Effect Analysis of banning of motorbikes and limiting of electric scooters

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Abstract: This paper establishes the optimization model of the policy of banning of motorbikes and limiting of electric scooters in China, so that the traffic situation in Shenzhen can meet the requirements of public travel and the total amount of traffic resources. Under the condition of ensuring road traffic safety, traffic efficiency and environmental protection requirements, giving the ideal time schedule. Through a three-day traffic index of Shenzhen urban area statistical analysis, software is used to match the speed of the vehicle to capture the speed and the relationship between each time period. Then, the speed of each day is analyzed to know the impact on traffic in Shenzhen. Using the model, we can get the impact of different sections of electric vehicles on the traffic conditions. It can be concluded that the policy of banning of motorbikes and limiting of electric scooters has a significant improvement effect on the traffic in Shenzhen. In the case of people, the impact of traffic on the case of small and appropriate to relax the restrictions on the motorcycle. The necessity and practicability of banning of motorbikes and limiting of electric scooters are analyzed by the situation of casualties in motorcycle and electric car accidents with the trend and prediction of data. By quantitative analysis, time, place, cause, casualty rate, trend of motorcycle and electric car accident, optimal time and place arrangement are obtained. Through the physical pollutant index of Shenzhen, the water pollution index mathematical analysis, its function trend is observed from the intuitive chart to see the above three indicators in the ban and power. After the promulgation of the policy, it has a more significant downward trend. The policy should be pursued as it had a positive impact on the environment and contributes to environmental protection.

Key words: Policy, Traffic efficiency, Traffic safety, Environmental protection.

1. Problem statement

1.1 Background knowledge

With the social and economic development, urban traffic problems are becoming more and more complicated and get more attention by people. Urban traffic resources are limited, and the impact of various modes of transport, especially motor vehicles, on safety and the environment must be controlled. The demand for people traveling is growing, and travel is varied, including the use of public transport tool. Therefore, it is unrealistic and unsustainable to meet the demands and desires of all without restriction and must be advocated, developed and limited.

From 21st of March 2016, the policy of banning of motorbikes and limiting of electric scooters was implemented in Shenzhen. According to the city traffic police, a total of 17975 electric cars are seized and 874 people are detained within 10 days the action carried out[1]. The phenomenon of lee off at the Subway exits, bus station, port and business district was significantly reduced. The remedial action to achieve initial results as the traffic accidents were also significantly reduced.

Although the policy is fruitful, it is opposed by many people. In order to make more people understand about this policy and get the support of most people, demonstration of the policy must be scientific and without ideological. The mathematical model is used and the quantitative analysis is carried out for the road traffic capacity, the traffic demand structure of Shenzhen, the efficiency of each kind of transportation and the influence to the safety and the environment, to draft a feasible plan.

1.2 Specific issues

Question 1: Through the comparison of the relevant data trend changes of the policy, analysis and demonstration of the policy showed improvements in the traffic efficiency, especially the traffic congestion. The introduction of the policy is to ensure the traffic demand, efficiency and environmental conditions remain stable.

Question 2: Analyze and demonstrate the impact of the policy on the traffic safety situation by comparing the changes of the relevant data before and after the policy.

Question 3: Analyze and demonstrate that the proposed policy has a positive impact on the improvement of environmental conditions by comparing the changes in the relevant data trends before and after the policy implementation.

2. Symbol description

N: The impact of road traffic index of electric scooters and motorcycles
V: Vehicle speed unit (km/h)
n : Traffic index
X: Number of lanes
Y: Road traffic unit (km/h)

3. Model analysis, establishment and solution

3.1 Question one

First of all, why does the motorcycle make traffic worse?

Road capacity is the ability of the road having the vehicle[2,3]. When the actual traffic on the road is less than its capacity, the driving vehicles on the road are in a free running state, the speed is higher, and the traffic density is smaller. The distribution of the front time is in accordance with the negative exponential distribution and the vehicle can carry out overtaking. When the actual traffic on the road exceeds its capacity, the vehicle on the road increases the density, and the speed decreases. Therefore, there is traffic congestion and obstruction.

According to the policy, Shenzhen restricts on excessive electric vehicles and motorcycles on the road from0:00 to 24:00. In fact, traffic is very good in the morning. Electric scooters for road driving has no effect. However, once the arrival of the traffic peak period, a large number of vehicles enter into one of the roads. In the process, the vehicle inflow rate greatly increased, far greater than the vehicle outflow speed. Then, it will produce a slow and congestion phenomenon. In addition, the influx of a large number of electric scooters, pedestrians and bicycles will be preemptive non-motor vehicle resources, but also and motor vehicles to seize the motor vehicle lane. Motorcycle overtaking is

particularly difficult, so the motorcycles had to slow down. The basic speed of motorcycles and electric scooters become flat. This results in reducing speed of the flow of vehicles and more serious congestion.

3.1.1 Model preparation

The capacity of the road is the maximum traffic volume per unit time. The maximum traffic volume that can be converted into the speed of traffic and the number of lanes in the unit time. The greater the speed, the more traffic numbers. Moreover, the more lanes, the more traffic numbers on the road and the stronger the road capacity. Therefore, from the data, this paper collected the urban area three-day traffic index[4]. Traffic index is a conceptual index that reflects the smooth or congested road network.

As the scope of the policy in Shenzhen City in the main urban areas and the information can only be collected to the historical traffic index, the calculations for traffic index and the speed of the transformation are necessary. Statistic of a three-day urban traffic in Shenzhen index, n was analyzed from 1 to 72, to make the scatter plot for each time to find the traffic index and the relationship between vehicle speed conversions. In this paper, we find the traffic index of Shenzhen city is corresponding with the vehicle speed for a certain period of time. The quadratic polynomial is used to find the function image and expression. The correlation coefficient is 0.9562. Then, the relationship between traffic index and time period is transformed into the relationship between travel speed and time period. A function and image are obtained by cubic spline interpolation. The integral of velocity and time is calculated by trapezoidal integral method, divided by the time to get the average speed of the vehicle.

The impact of electric scooters on road traffic:

The speed of the vehicle, V at the peak can be interpolated by the data fitting. The road traffic is Y. When the vehicle is congested at the peak, and the vehicle is impossible to overtake. We assume that there are X numbers of road lane. In the case of without electrical scooters, the car traffic can be expressed as

$$Y = XV$$

With the electric scooters, the number of electric scooters is very high. Assuming that to seize one of the motorway, the speed of electric scooter does not exceed 20 km/h, the impact of the minimum state, and the electric car to the maximum speed. The road traffic has become

$$Y_1 = (X - 1)V + 20$$

The ratio of two traffic can be obtained to show the impact of electric vehicles on the road traffic.

$$N = \frac{Y_1}{Y} = \frac{X - 1}{X} + \frac{20}{XV}$$

3.1.2 Establishment and solution of model

Table 1 shows the statistics of three-day urban traffic index in Shenzhen.

Table 1 Three-day traffic index of ShenZhen

Time (h)	Traffic index	Time (h)	Traffic index	Time (h)	Traffic index
1	0.2	25	0.2	49	0.2
2	0.2	26	0.2	50	0.3
3	0.3	27	0.3	51	0.2
4	0.4	28	0.4	52	0.4

5	0.2	29	0.3	53	0.3	
6	0.3	30	0.3	54	0.2	
7	0.2	31	2.2	55	0.4	
8	3.1	32	4.1	56	4.4	
9	4.2	33	6.2	57	4.4	
10	3.9	34	4.2	58	3.2	
11	3.7	35	2.7	59	2.7	
12	2.9	36	2.2	60	2.5	
13	1.8	37	1.8	61	1.9	
14	2.4	38	2.2	62	2.2	
15	3.7	39	2.8	63	3.2	
16	3.8	40	3.9	64	4	
17	4.1	41	3.8	65	3.9	
18	4	42	4.5	66	4.9	
19	6.3	43	6	67	7	
20	3	44	3.6	68	4.2	
21	2.3	45	2.4	69	2.6	
22	1.9	46	1.9	70	2.2	
23	0.6	47	0.6	71	0.6	
24	0.4	48	0.3	72	0.2	

The statistical analysis shows that from every day from 22:00 to 7:00, the road is in a very smooth phase. From 8:00 to 10:00 and 16:00 to 20:00, the road is in a state of relatively congested. The relationship between the traffic index and the speed of vehicle in a certain period of time in Shenzhen was analyzed in Table 2.

Table 2 Relationship between traffic index and speed in Shenzhen area

Traffic Index	Speed (km/h)	Traffic Index	Speed (km/h)	Traffic Index	Speed (km/h)	Traffic Index	Speed (km/h)
3.2	32.2	4.6	31.6	9.1	18.0	9.7	16.7
8.5	17.7	3.3	35.0	4.9	28.6	4.5	25.9
7.3	19.2	1	45.3	6.6	24.1	7.0	21.6
3.4	32.5	7.0	24.5	8.2	19.1		

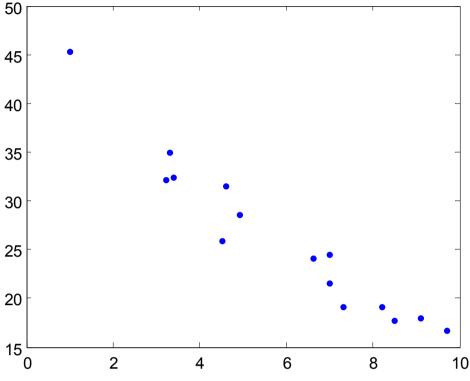The corresponding scatter plot is shown in Figure 1.

Figure 1 Scatter plot of vehicle exponent and velocity

According to the scatter plot, the traffic index is not simply related to the speed of the vehicle, but also with the lane status, vehicle size and other factors. Hence, the use of fitting the speed and traffic coefficient of the relationship between the approximate function are expressed. Multiple binomial fitting results as below:

Linear model Poly2:

$$f(x) = p_1 \cdot x^2 + p_2 \cdot x + p_3$$

Coefficients (with 95% confidence intervals):

p_1 = 0.2234   (0.05229, 0.3945)

p_2 = -5.56   (-7.525, -3.594)

p_3 = 49.77   (44.68, 54.87)

So, the speed of travel

$$V = 0.2234n^2 - 5.56n + 49.77$$

The basic expression of the car in the urban areas in line with the speed is analyzed. The fitting curve is shown in Figure 2.
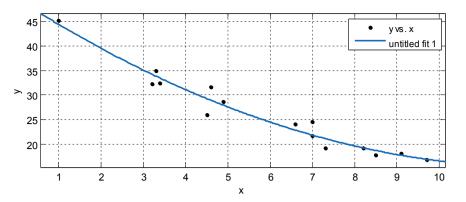
Figure 2 The relationship between traffic index and travel speed

Using the formula, the relationship between traffic index and time is transformed into the relationship between travel speed and time. The corresponding scatter plot is shown in Figure 3.
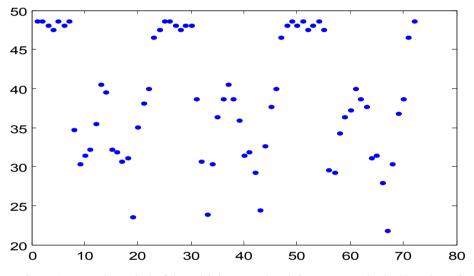

Figure 3 A certain period of time driving speed and time scatter plot in Shenzhen city area

From the map, the speed of travel at different times every day in Shenzhen is almost the same and it is consistent with the reality.

Subsequently, the three spline interpolation method is used to analyze the data in order to find the daily vehicle speed on the time integral, divided by the time is the average daily driving speed (Figure 4).
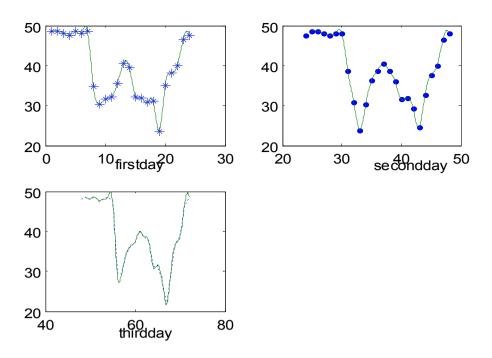
Figure 4 The three spline interpolation map of the speed in three days in Shenzhen city

1) The average impact of electric vehicles on urban traffic is $N = \dfrac{X-1}{X} + \dfrac{20}{XV}$

The operation results as below:

$f13 = 892.1567$ ($f13$ is the first day of the speed of time integration)

$f23 = 877.1081$ ($f23$ is the second day the speed of time integration)

$f33 = 885.6772$ ($f33$ is the third day of the speed of time points)

$$V_1 = \frac{892.1567}{24} = 37.17(km/h)$$

$$V_2 = \frac{877.1081}{24} = 36.55(km/h)$$

$$V_3 = \frac{885.6772}{24} = 36.90(km/h)$$

Analysis of data shows not much differences and in line with the reality of urban transport speed.

By using the average, $V = \dfrac{37.17 + 36.55 + 36.9}{3} = 36.90(km/h)$

If for 2 lanes, $N = 0.5 + \dfrac{20}{2 \times 36.9} = 0.77$ that is, the road traffic changes into 0.77 times than the original.

For 4 lanes, $N = \dfrac{3}{4} + \dfrac{20}{4 \times 36.9} = 0.89$, that is, the road traffic changes into 0.89 times than the original.

The more lanes, the smaller the impact.

2) During peak period, the impact of electric scooters on the urban transport capacity.

Peak period refers from 8:00 to 11:00 and 16:00 to 20:00. The average speed of the vehicle during this period is calculated.

From 8:00 to 11:00:   From

16:00 to 20:00:

Results:

Results:

$f81 = 62.542$ $f161 = 115.5441$

$f82 = 65.919$ $f162 = 116.0041$

$f83 = 60.339$ $f163 = 110.1394$

Two sets of data are divided by the average travel time

$$V_1 = \frac{62.542 + 115.5441}{7} = 25.44(km/h)$$

$$V_2 = \frac{65.919 + 116.0041}{7} = 25.99(km/h)$$

$$V_3 = \frac{60.339 + 110.1394}{7} = 25.25(km/h)$$

Mean $V = \frac{25.44 + 25.99 + 24.34}{3} = 25.25(km/h)$

For 2 lanes, $N = 0.5 + \frac{20}{2 \times 25.25} = 0.89$, that is, the road traffic changes into 0.89 times than the original.

For 4 lanes, $N = \frac{3}{4} + \frac{20}{4 \times 25.25} = 0.94$, that is, the road traffic changes into 0.94 times than the original.

Although the impact of the traffic by the electric vehicles during the peak period are reduced, traffic is still in congestion during peak hour. The addition of electric vehicles will exacerbate this situation and cause more chaotic traffic conditions. The electric vehicles are not the main reason of traffic congestion, but it is mainly due to large number of traffic.

However, there is a new problem, many electric vehicle owners will slip from the side of the motor vehicles during traffic congestion. This will greatly increase the security risks. Many electric vehicle owners do not comply with traffic laws, resulting in security incidents, and also a threat to the normal rights of the owner of the security, resulting in casualties. Therefore, after analysis, disable of the electric vehicles is very necessary during the peak period in order to reduce the traffic congestion and ensure safety.

In summary, in the case of traffic index greater than 2, the restrictions on the motorcycles can be reduced after 10 pm.

3.2 Question two

3.2.1 Model analysis

Road traffic safety is also a major reason for the implementation of the policy. By collecting detailed data on road traffic accidents over the past decade, the following data can be analyzed[5]:

1) Analyze the respective changes in the number of fatal accidents and the number of injured persons in motor vehicle accidents and electric car accidents in the past ten years, and thus determine the seriousness of motorcycles and electric vehicle accidents and the degree of threat to road safety;

2) Comparison of the motorcycle and electric car accident casualty rate and the same period car accident casualty rate. Analysis of motorcycle accidents and electric car accident severity;

3) Analysis of motorcycle accidents and electric vehicle accidents and the cause of the accident, analysis of the main

factors leading to the accident.

In this paper, the number of deaths and the number of casualties corresponding to motorcycles and electric car accidents in China between 2004 and 2013 (due to the inability to find the data of Shenzhen City, the data from the whole country are analyzed, and the data substitution process is included in the model error)[6] (Table 3).

Table 3 Statistics on the number of casualties in motorcycle accidents and electric vehicles

Year	Motorcycle		Electric vehicle		Total number in China	
	Number of deaths	Number of injuries	Number of deaths	Number of injuries	Number of deaths	Number of injuries
2004	22835	126166	589	5295	23424	131461
2005	21895	128434	1037	9485	22932	137919
2006	19993	115112	1601	12417	21594	127529
2007	18158	100279	2469	16468	20627	116747
2008	16270	79904	3107	17303	19377	97207
2009	14900	72101	3678	19573	18578	91674
2010	14264	65599	4029	20311	18393	85910
2011	13123	60029	4790	23830	17913	83859
2012	12856	55773	5324	26966	18180	82759
2013	12621	53179	5752	29010	18373	78189

After a simple analysis of the data in Table 3, the annual mortality and injury rate of motorcycle and electric vehicle accidents were calculated using MATLAB.
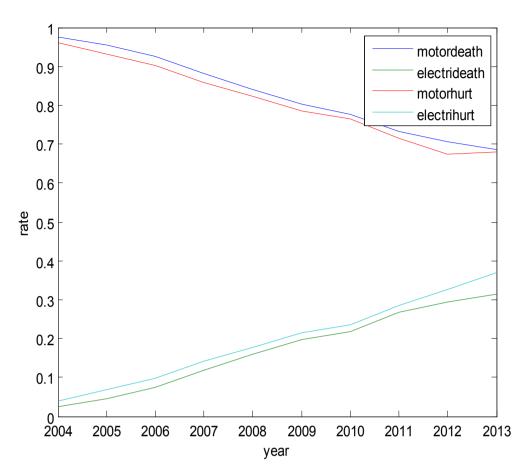
Figure 5   Statistics on casualty rate of motorcycles and electric vehicles 2004–2013

Figure 5 shows that the mortality rate and injury rate of the motorcycle accidents decreased year by year from 2004 to 2013, indicating that the policy has achieved effective results. The accident mortality and injury rate of electrical vehicles are increasing as the public generally use electric vehicles to replace the motorcycle travelling. As a result, the absolute number and relative number of accidents are increasing year by year. Moreover, electric vehicle accident casualty rate increased year by year, but it is still far below the motorcycle accident casualty rate. It can be seen that, compared to electric vehicles, motorcycles for road traffic safety is still a relatively major threat. Therefore, the policy should be maintained, and need to cooperate with the appropriate power limit measures, so as to the road traffic safety situation will have a better role in improving.

Separate analysis of motorcycle accidents and electric car accidents corresponding to the mortality rate and injury rate changes over time. Through the relationship between functions, the situation can be calculated in accordance with the current development in the future for the motorcycle accidents and electric vehicle accidents in the general mortality and casualty situation. This is a very cruel and terrible prediction, through this specific numerical analysis, we see the necessity and importance of the policy.
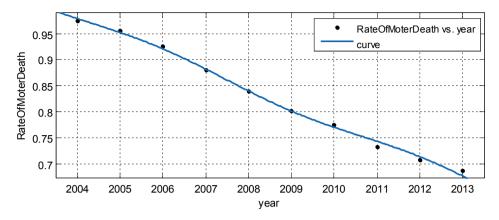
3.2.2 Model establishment and analysis

Figure 6　Rate of death of the motorcycle accidents

Linear model:

$$f(x) = a(\sin(x - p_i)) + b((x - 10)^2) + c$$

Coefficients (with 95% confidence intervals):

      a = -0.008025　(-0.01583, -0.0002206)

      b = -8.617e-06　(-9.076e-06, -8.158e-06)

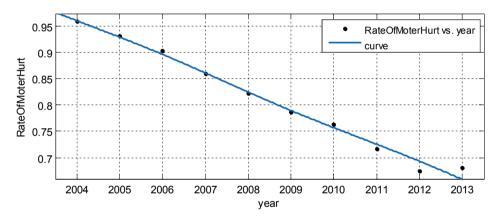   c = 35.24　(33.41, 37.08)

Figure 7. Rate of hurt of the motorcycle accidents

Coefficients (with 95% confidence intervals):

      a = -0.002625 (-0.01626, 0.01101)

      b = -8.47e-06 (-9.272e-06, -7.668e-06)

      c = 34.64 (31.44, 37.84)

Due to data constraints, several other research areas are temporarily unable to carry out, but the research method is similar. In summary, we can see the necessity and practicality of the policy. However, in terms of road safety, the Government cannot blindly implement the policy. The Government should give full consideration to the problem of public travel, collect a large amount of data, combine traffic conditions and give the public a reasonable traffic arrangement. In addition, qualitative improvement should be applied on public safety and comfort of the trip.

3.3 Question three

Air pollution, water pollution, noise pollution and waste pollution are four major environmental issues around the world.

The implementation of prohibited limits of power policy is an action of environmental protection. For example, the electric bicycles need to replace the battery half a year if high frequency of using. Annual electric bicycle battery usage in Shenzhen is about 20,000 tons and no regular recycling mechanism. Thus, it easily leads to environmental pollution and noise pollution. It can also cause hearing loss, insomnia, neurasthenia and if severe, it can increase blood pressure, heart dysfunction, and induce other diseases. It can be said that control of noise in a country reflects the economic development, scientific level and the degree of civilization[7].

In this paper, the impact of the policy on air pollution s used as an example and fitting analysis of images is used.

3.3.1 Model analysis

The indicators that used to determine the quality of air quality are SO_2, NO_2, IP and AOI. This paper collects the data in Table 4 below to analyze and judge the air quality[8].

Table 4 Air pollutants in Shenzhen from 2009 to 2015

Time Contaminants	SO_2 （$\mu g / m^3$）	NO_2 （$\mu g / m^3$）	IP （$\mu g / m^3$）
The first quarter of 2009	0.013	0.045	0.061
The second quarter of 2009	0.011	0.037	0.048
The third quarter of 2009	0.012	0.037	0.045
The fourth quarter of 2009	0.015	0.051	0.074
The first quarter of 2010	0.011	0.042	0.064
The second quarter of 2010	0.008	0.037	0.040
The third quarter of 2010	0.010	0.036	0.039
The fourth quarter of 2010	0.014	0.064	0.086
The first quarter of 2011	0.013	0.062	0.070
The second quarter of 2011	0.008	0.045	0.050
The third quarter of 2011	0.009	0.036	0.038
The fourth quarter of 2011	0.013	0.050	0.070
The first quarter of 2012	0.008	0.046	0.053

The second quarter of 2012	0.007	0.036	0.042
The third quarter of 2012	0.010	0.038	0.046
The fourth quarter of 2012	0.011	0.048	0.067
The first quarter of 2013	0.012	0.048	0.068
The second quarter of 2013	0.009	0.037	0.045
The third quarter of 2013	0.008	0.032	0.041
The fourth quarter of 2013	0.014	0.042	0.091
The first quarter of 2014	0.010	0.041	0.064
The second quarter of 2014	0.0077	0.033	0.040
The third quarter of 2014	0.008	0.031	0.040
The fourth quarter of 2014	0.010	0.038	0.070
The first quarter of 20015	0.009	0.038	0.066
The second quarter of 2015	0.008	0.030	0.036
The third quarter of 2015	0.009	0.031	0.040
The fourth quarter of 2015	0.008	0.034	0.053

According to the table, a comprehensive analysis of air pollutants is ontained before and after the implementation of policy (Figure 8–10).
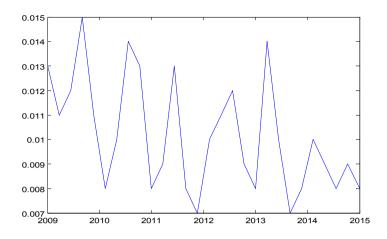
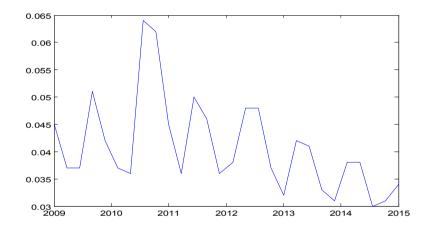Figure 8 Quarterly results for SO_2 from 2009 – 2015

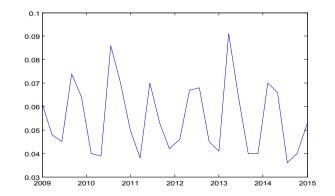Figure 9 Quarterly contents for NO_2 from 2009–2015

Figure 10 Quarterly contents for IP from 2009–2015

Observing the linear trend on the chart, the value of air pollutants fluctuated year by year from 2009 to 2015. There are many factors that causing air pollution, and some of the reasons for the decline in air pollution can be attributed to the proposed and effective implementation of the policy under the premise of ensuring that other factors are fixed.

3.3.2 Establishment of the model

Smoothing Spline in the MATLAB is used to find the relationship between the policy implementation time and the value of the air pollutant. The model is given as follows:
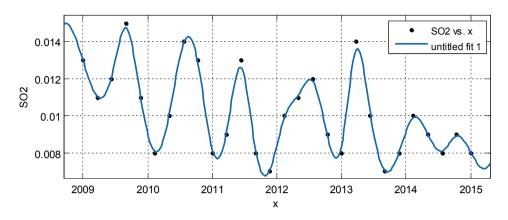

Figure 11 SO$_2$

Smoothing spline:

$f(x)$ = piecewise polynomial computed from p

Smoothing parameter:

      p = 0.99989992

Goodness of fit:

  SSE: 8.315e-07

  R-square: 0.9942

  Adjusted R-square: 0.9403

  RMSE: 0.0005646

To sum up, it is easier to conclude that the effective implementation of the policy will be one of the important means to solve the environmental protection problem, especially the atmospheric environment protection. The implementation of the policy is a very correct choice.

3.3.3 Supplements to the model

In the study by Zhang (2006)[9], the annual report of the motorcycle waste reached about 50%, and in the scrapping of motorcycles produced a large number of waste and waste emissions problems. Incorrect emissions cause a very serious environmental pollution problems. The current heat treatment process is in imperfect conditions. Limit or even disable the use of motorcycles is very necessary, where the policy is compliant with the current situation.

Wang (2005)[10] outlined the current gap between the noise standards and foreign laws and regulations, the status of motorcycle noise management in China and the motorcycle noise standards and noise pollution control trends. With the increase in motorcycle production and ownership, motorcycle noise pollution is increasingly serious, especially in some crowded neighborhoods. Although stringent requirements of motorcycle noise standards have been increasing, it still have a large gap with foreign countries. The compliance situation is not very optimistic. Even there are more stringent standards, the noise caused by motorcycles is still high. The existence of the phenomenon is also one of the important reasons for implementation of the policy.

Conclusion

The improved policy can guarantee the total amount of traffic resources in Shenzhen (ie, road capacity), traffic demand structure, the efficiency of various modes of transport and the impact on safety and the environment under the premise of loose policy. As a result, the public will be more acceptable towards the policy.

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