The Demand Prediction of Power Emergency Material Based on Grey-Markov Chain Model

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ABSTRACT: In this research paper, the Grey-Markov chain model is proposed to solve the problem in the demand prediction of power emergency material. We first conducted preliminary prediction with the Grey model, and then proceeded to modify the prediction result with the Markov chain model. We also collected the data from 20 earthquakes, both in China and abroad and made predictions of three indexes including the households of power outage, crew in emergency maintenance and the number of damaged oil-immersed transformer. The testing results indicated that the Grey model can be separately used to predict the demand for the power emergency material, but the precision is not quite satisfying; the Markov chain model can modify the relative error of the Grey model, and the average absolute error of the three indexes decreased from 6.20%, 6.16% and 5.46% to 5.77%, 5.38% and 4.56%, respectively.

Keywords: power emergency material; Grey model; Markov chain model; earthquake

1 INTRODUCTION

In recent years, with the rapid development of social economy in our country, the dependence on the electricity market is unprecedented. The material management directly affects the operation of power supply system, and it is a guarantee for the sustaining development of the electric power supply enterprises. As the power supply system is characterized with wild fluctuation of material demand under environmental effects and high expenses for the power equipment, the storage house are always unable to accurately predict the material demand, thus leading to failure in the actual management. For example, when a natural disaster occurs, the need for the power material cannot be only one kind to ensure network unobstructed. Meanwhile, the possibility of external disturbance like the transportation and the weather can also impact the storage and management of the power material.

In the management of power system, the power materials are classified into three groups based on the differences in the characteristics, the demand and the supply (See Table 1). Due to the complexity in the management of the power material and its significance to the running of the whole power system, it needs to effective and efficient, especially in the disasters with large scale and serious damage like WenChuan earthquake, LuDian earthquake and floods in the south part which happen with high frequency. The smooth running of power system is essential to the rescue activities. When a disaster occurs, if we can make accurate prediction for the power emergency material (the demand for each kind of material and the optimal route of transportation) based on the information of the disaster, it can be a great help to the personnel rescue and the reduction of economy loss.

Currently, the methods of demand prediction of power emergency material include: dynamic allocation and scheduling of emergency rescue material in large-scale disaster[1], the demand prediction of emergency rescue material based on Fourier_GM (1,1) [2], the demand prediction of emergency rescue material based on the modified GM (1,1) model [3], the demand prediction of emergency rescue material based on Grey-Markov chain model [4], the demand prediction of emergency rescue material based on

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The Grey model [12, 13] was proposed by a famous professor Deng Julong in China. From enormous studies of the information systems, he found that the unknown information can be obtained from the known. And then the Grey prediction theory was formed based on the idea of predictive control.

The model GM (1, 1) is the simplest and most basic in the grey prediction models, which also is the core of the grey model. The steps to process a data sequence $X^{(0)}$ by using the model GM(1,1) is as following.

2.1 Preprocess the data sequence

In order to ensure the feasibility of the model GM (1, 1), we first tested the data sequence $X^{(0)}$. Set the data not negative, that is:

$$X^{(0)} = \{x^{(0)}(1), x^{(0)}(2), x^{(0)}(3), \ldots, x^{(0)}(n)\} \quad (1)$$

(1) Test the smoothness of $X^{(0)}$

$$\beta(k) = \frac{x^{(0)}(k-1)}{x^{(0)}(k)}, k = 3, 4, \ldots, n \quad (2)$$

When all values of $\beta(k)$ are in $\left( e^{-\frac{2}{n+1}}, e^{\frac{2}{n+1}} \right)$, the data sequence $X^{(0)}$ can be directly established on the GM(1,1) model. Otherwise, the preprocessing of $X^{(0)}$ is needed. The mostly used methods of preprocessing include taking logarithm, extracting $n$-th root and smoothing.

(2) After the preprocessing, we need to accumulate the processing of the data $X^{(0)}$ and obtain a new data sequence:

$$X^{(1)} = \{x^{(1)}(1), x^{(1)}(2), x^{(1)}(3), \ldots, x^{(1)}(n)\} \quad (3)$$

Among which,

$$X^{(1)}(k) = \sum_{i=1}^{k} X^{(0)}(i), k = 1, 2, 3, \ldots, n \quad (4)$$
Test whether the sequence $X^{(i)}$ follows the quasi exponential law:

$$\sigma^{(i)}(k) = \frac{x^{(i)}(k)}{x^{(i)}(k-1)}, k = 3, 4, \ldots, n \quad (5)$$

If $\sigma^{(i)}(k) \in [1, 1 + \delta]$, $\delta$ is usually set as 0.5 and follows the exponential law; otherwise, it needs to accumulate the value at least once in common situation.

2.1.2 Establish differential equations
As $X^{(i)}$ conforms to the exponential growth law, it can be considered as the solution of first order differential equation, which is:

$$\frac{dX^{(i)}}{dx} + aX^{(i)} = u \quad (6)$$

Where, $a$ is the development coefficient and $u$ is the coordination coefficient.

2.1.3 Calculate the values of $a$ and $u$
Use least squares estimation method, and then:

$$\hat{a} = \begin{pmatrix} a \\ u \end{pmatrix} = (B^T B)^{-1} B^T Y_n \quad (7)$$

Among which,

$$B = \begin{bmatrix} -Z^{(1)}(2) & 1 \\ -Z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -Z^{(1)}(n-1) & 1 \\ -Z^{(1)}(n) & 1 \end{bmatrix}, Y_n = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n-1) \\ x^{(0)}(n) \end{bmatrix}$$

Where,

$$Z^{(i)}(k) = \frac{1}{2} x^{(i)}(k-1) + \frac{1}{2} x^{(i)}(k), k = 2, 3, \ldots, n \quad (8)$$

2.1.4 Establish grey prediction model
(1) The function of discrete time of the GM (1, 1) is the prediction model of $X^{(i)}$.

Introduce the values of $a$ and $u$ in the above calculation into Formula 6, and then:

$$\hat{x}^{(i)}(k) = x^{(0)}(1) - \frac{u}{a} e^{-a(k-1)} + \frac{u}{a}, k = 2, 3, \ldots, n \quad (9)$$

(2) Accumulate to subtract the value and generate the prediction model of $X^{(i)}$

$$\hat{x}^{(i)}(k) = \hat{x}^{(i)}(k) - \hat{x}^{(i)}(k-1) = (e^{-a} - 1) \left( x^{(0)}(1) - \frac{u}{a} e^{-a(k-1)} \right), \quad (10)$$

$$k = 2, 3, \ldots, n$$

2.2 The Markov chain model
The Markov prediction mainly focuses on the change rules in random process. It basically predicts the change rules of a random event on the basis of its probability that transfer from current state to other states. As the following state of the random event correlates with the current state but not the former state, only the experience can help to predict the changing tendency. And then we can predict the changing rules by calculating the probability of current event and that it transfers from the current state to other states. The Markov prediction has been widely used in the fields of energy, economy and scientific research [14-16].

Set the state space of a discrete time series $X(k)$ as $E = \{ e_0, e_1, e_2, \ldots, e_r \}$, the probability of $X(k)$ being in state $e_i$ is $A_i = P(x(k) = e_i) = P(x(i)) = P(i)$, and the probability of $X(k)$ transferring the state from $e_i$ to $e_j$ is $P_{ij}$, and then we can get that: $P_{ij} = P(x(j) | x(i))$.

Therefore, the probability of each state is

$$A_k = [P(1), P(2), \ldots, P(r)] \sum_r P(i) = 1 \quad (11)$$

The probability of transition between each state is:

$$P = \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1r} \\ P_{21} & P_{22} & \cdots & P_{2r} \\ \vdots & \vdots & \ddots & \vdots \\ P_{r1} & P_{r2} & \cdots & P_{rr} \end{bmatrix}, \quad (12)$$

$$(P_{ij} \geq 0, \sum_j P_{ij} = 1)$$

The Markov prediction is usually conducted in the following steps:
(1) Group the original data;
(2) Group the states and determine the state of the observation data;
(3) Determine the initial probability of each state.

The frequency that the observation data falls into each state can be used to replace the probability of each state:

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The frequency that the observation data falls into each state can be used to replace the probability of each state:
\[ P_i = D_i = \frac{C_i}{n-1} \]  
\[ (13) \]

Among which, \( n - 1 \) is the amount of the observation data, \( C_i \) is the amount of the observation data which fall into state \( e_i \).

(4) Calculate the transition probabilities between the states

The frequency that the current state transfers to the next state can be set as the transition probability, that is:

\[ P_{ij} = D_{ij} = \frac{C_{ij}}{C_i} \]  
\[ (14) \]

Among which, \( C_i \) is the number of states that transferred into the state \( e_i \), \( C_{ij} \) is the number of states which transferred from state \( e_i \) to state \( e_j \).

(5) Use transition probability prediction

Set the observation data is in state \( e_i \), and then the probability that it transfers into each state is the values of row \( i \) in matrix \( P \).

If \( P_{ij} = \max\{P_{i1}, P_{i2}, P_{i3}, \ldots, P_{iw}\} \), the observation data will transfer into state \( e_j \) in the next step.

2.3 The Grey Markov chain model

As the demand of power emergency material is susceptible to many influencing factors and always fluctuates greatly, the prediction of the traditional Grey model is relatively lower in precision. While the Markov chain model mainly focuses on the change rules of different states in the systems, and can be applied in the situation with large random fluctuations. Therefore, the two prediction modes can work together, and then both can give full play to the advantages and correct the imperfections in each other as well. The working steps are as follows:

1. Use the Grey model and make preliminary prediction of the data sequence.
2. Calculate the relative errors between the predicted values and the actual values, and group the relative errors into several states (3-5 states in general).
3. Calculate the transition probability matrix based on the state space.
4. Calculate the predicted value, and make modification to the predicted value with the use of transition probability and error state.

3 EXPERIMENT AND RESULT

3.1 Experimental data

This paper mainly focuses on the demand prediction of power emergency material. The storage of different material varies in different emergent situations. We selected three indexes including the households of power outage, crew in emergency maintenance and one kind of power equipment (oil-immersed transformer) for the experiments and analysis (See Figure 2).

The emergent events can be classified into many types (for example, earthquake in the natural disaster, accident in the construction work and terrorist attack in public life etc.). This paper collected the data from 20 earthquakes in China and abroad as the samples, among which some were obtained from the references and the actual data of a power supply company (See Table 2).

3.2 Establish GM (1,1) model

As aforementioned, we used the households of power outage, crew in emergency maintenance and the number of damaged oil-immersed transformer for the experiment. Therefore, we need the prediction values of these three indexes.

As shown in Table 2, the original data sequences are \( X_i^{(0)} = (3121, 5246, 7170, \ldots, 662370, 841076) \), \( X_2^{(0)} = (88, 102, 136, \ldots, 2129, 2516) \) and \( X_3^{(0)} = (12, \ldots) \).
Use the Grey model and process the data sequences as stated in Section 2.1, we can obtain the prediction functions as:

\[
\hat{X}_1^{(0)}(k) = 8694.37e^{0.44349k}, \quad k = 2,3,\ldots,20 (15)
\]

\[
\hat{X}_2^{(0)}(k) = 157.22e^{0.313429k}, \quad k = 2,3,\ldots,20 (16)
\]

\[
\hat{X}_3^{(0)}(k) = 16.35e^{0.375469k}, \quad k = 2,3,\ldots,20 (17)
\]

As shown in Table 3, the relative error rates of the households of power outage, the crew in emergency maintenance and the damaged oil-immersed transformer are [-11.71%, 17.55%], [-8.64%, 25.49%] and [8.51%, 23.53%] respectively. And then we can know that the Grey model can be used to predict the demand of power emergency material, but the precision is low and needs further improvements.

### 3.3 Establish the Grey-Markov chain model

The Markov chain model can make modifications to the prediction values and improve the precision of the Grey model. The final value can be obtained by modifying the relative error. And then the Grey-Markov chain model is established to predict the demand of the power emergency material. The specific steps are as follows:

1. Use the Grey model to preliminarily predict the demand of power emergency material.

2. Group the relative errors of the prediction values into several states (See Table 3 and Table 4).

3. Calculate the transition probability between each state and determine the transition matrix.

It can be seen from Section 2.2 that the transition probability between different states is replaced by the transition frequency of the states of the observation data. And then the transition matrixes of the three indexes in the earthquake can be obtained finally.

Note: The earthquakes are listed according to ascending order of their magnitudes.

1. Sichuan Dege; 2. Shandong Cangshan; 3. Liaoning Xiuyan; 4. Morocco Agadir; 5. Hebei Zhangbei; 6. Nicaragua Managua; 7. Xinjiang Jiashi; 8. Yunnan Wuding; 9. Losangeles; 10. Yunnan Lijiang; 11. Xingtai; 12. Romania conflans; 13. Songpan; 14. Haicheng; 15. Longlin; 16. Iran Longling; 17. Peru Lima offshore earthquake Tabas; 18. Tangshan (1976); 19. Sichuan Wenchuan; 20. San Francisco

| Serial number | Magnitude | Epicenter intensity | Damage degree of buildings (%) | Households of power outage | Crew in emergency maintenance | Number of damaged oil immersed transformer |
|---------------|-----------|---------------------|--------------------------------|---------------------------|------------------------------|---------------------------------------------|
| 1             | 5.0       | 6                   | 8                              | 3121                      | 88                           | 12                                         |
| 2             | 5.2       | 7                   | 6                              | 5246                      | 102                          | 17                                         |
| 3             | 5.6       | 8                   | 9.7                            | 7170                      | 136                          | 21                                         |
| 4             | 5.9       | 9                   | 16                             | 15469                     | 184                          | 24                                         |
| 5             | 6.2       | 8                   | 23.9                           | 21157                     | 216                          | 31                                         |
| 6             | 6.3       | 8                   | 32.36                          | 38365                     | 297                          | 35                                         |
| 7             | 6.4       | 8                   | 53.04                          | 58486                     | 382                          | 47                                         |
| 8             | 6.5       | 9                   | 50                             | 65508                     | 413                          | 52                                         |
| 9             | 6.6       | 9                   | 60                             | 78140                     | 468                          | 58                                         |
| 10            | 7.0       | 9                   | 70                             | 102587                    | 492                          | 67                                         |
| 11            | 7.2       | 10                  | 80                             | 146265                    | 546                          | 71                                         |
| 12            | 7.2       | 9                   | 85                             | 195632                    | 589                          | 74                                         |
| 13            | 7.2       | 9                   | 85                             | 256352                    | 648                          | 75                                         |
| 14            | 7.3       | 9                   | 90                             | 300670                    | 705                          | 83                                         |
| 15            | 7.3       | 9                   | 90                             | 332689                    | 867                          | 85                                         |
| 16            | 7.4       | 10                  | 90                             | 489864                    | 1046                         | 88                                         |
| 17            | 7.6       | 10                  | 90                             | 541692                    | 1566                         | 93                                         |
| 18            | 7.8       | 11                  | 90                             | 611000                    | 1743                         | 102                                        |
| 19            | 8.0       | 11                  | 95                             | 662370                    | 2129                         | 112                                        |
| 20            | 8.3       | 12                  | 95                             | 841076                    | 2516                         | 138                                        |

Note: The earthquakes are listed according to ascending order of their magnitudes.
Calculate the prediction values of the Grey-Markov model. Modify the relative error rates of the three indexes respectively (See Table 5, Table 6 and Table 7).

\[ \hat{y}(k) = \left[ 1 + \left( \omega_1 + \omega_2 \right) / 2 \right] \hat{x}^{(0)}(k), k = 2, 3, \ldots, 20 \]  

Among which, \( \omega_1 \) \( \omega_2 \) are the state intervals, and \( \hat{x}^{(0)}(k) \) is the grey prediction value.

### Table 3. Prediction values of the three indexes in 20 earthquakes by the Grey model.

| Serial number | Households of power outage | Crew in emergency maintenance | Number of damaged oil-immersed transformer |
|---------------|----------------------------|-------------------------------|------------------------------------------|
|               | Prediction value | Relative error rate (%) | State | Prediction value | Relative error rate (%) | State | Prediction value | Relative error rate (%) | State |
| 1             | 3121           | 0                           | A3     | 88             | 0                           | B3     | 12             | 0                           | C3     |
| 2             | 5763           | 9.86                         | A3     | 128            | 25.49                       | B4     | 21             | 23.53                       | C4     |
| 3             | 8428           | 17.55                        | A4     | 150            | 10.29                       | B4     | 24             | 14.29                       | C4     |
| 4             | 13657          | -11.71                       | A1     | 188            | 2.17                        | B3     | 26             | 8.33                        | C4     |
| 5             | 21957          | 3.78                         | A1     | 267            | -4.18                       | B2     | 30             | -3.23                       | C2     |
| 6             | 35374          | -7.80                        | A1     | 273            | -8.09                       | B1     | 35             | 0                           | C3     |
| 7             | 60253          | 3.02                         | A3     | 349            | -8.64                       | B1     | 43             | -8.51                       | C1     |
| 8             | 62598          | -4.44                        | A2     | 430            | 4.12                        | B3     | 55             | 5.77                        | C3     |
| 9             | 73547          | -5.88                        | A1     | 447            | -4.50                       | B2     | 63             | 8.62                        | C4     |
| 10            | 110896         | 8.10                         | A3     | 522            | 6.10                        | B4     | 68             | 1.49                        | C3     |
| 11            | 165439         | 13.11                        | A4     | 550            | 0.73                        | B3     | 72             | 1.41                        | C3     |
| 12            | 201782         | 3.14                         | A3     | 624            | 5.94                        | B4     | 77             | 4.05                        | C3     |
| 13            | 271763         | 6.01                         | A3     | 663            | 3.31                        | B3     | 81             | 8.00                        | C4     |
| 14            | 308796         | 2.70                         | A3     | 757            | 7.38                        | B4     | 86             | 3.61                        | C3     |
| 15            | 320775         | -3.58                        | A2     | 832            | -4.04                       | B2     | 87             | 2.35                        | C3     |
| 16            | 466574         | -4.73                        | A2     | 993            | -5.08                       | B1     | 90             | 2.27                        | C3     |
| 17            | 554720         | 2.41                         | A3     | 1496           | -4.48                       | B2     | 97             | 4.30                        | C3     |
| 18            | 583207         | -7.10                        | A3     | 1827           | 4.82                        | B3     | 100            | -1.96                       | C2     |
| 19            | 693207         | 4.66                         | A3     | 2305           | 8.27                        | B4     | 111            | -0.39                       | C2     |
| 20            | 878753         | 4.48                         | A3     | 2658           | 5.64                        | B4     | 129            | -6.52                       | C1     |
| Mean absolute error rate (%) | 6.20 | 6.16 | 5.46 |

### Table 4. States division of the three indexes in the earthquakes.

| Households of power outages | Crew in emergency maintenance | Number of damaged oil-immersed transformer |
|-----------------------------|-------------------------------|------------------------------------------|
| Relative error interval     | State | Relative error interval | State | Relative error interval | State |
| [-12, -5)                   | A1    | [-9, -5)                  | B1    | [-9, -5)                  | C1    |
| [-5, 0)                     | A2    | [-5, 0)                   | B2    | [-5, 0)                   | C2    |
| [0, 10)                     | A3    | [0, 5)                    | B3    | [0, 8)                    | C3    |
| [10, 18)                    | A4    | [5, 26)                  | B4    | [8, 24)                  | C4    |

\[ P_C = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 1/3 & 1/3 & 1/3 & 0 \\ 1/10 & 1/10 & 1/2 & 1/10 \\ 0 & 1/5 & 2/5 & 2/5 \end{bmatrix} \]  

(20)

(4) Calculate the prediction values of the Grey-Markov model. Modify the relative error rates of the three indexes respectively (See Table 5, Table 6 and Table 7).

\[ \hat{y}(k) = \left[ 1 + \left( \omega_1 + \omega_2 \right) / 2 \right] \hat{x}^{(0)}(k), k = 2, 3, \ldots, 20 \]  

Among which, \( \omega_1 \), \( \omega_2 \) are the state intervals, and \( \hat{x}^{(0)}(k) \) is the grey prediction value.

### Table 5. The modified values of the households of power outage by Markov chain model.

| Serial number | Actual value | Prediction value | Modified value | Relative error rate (%) |
|---------------|--------------|------------------|----------------|-------------------------|
| 1             | 3121         | 3121             | 3121           | 0                       |
| 2             | 5246         | 5763             | 5542           | 5.64                    |
| 3             | 7115         | 8428             | 8107           | 13.07                   |
| 4             | 15469        | 13657            | 13465          | -12.95                  |
| 5             | 21157        | 21957            | 22028          | 4.12                    |
| 6             | 38365        | 35374            | 37149          | -3.17                   |
| 7             | 58486        | 60253            | 59753          | 2.17                    |
| 8             | 65508        | 62598            | 64006          | -2.29                   |
| 9             | 78140        | 73547            | 76764          | -1.74                   |
| 10            | 102587       | 110896           | 115358         | 12.45                   |
| 11            | 146265       | 165439           | 160763         | 9.91                    |
| 12            | 195632       | 201782           | 217569         | 11.21                   |
| 13            | 256352       | 271763           | 254312         | -0.80                   |
| 14            | 300670       | 308796           | 321967         | 7.08                    |
| 15            | 332689       | 320775           | 309762         | -6.89                   |
| 16            | 489864       | 466574           | 462759         | -5.53                   |
| 17            | 541692       | 554720           | 571430         | 5.47                    |
| 18            | 611000       | 583207           | 602782         | -1.35                   |
| 19            | 662370       | 693207           | 709326         | 7.09                    |
| 20            | 841076       | 878753           | 864524         | 2.79                    |
| Mean absolute error rate (%) | 5.77 |

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Table 6. Modified values of the crew in emergency maintenance by Markov chain model.

| Serial number | Actual value | Prediction value | Modified value | Relative error rate (%) |
|---------------|--------------|------------------|----------------|-------------------------|
| 1             | 88           | 88               | 88             | 0                       |
| 2             | 102          | 116              | 116            | 13.73                   |
| 3             | 136          | 142              | 142            | 4.41                    |
| 4             | 184          | 193              | 193            | 4.89                    |
| 5             | 216          | 210              | 210            | 2.78                    |
| 6             | 297          | 275              | 275            | -7.41                   |
| 7             | 382          | 342              | 342            | -10.47                  |
| 8             | 413          | 422              | 422            | 2.18                    |
| 9             | 468          | 452              | 452            | -3.42                   |
| 10            | 546          | 568              | 568            | 4.03                    |
| 11            | 589          | 607              | 607            | 3.06                    |
| 12            | 648          | 659              | 659            | 1.70                    |
| 13            | 705          | 741              | 741            | 5.11                    |
| 14            | 867          | 830              | 830            | -4.27                   |
| 15            | 1046         | 993              | 993            | -4.68                   |
| 16            | 1566         | 1467             | 1467           | -6.32                   |
| 17            | 1743         | 1908             | 1908           | 9.47                    |
| 18            | 2129         | 2283             | 2283           | 7.23                    |
| 19            | 2516         | 2704             | 2704           | 7.47                    |
| Mean absolute error rate (%) | 5.38         |                  |                |                         |

Table 7. Modified value of number of damage oil-immersed transformer by Markov chain.

| Serial number | Actual value | Predicted value | Modified value | Relative error rate (%) |
|---------------|--------------|-----------------|----------------|-------------------------|
| 1             | 12           | 12              | 12             | 0                       |
| 2             | 21           | 24              | 23             | 9.52                    |
| 3             | 24           | 26              | 27             | 12.50                   |
| 4             | 31           | 32              | 32             | 3.23                    |
| 5             | 35           | 36              | 36             | 2.86                    |
| 6             | 47           | 46              | 46             | -2.13                   |
| 7             | 52           | 54              | 54             | 3.85                    |
| 8             | 58           | 65              | 65             | 12.07                   |
| 9             | 67           | 69              | 69             | 2.99                    |
| 10            | 71           | 73              | 73             | 2.82                    |
| 11            | 74           | 77              | 77             | 4.05                    |
| 12            | 75           | 83              | 83             | 10.67                   |
| 13            | 83           | 85              | 85             | 2.41                    |
| 14            | 85           | 88              | 88             | 3.53                    |
| 15            | 88           | 92              | 92             | 4.55                    |
| 16            | 93           | 101             | 101            | 8.60                    |
| 17            | 102          | 103             | 103            | 0.98                    |
| 18            | 112          | 110             | 110            | -1.79                   |
| 19            | 138          | 135             | 135            | -2.17                   |
| Mean absolute error rate (%) | 4.56         |                  |                |                         |

4 CONCLUSION

This paper proposed the Grey-Markov chain model to predict the demand of power emergency material. The test selected 20 earthquakes in China and abroad to validate the model. The households of outage, crew in emergency maintenance and the number of damaged oil-immersed transformer were set as the indexes. It is concluded that: (1) The Grey model can predict the demand of power emergency material, while the precision is not satisfying. (2) The Markov chain model can be applied to modify the prediction results, and the relative errors decreased from 6.20%, 6.16% and 5.46% to 5.77%, 5.38% and 4.56%. This paper only made predictions of one kind power emergency material (oil-immersed transformer); the prediction of other similar equipment can also be conducted.

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REFERENCE

[1] Jiang Yiping. 2013. Dynamic allocation and scheduling research of emergency material in large scale disasters. Nanjing: Southeast University.
[2] Wang Zhengxin & Liu Sifeng. 2013. Dynamic allocation and scheduling research of emergency material in large scale disasters. Systems Engineering, 31: x61-64.
[3] Song Xiaoyu, Liu Chunhui & Liu Chunguang. 2010. The demand prediction of emergency material based on the improved GM (1,1) model. Journal of Shenyang Construction University (Natural Science Edition), 26 (6): 1214-1218.
[4] Luo Jianfeng & Zhou Lingyun. 2012. The demand prediction of emergency material based on the Grey-Markov chain model. Productivity, 5: 84-85.
[5] Zhao Yibing, Gao Hongni & Feng Shaobo. 2013. The demand prediction of emergency material based on support vector machine (SVM) regression. Computer Simulation, 30 (8): 408-412.
[6] Wang C.B. & Li L.H. 2007. The forecast of gold price based on the GM (1,1) and Markov chain model. Grey Systems and Intelligent Services, 18(1): 739-743.
[7] Li G.D., Daisuke Y. & Masatake N. 2007. A GM (1, 1) - Markov chain combined model with an application to predict the number of Chinese international airlines. Technological Forecasting & Social Chang, 74(1): 1465-1482.
[8] THM EI-Fluly & EF EI-Saadany. 2012. Grey predictor for hourly wind speed and power forecasting. Green Energy & Technology, 78: 197-226.
[9] Ma Qingyan. 2014. Design and implementation of emergency logistics information system based on Internet of Things technology. Technology and Application, pp: 105-107.
[10] Chen Yan. 2015. Research on emergency material reserve strategy of ZH power supply enterprise. Guangzhou: South China University of Technology.
[11] Wang Zhifa. 2012. Research on emergency materials management in electric power enterprises. Logistics Engineering and Management, 34: 81-82, 97.
[12] Deng Y.H. 2002. Basic Method of Grey System. Wuhan: Huazhong University of Science and Technology Press.
[13] Deng YH. 1988. Basic Method of Grey System. Wuhan: Huazhong University of Science and Technology Press.
[14] Liu Chun & Lv Zhenhua, et al. 2013. Research on a new method for modeling wind power output time series with long time. Power System Protection and Control, 41: 7 – 13.

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[15] Ottawa & Chen Mingyu. 2009. Shanghai index weekly returns time series analysis based on Markov switching model. *China Management Science*, 17 (6): 33-38.

[16] Li G.D., Shiro M. & Masatake N. 2013. The prediction model for electrical power system using an improved hybrid optimization model. *Electrical Power and Energy Systems*, 44(1): 981-987.