Study on the Relationship between the Sharing Rate of Vehicle Exhaust Pollution and the Quantity of Possession

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Abstract. The pollution caused by motor vehicle exhaust is largely affected by the quantity of motor vehicles. This paper improves the calculation method of emission inventory by analyzing the statistical characteristics of starting pollutant emission factors and operating emission factors of motor vehicles and gives the calculation plan of the total emission sharing rate and emission concentration sharing rate. Based on the GM (1,1) model, the vehicle ownership of the five-year basic data was predicted. The results show that the model accuracy is $P^{1-\xi} = 98.11\%$ and the correlation degree is $0.66>0.6$. This shows that the accuracy of the model prediction results meets the requirements, and the vehicle ownership value can be used as a reference for relevant policies.

1. Background
With the development of science and technology, electric vehicles are gradually entering people's field of vision. It can be expected that with the increase of electric vehicles, the pollution of automobile exhaust to the atmosphere will be greatly alleviated. However, in the short term, electric vehicles cannot replace existing motor vehicles. The development of the automobile industry and the number of motor vehicles continue to grow, and air pollution is still getting worse. In the case of higher and higher atmospheric pollutants, it is necessary to pay attention to the interaction relationship between vehicle exhaust pollution sharing rate and possession\cite{1-10}.

According to a survey report on the source of atmospheric pollutants from the United States in the 1970s, 77.3% of CO, 55.3% of HC and 50.9% of NOx in the urban atmosphere are derived from vehicle exhaust emissions. Motor vehicle exhaust emissions have become an important source of urban air pollution\cite{11-23}. The motor vehicle pollution sharing rate is divided into two categories\cite{24-36}: the total emission sharing rate and the emission concentration sharing rate according to different measurement priorities and calculation methods\cite{37-41}.

Car ownership is related to urban construction and planning. In this paper, the statistical characteristics of vehicle emission factors and operational emission factors are analyzed, the calculation method of emission inventory is improved, and the calculation scheme of total emission sharing rate and emission concentration sharing rate is given\cite{35-39}. Based on the GM (1,1) model, the vehicle ownership of the collected five-year basic data was predicted. The calculation results are for the government to formulate a social macroeconomic development plan, and it is of reference
significance to implement energy conservation and emission reduction and traffic management in cities.

2. Emission Measurement Factor

The sharing rate is to quantify the contribution of different pollution sources to an air pollutant, and it is the share of pollution sources in air pollution. The motor vehicle pollution sharing rate represents the percentage of pollutants emitted by motor vehicles in the total emissions of all atmospheric pollutants [42-49].

The total vehicle exhaust emission sharing rate is usually expressed by $\eta_1$. It is the ratio of the total amount of pollutants $Q_{car}$ emitted by the vehicle exhaust to the total amount $Q$ of all local pollutants. The total amount of pollutant emissions is usually composed of pollutants emitted by mobile sources and pollutants emitted by stationary sources. There are expressions:

$$\eta_1 = \frac{Q_{car}}{Q} \times 100\%$$

The vehicle emission concentration sharing rate is calculated by obtaining a detailed emission inventory of each pollution source in the region, and using a verified regional multi-source diffusion model (such as ISC ST3) to calculate and analyze the concentration sharing rate of different pollution sources in different seasons and locations. If the concentration near the road is $c$, and the pollution concentration away from the road in this area is $c_1$, the car pollution concentration share near the road can be calculated as:

$$\eta = \frac{c - c_1}{C} \times 100\%$$

3. Motor Vehicle Emission Factor Model

The vehicle emission factor refers to the amount of pollutants discharged by the motor vehicle operating unit and is sometimes expressed by the amount of pollutants discharged per unit of fuel [50-56]. The unit is g/km or g/L, which indicates the level of vehicle exhaust emissions. To obtain a vehicle emission factor (start emission factor (g/time) and operational emission factor (g/km)) for a vehicle exhaust emission list, it is necessary to separately measure the pollutants emitted by the vehicle at start-up and the amount of pollutants emitted during operation.

4. Calculation of Motor Vehicle Pollution Discharge List

The calculation formula of the vehicle exhaust pollutant discharge list is as follows:

$$Q = Q_1 + Q_2 = \sum_{i=1}^{n} (A_i \times EF1 \times T_i) + \sum_{i=1}^{n} (A_i \times EF2 \times L_i)$$

Where: $Q$ represents the total annual emissions (t/a) of motor vehicle pollutants. $Q_1$ represents the annual emissions (t/a) of the vehicle when it is running. $Q_2$ represents the annual emissions (t/a) of the vehicle during the start-up process. $A_i$ is the number of i-type cars. $EF1$ is the operating emission factor (t/km) of the i-type vehicle. $T_i$ is the annual mileage (km/a) of the i-type car. $L_i$ is the number of annual starts of the i-type car (times / a). $EF2$ is the starting emission factor (t/time) for the i-type vehicle.

Using formula (3), calculate the pollutant discharge list of motor vehicles.

The emission total sharing rate is calculated from the emission inventory and calculated fixed source emission data and formula (1). Through the calculation results we can know that the exhaust emissions of motor vehicles account for a considerable proportion of the emissions of atmospheric pollutants. Therefore, it is urgent to strengthen the control of tail gas pollution.
5. Vehicle ownership forecasting model

The grey system has the characteristics of fuzzy hierarchy and structural relationship, random data dynamic change and incomplete basic data, which is referred to as GM model. The most commonly used one is GM(1,1).

Assume that there are \( n \) equal time interval observations \( \{X^{(0)}(i)\} \), add up \( m \) times to get \( X^{(m)}(k) = \sum_{i=1}^{k} X^{(m-1)}(i) \) derive array \( X^{(m)} = \{X^{(m)}(1), \ldots, X^{(m)}(n)\} \) \( (m=1, 2, \ldots) \). Let \( Z^{(m)}(k) = \left[ X^{(m)}(k) + X^{(m)}(k+1) \right]/2 \), so \( Z^{(m)} = \{Z^{(m)}(2), \ldots, Z^{(m)}(n)\} \).

When \( m=1 \), a grey prediction model is established for the new array \( X^{(1)} = \{X^{(1)}(1), \ldots, X^{(1)}(n)\} \). The differential equation corresponding to the GM(1,1) model is:

\[
\frac{dx^{(1)}}{dt} + ax^{(1)} = b
\]

Where: \( a \) is the development grey number; \( b \) is the endogenous control grey number. Let \( \alpha^* \) be the parameter vector to be estimated, \( \alpha^* = (a, b)^T \). Then the least squares estimation parameter sequence of the gray differential equation satisfies:

\[
\hat{\alpha} = (B^T B)^{-1} B^T Y
\]

Where:
\[
B = \begin{bmatrix}
-z^{(2)}(2) & 1 \\
-z^{(3)}(3) & 1 \\
& \ddots & \ddots & \ddots \\
-z^{(n)}(n) & 1
\end{bmatrix} \quad \begin{bmatrix}
-(x^{(1)}(1)+x^{(1)}(2))/2 & 1 \\
-(x^{(1)}(2)+x^{(1)}(3))/2 & 1 \\
& \ddots & \ddots & \ddots \\
-(x^{(1)}(n-1)+x^{(1)}(n))/2 & 1
\end{bmatrix} \quad \begin{bmatrix}
x^{(2)}(2) \\
x^{(3)}(3) \\
& \ddots & \ddots & \ddots \\
x^{(n)}(n)
\end{bmatrix}
\]

According to the principle of least squares, the parameters \( a, b \) are obtained:

\[
a = \frac{CD-(n-1)E}{(n-1)F-C^2} \quad b = \frac{DF-CE}{(n-1)F-C^2}
\]

Where:
\[
C = \sum_{i=1}^{n} z^{(0)}(k) ; \quad D = \sum_{i=1}^{n} x^{(0)}(k) ; \quad E = \sum_{i=1}^{n} x^{(0)}(k)x^{(0)}(k) ; \quad F = \sum_{i=1}^{n} z^{(0)}(k)
\]

In the application, the development of the grey number should satisfy \(-2 < a < 2\). When \( a \geq -0.3 \), the model predicts better.

The prediction model can be obtained by solving the differential equation:

\[
\hat{x}^{(1)}(k+1) = \left[ x^{(0)}(1) - \frac{b}{a} \right] e^{ak} + \frac{b}{a} \quad (k=0,1,\ldots,n-1)
\]

Calculate the simulated value of \( W \) according to the model and restore the model,

\[
\hat{x}^{(0)} = \begin{cases}
\hat{x}^{(0)}(1) = x^{(0)}(1)
\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) \quad (k=1,2,\ldots,n)
\end{cases}
\]

The \( X^{(0)} \)'s simulated value \( \hat{x}^{(0)} = \{\hat{x}^{(0)}(1), \ldots, \hat{x}^{(0)}(n)\} \) is available.

In practical applications, the model accuracy is usually required to be greater than 80%. When the resolution is 0.5, the correlation degree is not less than 0.6.

6. Practical application of the grey PARC prediction model

Original series \( x^{(0)} = \{10273.6, 11418.4, 12742.5, 15543.4, 16993.5\} \) is the total number of motor vehicle ownership data for China for 2005-2009. Generate an array by accumulating once: \( x^{(1)} = \)
\{10273.6, 21692, 34434.5, 49977.9, 66971.4\}. Construct the matrix \( B \) and the data vector \( Y_n \), calculating respectively \( B^T B \), \( (B^T B)^{-1} \), \( B^T Y_n \), \( \alpha \).

The parameter sequence \( a=-0.137400721 \) and \( b=9203.054897 \) are obtained by using equation (6). Since \( a \) satisfies: \( a \in (-2,2) \) and \( a \geq -0.3 \), the GM(1,1) model can be used for medium- and long-term prediction. Substituting \( a \) and \( b \) into equation (7), the final prediction model is:

\[
\hat{x}^{(1)}(k+1) = \left[ 10273.6+67000 \right] e^{0.137400721(k-1)} - 67000 = 77273.6 e^{0.137400721(k-1)} - 67000
\]

\[
\hat{x}^{(0)}(k+1) = 77273.6 e^{0.137400721(k-1)} - 0.137400721e^{k} (k=1,2,\cdots, n-1).
\]

Restore model to get predicted value: when \( k=0 \), \( \hat{x}^{(0)}(1) = 10273.6 = x^{(0)} \).

\[ \hat{x}^{(0)}(6) = 19713.9 \] is the forecast data for 2010 when \( k=5 \). The forecast results after 2010 are available.

It is usually necessary to test both the residual and the correlation: the correlation degree is \( 0.66 > 0.6 \), and the prediction accuracy meets the requirements. Therefore, the vehicle holdings in 2015 can be used as a reference for relevant policies.

7. conclusion

It is of theoretical and practical significance to use the grey PARC prediction model to support relevant policy data. This method has characteristics: if the positive data are added, \( m \) will increase continuously and the randomness of the generated sequence will be weakened a lot. When \( m \) is large enough, it can be considered that the time series has changed from the disordered random sequence to the ordered non-random sequence, and the obtained non-random sequence can be approximated by exponential curve.

Motor vehicle exhaust pollution is largely affected by motor vehicle ownership, and the prediction of motor vehicle ownership can provide data basis for relevant policies, and according to the model calculation results, the planning Suggestions of motor vehicle exhaust pollution control are given from a quantitative perspective.

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