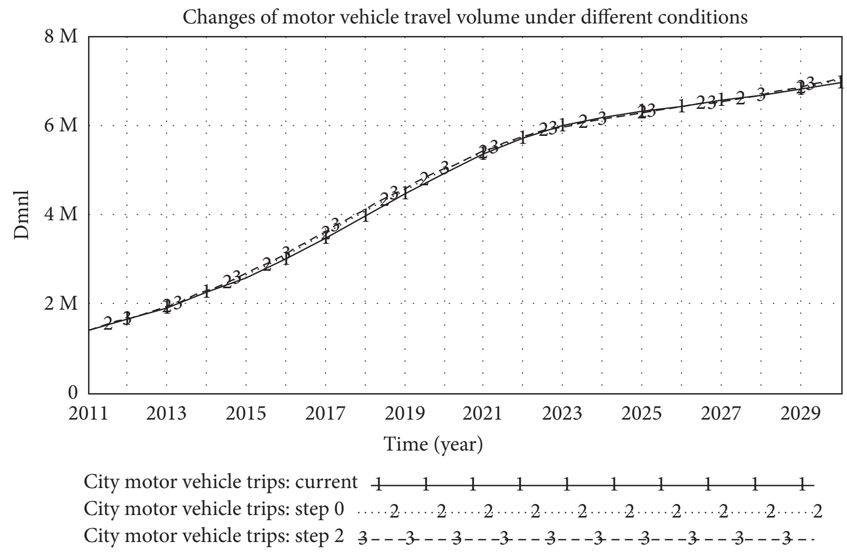

Figure 6: Historical test.

Table 4: Comparison of model simulation predictions with real values (2017).

Variable (unit)	Predictive value	Actual value	Error (%)
Private car (10,000 cars)	324.51	320.14	1.37
Private car (10,000 cars)	18975	19015	−0.21
City GDP (100 million yuan)	18990.2	19500.27	−2.62
Permanent residents (10,000 people)	3069.24	3075.16	−0.19
Total household registration population (10,000 people)	3400.35	3389.82	0.31
NO_2 stock (10,000 tons)	214031	203954.91	4.94

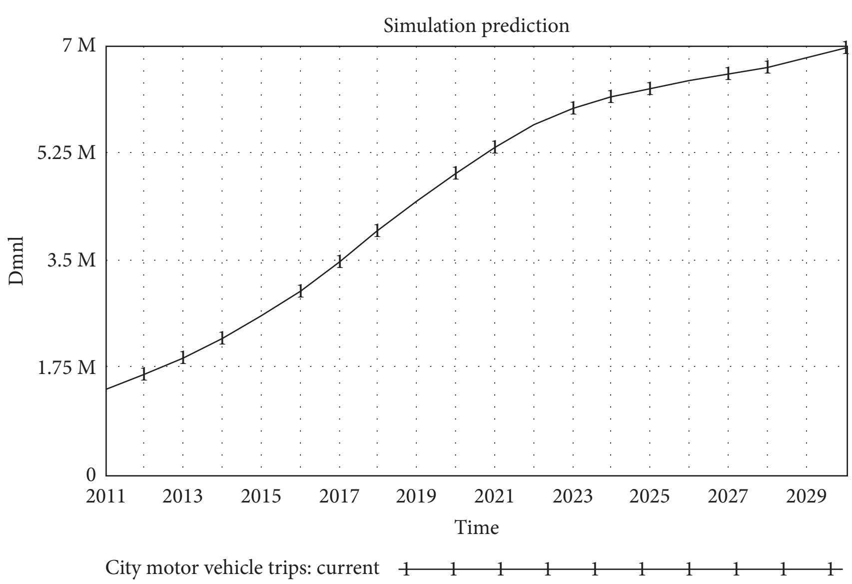

Figure 7: Changes in city motor vehicles trips over time.

a shelf life. If it is not used until the deadline, the quota will be invested in the next time. Referring to the previous period of Beijing, the allocated number of vehicles given in each period is x, and the number of people participating in the survey is y. The winning rate is $x/y * 100\%$. After investigation, it was found that not all of the people involved in the

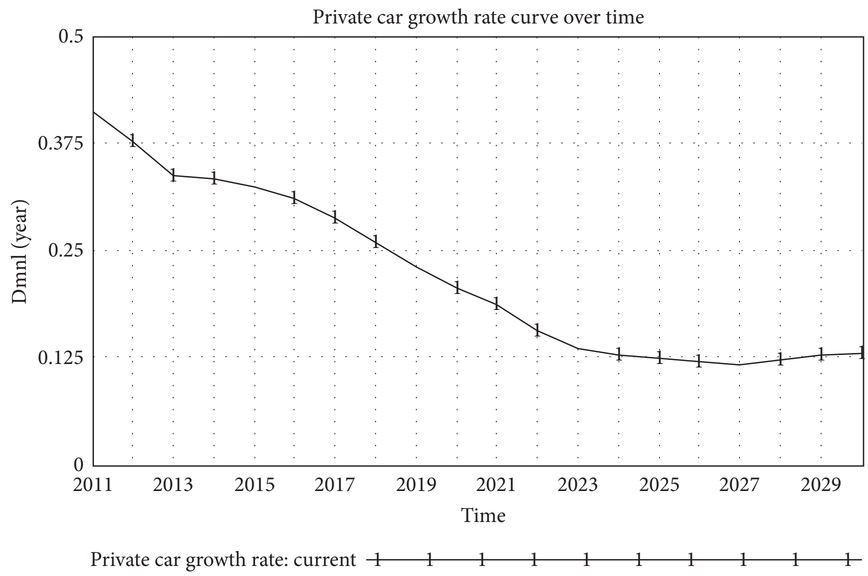

Figure 8: Changes in the growth rate of private cars.

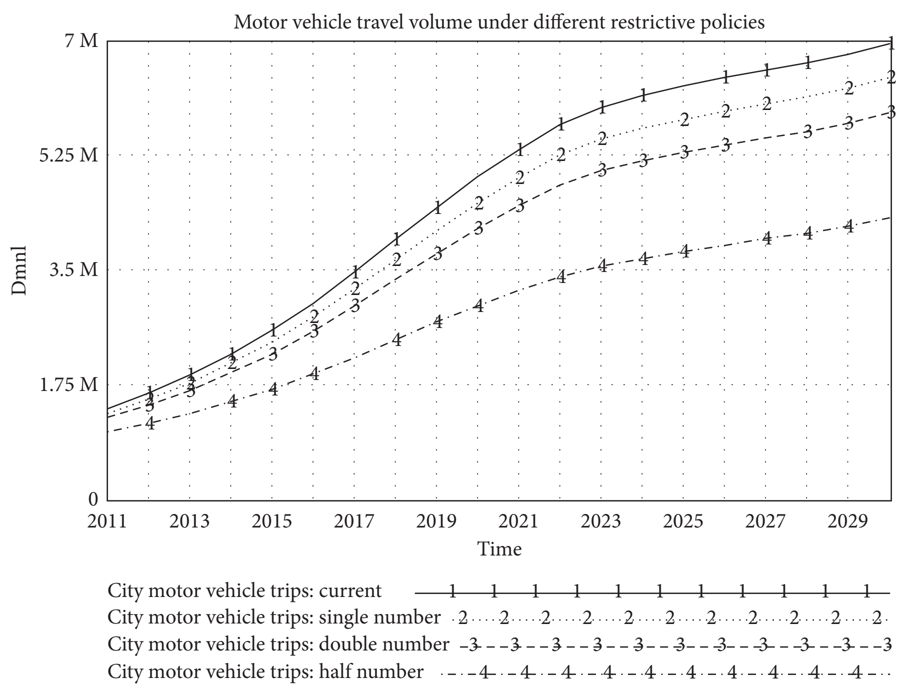

Figure 9: Vehicle traffic in cities under different restrictions.

extraction were those who had the demand for car purchases. Due to the lower and lower rate of winning in recent years, many people will choose queue for a long time, so $y \geq$ the annual demand for private cars.

As shown in Table 5 and Figure 10, the car purchase restriction policy is a good measure to limit the total number of private cars. In the case of each period, you can effectively limit the number of cars you buy. Regardless of other factors, the purchase of a car is an effective policy to alleviate traffic congestion.

Table 5: Comparison of the number of private cars with and without implementation of the private car purchase restriction policy.

Time	Without policy (10,000 units)	With policy (10,000 units)
2012	117.163	94.867
2013	148.558	100.457
2014	182.229	106.752
2015	222.717	113.452
2016	270.452	120.868
2017	324.719	128.637

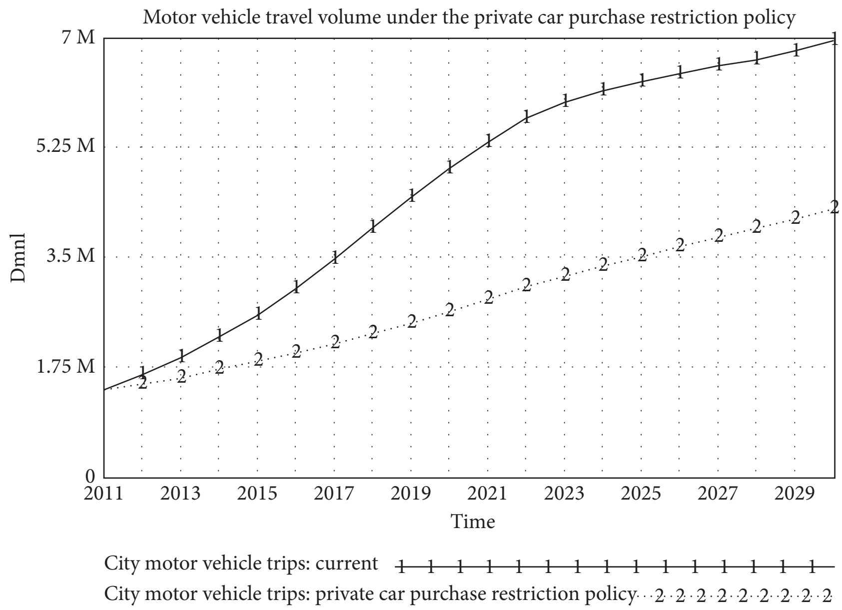

Figure 10: The number of motor vehicle trips in the city under the swaying policy.

Table 6: Travel mode selection and travel distance [9].

Travel mode (km) (%)	0–2	2–5	5–8	8–10	10–20	>20
Walk	56.41	4.5	0.43	0.36	0	0
Bicycle	3.05	30.01	14.21	13.03	5.1	1.23
Public transit	3.07	31.32	46.16	47.88	38.88	36.75
Private car	7.6	30.17	40.3	43.98	43.98	63.97
Others	3.54	2.33	2.33	0.81	0.81	2.66

5.3. Focus on the Development of Public Transportation. In addition to private cars, public transportation is also an indispensable way for contemporary travel. Public transportation has the advantages of being cheap, convenient, and green. Promoting public transportation can not only reduce traffic congestion but also reduce environmental pollution. In this paper, when the initial value of the model is set, it is assumed that the public transportation sharing rate is constant. In fact, this is impossible because the government invests a large amount of money every year to build public transportation. For example, in recent years, more and more bus lines have been established in Chongqing. The light rail line has formed a network, and most of the landmark locations and business districts in the main city are included.

From Table 6, it can be found that when travelling more than two kilometers and less than twenty kilometers, people choose public transportation with a similar probability to private cars, so we think that transportation and private cars can be substituted. In an increasingly convenient public transportation network, people are more inclined to choose public transportation because of the difficulty of parking and the trouble of traffic jams.

Therefore, while vigorously developing public transportation, the sharing rate of public transportation to private car travel is also constantly rising. The article assumes that the public transportation sharing rate is a variable that changes over time. After adjusting the function, we perform simulation analysis, and the result is shown in Figure 11. With the continuous development of public transportation, city motor vehicle trips have been greatly reduced.

5.4. Freight Car Limit Policy. In order to restrict the passage of freight vehicles in urban areas, the Chongqing Municipal Government has also adopted some restrictions on freight cars. The main restrictions are as follows: first, every day from 7:00 to 22:00, all freight cars with registered addresses not in Chongqing are prohibited. In Chongqing, the three-axis (including) freight cars that do not hold valid passports are forbidden to enter the main section. Second, 24 hours a day, all freight cars are prohibited from entering the following sections: Yubei District Shuanghu Road (the intersection of Huangjiaoping Park and Shenghu Tianyu Road), Baiguo Road, and Qihang Avenue; it is forbidden to approve the trucks with a load of more than 1 ton (inclusive) and enter the Xingsheng Avenue of Yubei District.

However, because the base of freight cars is too small, the proportion of travels in the whole city is not large, and there is no obvious change in the amount of motor vehicles. The

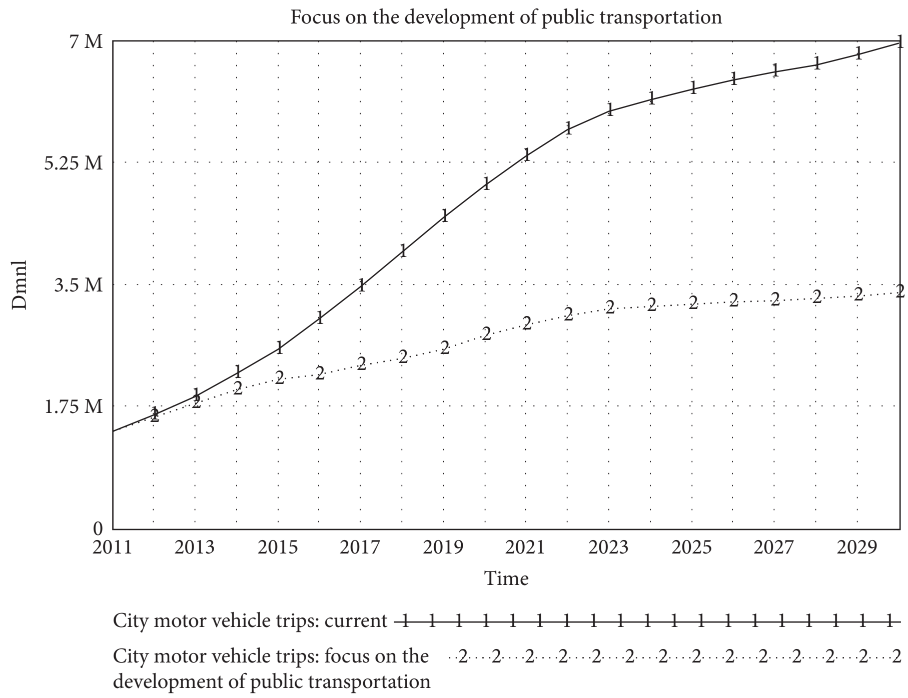

Figure 11: Focus on the development of public transportation.

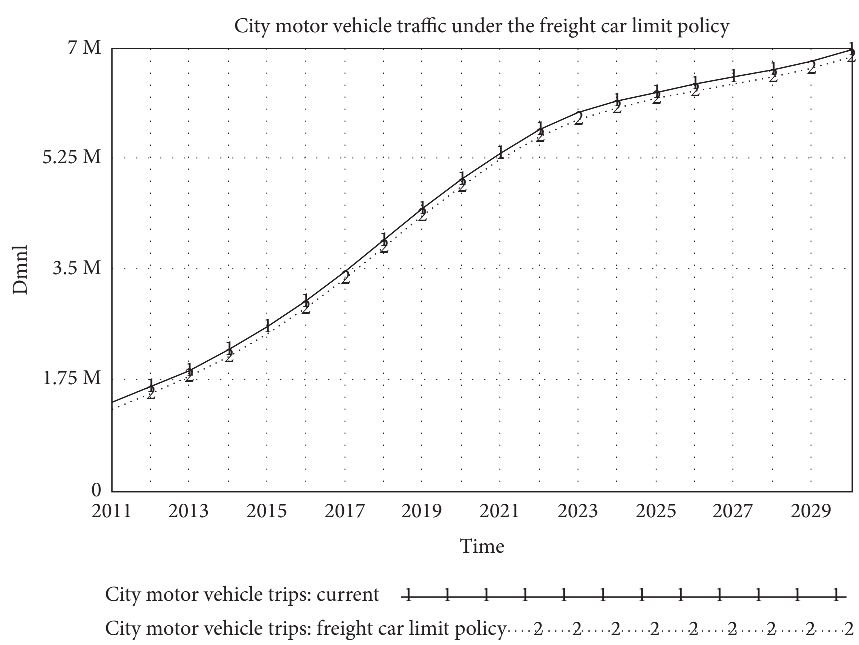

Figure 12: City motor vehicle trips under the restricted truck policy.

results after the simulation are shown in Figure 12. Moreover, since the freight car is closely related to the logistics industry, if the road section of the truck entering the city center is greatly restricted, it will have a great impact on the city logistics circulation.

Based on the comparison of the city motor vehicle trips under the above four different policies, we can get Figure 13.

6. Conclusions

In the previous section, we analyzed four types of restrictive policies. We found that these four policies have certain impacts on urban motor vehicle travel. The main purpose of this paper is to provide reasonable policy recommendations for Chongqing's current congestion caused by motor vehicles, so the final step is to compare policies.

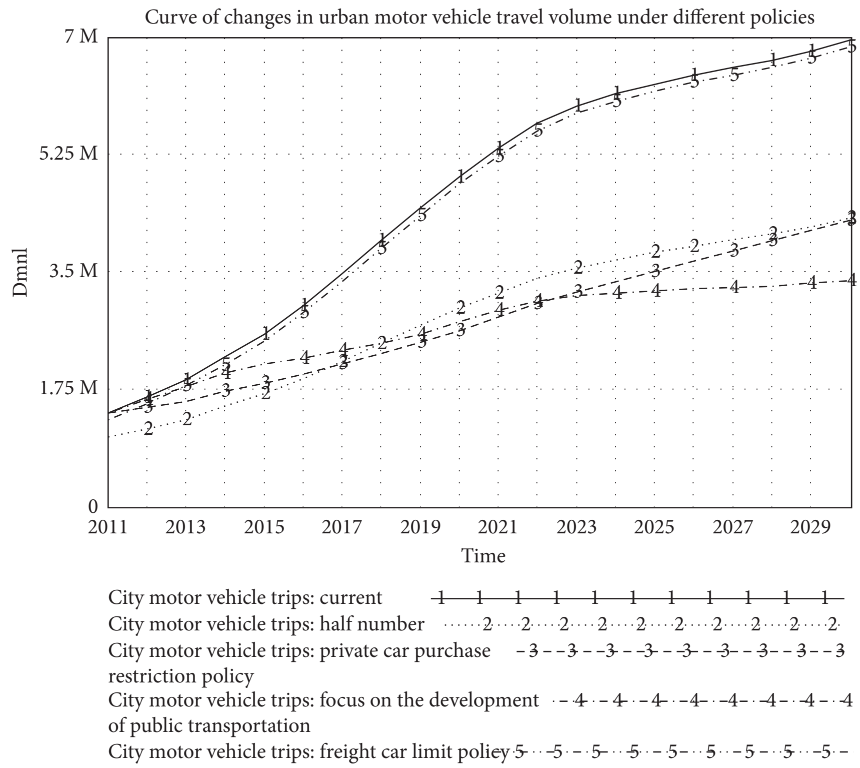

Figure 13: City motor vehicle travel volume under policy comparison.

From Figure 13, we found that each policy has a certain effect on controlling the amount of motor vehicle travel in the city, and the effect of the freight car limit policy is the weakest. In the short term, the private car restriction policy has the best effect. The effect of the purchase restriction policy has been very good, indicating that restricting car purchase is a rooted solution. The method of developing public transportation is not as effective as the private car restriction policy and the purchase restriction policy in the early stage. However, it will show its advantages in the later period, and it is also an effective way to control the growth of motor vehicle travel.

When no policies are used, the simulation results show that in the future, the growth rate of private car growth will gradually flatten. Although its overall trend is still growing, the demand for private cars will gradually flatten due to the increase in consumer satisfaction.

It can be concluded that the number of private cars will be reduced if Chongqing implements the restriction policy of private cars. Neither single-number limit nor double-number limit is less effective than the parity-number restriction policy. Therefore, the parity-number limit is a measure that can reduce traffic congestion in a short period of time. The purchase restriction policy has reduced the number of private cars from the root cause and so it is a valid measure. Developing public transportation is a long-term solution to solve the problem of traffic congestion. It is known that ordinary people choose to walk when they travel normally for less than two kilometers. In the ordinary travel of more than two kilometers, the ratio of people choosing public transportation and private car travel is generally close. Considering that the supply of parking spaces in today's cities is small, if public transportation is convenient enough, people may be more inclined to choose convenient travel. Therefore, the government should plan more funds and plans for public transportation, which not only helps to manage traffic congestion but also helps control environmental pollution. The control effect of the truck limit policy on traffic congestion is not obvious.

But because the model is a simplification of the actual transportation system, many related factors and policies are also ignored. First of all, it is common sense to measure the degree of traffic congestion with city motor vehicle trips as an indicator, but it is not comprehensive enough. The actual traffic congestion may also be due to factors such as road network density and road width. Secondly, when considering the policy of controlling traffic congestion, this paper mainly considers factors such as controlling the amount of private car travel and improving the replacement rate of public transportation.

For the implementation of the restriction policy and the limit policy, the article is simplified into a linear relationship, which has a certain deviation from the actual impact. The research on the impact of truck traffic is also related to the development of urban logistics industry. This paper only considers the city's daytime limit policy and has certain limitations. Finally, in order to control traffic congestion and environmental pollution, the government has to come up with a variety of new methods that are closely related to the development of science and technology. For example, some foreign cities have begun to adopt congestion pricing policies. Therefore, in the future, factors such as parking charges and road construction can be considered to improve the construction of the transportation system.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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