Advanced Science and Technology Letters
Vol.111 (NGCIT 2015), pp.185-190
http://dx.doi.org/10.14257/astl.2015.111.36

Models for the Prediction of Private Vehicle Ownership in China

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Abstract. In this article, we take 11 indicators as the independent variables, while the private vehicle ownership as the dependent variable. multiple linear regression (MLR) model and artificial neural networks (ANNs) models were developed respectively in order to predict the private vehicle ownership. As an alternative model, we developed grey model GM (1,1) according to the regulation of the private vehicle ownership. Detailed comparisons among the MLR, ANNs and GM (1,1) models were made and results shows that they have different advantages respectively. Our results shows that all the three types of computation models can be used for the prediction of the private vehicle ownership in Chinese area.

Keywords: Private; grey model GM (1,1); artificial neural networks;

1 Introduction

With the development of Chinese economics, there is an increasing tendency that people have the abilities to purchase private vehicles [1-3]. Nevertheless, the gas emission of the private vehicles has generated relatively serious air pollution [4-6]. Previous research indicates that the ownership of private vehicles has a linear correlation with the air pollution. Therefore, it is crucial for scientists to study the change regulation of the ownership of private vehicles and put forward a series related solutions to air pollution.

We first developed a multiple linear regression (MLR) model in order to analyze the weights of different components. Then 15 artificial neural network (ANNs) as a powerful non-linear machine learning techniques were developed on the basis on the same variable components as the MLR model. Finally, as an alternative and comparable approach, grey model GM (1,1) was developed based on the private vehicle ownership in the time series, independent to those 11 indicators. By developing these three types of computation models, we aim at find out the suitable computation methods for the prediction of private vehicle ownership in Chinese areas.

ISSN: 2287-1233 ASTL

2 Artificial Neural Network

An artificial neural network (ANNs) is a common non-linear machine learning approach [8-11]. Usually, an complete ANN model consists of a series of "neurons", which is similar to human brain.

3 Grey Model GM (1,1)

Grey Model GM (1,1) [12-15] is a mathematical approach that is currently widely used for the prediction in uncertain systems. It can undertake relationship analysis by determining the differences among different factors in the system. Afterwards, the original data can be changed into new forms for the sake of finding out regulations of the change of the system. The prediction work based on GM (1,1) is completely independent to exterior independent variables. GM (1,1) is frequently used for the prediction of the values which change with a certain gap of time.

4 Results and Discussion

Here, we develop the MLR, ANN models the GM (1,1) model respectively, using the data provided by reference [7]. The establishing process are shown respectively in the following three sections.

4.1 Development of the MLR Model

Here, we use SPSS for develop an equation for the change regulation of private vehicle ownership. The 11 indicators were presented by x_1 to x_{11} respectively (in the order of the indicates listed in previous sections), and y is the private vehicle ownership.

$$y = 0.062x_2 - 0.1x_3 + 3.604x_5 + 0.007x_8 - 0.006x_9 - 0.14x_{10} + 22.274x_{11} - 353.734 \quad (1)$$

Equation (1) presents the MLR regression result, which shows that only x_2, x_3, x_5, x_8, x_9, x_{10}, x_{11} has significant impacts to y. Fig. 1 shows the comparison between actual values and the predicted values using MLR.

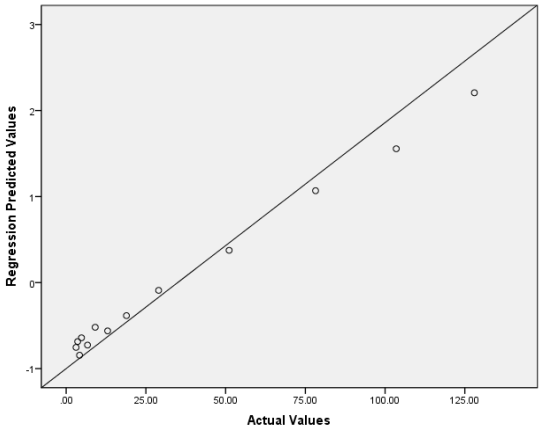


Fig. 1. Regression results of the MLR model

Fig. 1 indicates that MLR model has a very suitable result in the prediction. However, using MLR model cannot test the robustness due to the limited data scale. Therefore, we should use ANN and GM (1,1) models as alternative models.

4.2 Development of ANN Models

In order to develop a series of ANN models, we set the same indicators and dependent variable as the MLR model. We used the general regression neural network (GRNN) [16-20] and multi-layer feed-forward neural network (MLFN) [21-24] to develop the models. The numbers of nodes of MLFN models were set from 2 to 15 in order to find out the most suitable nodes of MLFN model for the prediction.

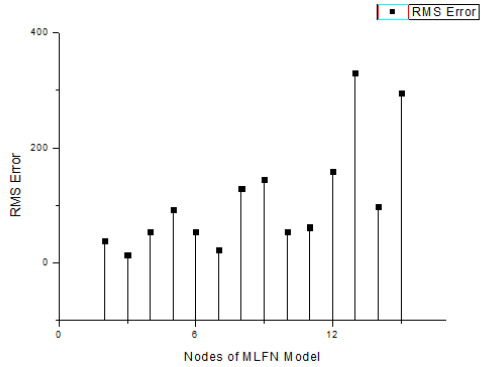
Table 1 shows the best net search results of ANN models for the prediction of the emission of HC in the first system:

Table 1. Best net search results of models for the prediction of private vehicle ownership in Chinese area

ANN Model	Trained Samples	Tested Samples	RMS Error
GRNN	8	5	13.90
MLFN with 2 Nodes	8	5	38.48
MLFN with 3 Nodes	8	5	13.89
MLFN with 4 Nodes	8	5	54.71
MLFN with 5 Nodes	8	5	92.33
MLFN with 6 Nodes	8	5	53.61
MLFN with 7 Nodes	8	5	22.19
MLFN with 8 Nodes	8	5	129.73
MLFN with 9 Nodes	8	5	144.92
MLFN with 10 Nodes	8	5	53.17

MLFN with 11 Nodes	8	5	61.89
MLFN with 12 Nodes	8	5	158.16
MLFN with 13 Nodes	8	5	329.82
MLFN with 14 Nodes	8	5	98.02
MLFN with 15 Nodes	8	5	296.05

Table 1 shows that the MLFN model with 3 nodes is the best model for prediction, with an lowest RMS error (13.89) in the result list. Fig. 3 is used for illustrating the change regulation of the RMS errors of MLFN models with the change of nodes:



4.3 Development of Grey Model GM (1,1)

We develop a GM (1,1) model based on the sequence of numbers of private vehicle ownership. 8 data was used for the model development, while 5 data was used for testing. Results are presented as follows:

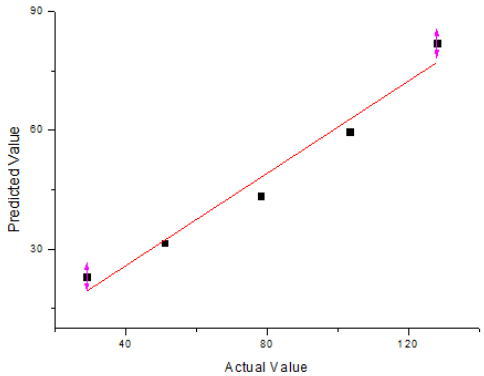


Fig. 3. Testing result of GM (1,1) model for the prediction of private vehicle ownership in Chinese area.

Fig. 3 presents the results of GM (1,1) model for the prediction of private vehicle ownership in Chinese area, which is a testing process based on a number of training set. Results show that the predicted values are highly close to the actual values. Results show that the prediction based on GM (1,1) is effective.

5 Conclusion

With the development of Chinese areas, there is an increasing trend that people has become more and more willing to purchase their private vehicles. Nevertheless, this increasing tendency sharply increases the air pollution. Hence, it is highly necessary that scientists should study the change regulation of the private vehicle ownership in Chinese area in order to find out the reason of the pollution and find out the regulation of the change. Due to the impact factors of the change regulation of the private vehicle ownership is various and uncertain, we should take various factors into consideration as much as possible. In this paper, we consider 11 indicators as independent variables, while the private vehicle ownership as the dependent variable. multiple linear regression (MLR) model and artificial neural networks (ANNs) models were developed respectively in order to predict the private vehicle ownership. As an alternative model, we developed grey model GM (1,1) according to the regulation of the private vehicle ownership. Comparisons among the MLR, ANNs and GM (1,1) models were made and results shows that they have different advantages respectively. Our results shows that all the three types of computation models can be used for the prediction of the private vehicle ownership in Chinese area. The MLR model has the advantage that we can obtain the prediction results using Equation (1), without a computer. The ANN model is precise, but it takes time to search the best network. And the GM (1,1) model is quick, but it is less precise than that of ANN models. We should take all the circumstances into consideration in order to decide which model we should use in practical applications. In further research, we will definitely aim at using a large scale of date to modify the models and find out a common regulation of the change regulation of private vehicle ownership in Chinese areas. Solutions will be proposed in order to resolve related problems in order to improve the effectiveness of our society.

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