An improvement the accuracy of grey forecasting model for cargo throughput in international commercial ports of Kaohsiung

Chia- Nan Wang, Van- Thanh Phan*

Department of Industrial Engineering and Management, National Kaohsiung University of Applied Sciences, 415 Chien- Kung Road, Kaohsiung city, Taiwan

Email address:
 cn.wang@cc.kuas.edu.tw (Chia- Nan, Wang), thanhkem2710@gmail.com (Van- Thanh, Phan)

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Abstract: Based on the grey theory, grey prediction models, which are GM (1, 1), have been adopted to predict the cargo throughput and modified GM (1, 1) using Fourier series called "FRMGM (1, 1)" for improving the accuracy of forecast model. A forecasting the cargo throughput in the international commercial port of Kaohsiung from 2013-2015 has also been conducted based on the previous data to serve as a reference for port management in making development plans and construction as well as orienting development in the future. All data source is collected from the Ministry of Transportation and Communication of Taiwan. Through simulation results, this study showed that both of two models are suitable but the FRMGM (1, 1) is the excellent model in forecast with average accuracy of predict is 100%. Hence, the FRMGM (1, 1) model is strongly suggested for forecast the cargo throughput in the port of Kaohsiung.

Keywords: Cargo Throughput, Grey forecasting model, International Commercial Ports, Kaohsiung

1. Introduction

Grey system theory, founded by Prof. Deng in the 1980s [1], is a quantitative method for dealing with grey systems that are characterized by both partially known and partially unknown information [2-4]. As a vital part of Grey system theory, grey forecasting models with their advantages in dealing with uncertain information by using as few as four data points [5, 6]. It has been successful in applied to various fields such as tourism [7, 8], energy [9, 10], financial and economic [11-13], integrated circuit industry [14]. In the recent year, Grey forecasting model appeared more and more in transportation industry [15-17].

Cargo throughput is one of important indicators for a port; it is not only the most basic production index for reflecting the infrastructure situation, equipment as well as the development level of this port, but also a significant reference to organize its production, make its development plans and construction.

The determinations as well as accurate prediction of Cargo throughput become significant content. So many researchers focused on the forecasting of the Cargo Throughput [18-20]. This issue is not easy task. It’s more and more complex in the volatility and the uncertainty information environment. Therefore, this paper proposes an advance grey prediction called FRMGM (1, 1) as purposes: (1) Improve the accuracy performance of basic grey forecasting models GM (1, 1) to forecasting the cargo throughput. (2) Help port manager for making decision in formulating policies as well as orienting development in the future. The remaining of this paper was organized as follows. In section 2, the concept of grey theory was presented and the fundamental function of GM (1, 1) and Modified GM (1, 1) by Fourier series was shown. Based on the fundamental function of GM (1, 1) and FRMGM (1, 1), the empirical results was shown in section 3. Finally, section 4 concluded this paper.

2. Concept of Grey Forecasting

2.1. Mathematic Models

2.1.1. GM (1, 1)

The GM (1, 1) is based on GM (n, m) where n is the order of Grey difference equation and m is the number of
variables. Among the family of Grey forecasting model, most of the previous researchers have focused on GM (1, 1) model in their prediction. GM (1, 1) model ensure a fine agree between simplicity and accuracy of the results

A non-negative sequence of raw data as

\[ x^{(0)} = x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n), n \geq 4 \]  

(1)

Where n is the sample size of data

Accumulating Generation Operator (AGO) is used to smooth the randomness of primitive sequence. The AGO converting the original sequence into a monotonically increasing sequence. A new sequence \( x^{(1)} \) is generated by AGO as:

\[ x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), k = 2, 3, \ldots, n \]  

(2)

The generated mean sequence \( z^{(1)} \) of \( x^{(1)} \) is defined as:

\[ z^{(1)} = (z^{(1)}(1), z^{(1)}(2), \ldots, z^{(1)}(n)) \]  

(3)

Where \( z^{(1)}(k) \) is the mean value of adjacent data, i.e

\[ z^{(1)}(k) = 0.5x^{(1)}((k) + (k - 1)), k = 2, 3, \ldots, n \]  

(4)

The GM (1, 1) model can be constructed by establishing a first order differential equation for \( x^{(1)}(k) \) as:

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

(5)

The solution, also known as time response function, of above equation is given by:

\[ x^{(1)}(k) = \left[ x^{(0)}(1) - \frac{b}{a} \right] e^{-a(k-1)} + \frac{b}{a} e^{-a(k-1)} \]  

(6)

Where \( x^{(1)}(k) \) denotes the prediction \( x \) at time point \( k \) and the coefficients \( [a, b]^T \) can be obtained by the Ordinary Least Squares (OLS) method:

\[ [a, b]^T = (P^T P)^{-1} P^T y \]  

(7)

In that

\[ y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix} \]  

(8)

and

\[ P = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -z^{(1)}(n) & 1 \end{bmatrix} \]  

(9)

Where: Y is called data series, B is called data matrix, and \( [a, b]^T \) is called parameter series.

Inverse AGO (IAGO) is used to find predicted values of primitive sequence. By using the IAGO:

\[ x = x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n) \]  

(10)

Therefore, the fitted and predicted sequence is given \( \hat{x}^{(0)} \) as:

\[ x^{(0)} = x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n) \]  

(11)

Where:

\[ x^{(0)} = x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n) \]  

(12)

Are called the GM (1, 1) fitted sequence while:

\[ \hat{x}^{(0)} = \hat{x}^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n) \]  

(13)

Are called the GM (1, 1) forecast values.

2.1.2. Fourier Residual Modification GM (1, 1) “FRMGM (1, 1)”

In order to improve the accuracy of forecasting models, the Fourier series has been widely and successfully applied in modifying the residuals in Grey forecasting model Fourier Residual Modification GM (1, 1) is:

1) According to the original sequence to build the GM(1,1), then we have \( x^{(0)}(k) \) and original residual sequence \( r^{(0)}(k) \)

2) Transfer \( r^{(0)}(k) \) into Fourier series form
3. Empirical Results

Kaohsiung port is today the world’s 13th largest container port and Taiwan’s largest international commercial harbor [22]. It encompasses five container terminals. All are at your service to handle a comprehensive range of logistics services promptly and accurately. With an annual handling capacity of 10 million TEU, the port of Kaohsiung handles shipments quickly and effectively with state-of-the-art facilities, equipment and supporting infrastructure and professional. In 2012, the port of Kaohsiung handled container throughput of 9.78 million TEU, an increase of 1.5% from 2011.

The data of cargo throughput from 2003 – 2012 in the port of Kaohsiung are obtained from the Ministry of Transportation and Communication of Taiwan [23]. All data was shown in table 1 and the unit is million tons “M.T.”

<table>
<thead>
<tr>
<th>Year</th>
<th>Incoming (Unit: M.T.)</th>
<th>Outgoing (Unit: M.T.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>100,916,018</td>
<td>37,916,190</td>
</tr>
<tr>
<td>2004</td>
<td>108,454,669</td>
<td>44,013,275</td>
</tr>
<tr>
<td>2005</td>
<td>94,375,576</td>
<td>43,544,755</td>
</tr>
<tr>
<td>2006</td>
<td>90,764,693</td>
<td>44,317,320</td>
</tr>
<tr>
<td>2007</td>
<td>103,756,571</td>
<td>45,468,455</td>
</tr>
<tr>
<td>2008</td>
<td>102,325,923</td>
<td>44,402,957</td>
</tr>
<tr>
<td>2009</td>
<td>84,593,315</td>
<td>38,976,947</td>
</tr>
<tr>
<td>2010</td>
<td>88,018,045</td>
<td>36,934,388</td>
</tr>
<tr>
<td>2011</td>
<td>87,204,585</td>
<td>36,727,315</td>
</tr>
<tr>
<td>2012</td>
<td>84,392,281</td>
<td>36,363,719</td>
</tr>
</tbody>
</table>

2.2. Evaluative Precision of Forecasting Models

In order to predict the accuracy of forecasting model in this study, Means Absolute Percentage Error (MAPE) index was used to evaluate the performance and reliability of forecasting technique [21]. It is defined as follows:

\[
MAPE = \frac{1}{n} \sum_{k=2}^{n} \frac{|x^{(0)}(k) - \hat{x}^{(0)}(k)|}{x^{(0)}(k)} \times 100\%
\]

Where: \(x^{(0)}(k)\): The actual value in time period \(k\)
\(\hat{x}^{(0)}(k)\): The forecast value in time period \(k\)
And the grade of MAPE are divided into four grades

<table>
<thead>
<tr>
<th>MAPE</th>
<th>Grade level</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 1%</td>
<td>Excellent</td>
</tr>
<tr>
<td>1% - 5%</td>
<td>Good</td>
</tr>
<tr>
<td>5% - 10%</td>
<td>Qualified</td>
</tr>
<tr>
<td>&gt; 10%</td>
<td>Unqualified</td>
</tr>
</tbody>
</table>

3.1. Forecasting Model for the Incoming and Outgoing Cargo Throughput

Based on the algorithm expressed in section 3.1, the fundamental Grey forecasting model for the incoming cargo named GM(1,1)_in and outgoing cargo named GM(1,1)_out are found as:

\[
x^{(1)}(k) = -41465982.42 \times e^{-0.02528(k-1)} + 4247514231.42
\]

And

\[
x^{(1)}(k) = -163481482.374 \times e^{-0.0285793(k-1)} + 1672731013.74
\]

respectively.

The residual series gained from GM (1, 1)_in is then modified with Fourier series, which results in the modified model FRMGM (1, 1)_in as per the algorithm stated in section 2.1. The evaluation indexes of GM(1,1)_in and FGM(1,1)_in are summarized as in Table 3.
Table 3. Forecasted incoming cargo throughput in Kaohsiung port using GM (1, 1) and FRMGM (1, 1)

<table>
<thead>
<tr>
<th>Year</th>
<th>Actual value</th>
<th>GM(1,1)</th>
<th>FRMGM(1,1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forecasted Value</td>
<td>Residual Value</td>
<td>Error (%)</td>
</tr>
<tr>
<td>2003</td>
<td>100,916,018</td>
<td>100,916,018</td>
<td>0.00000</td>
</tr>
<tr>
<td>2004</td>
<td>108,454,669</td>
<td>103,518,446.55</td>
<td>-4,936,222</td>
</tr>
<tr>
<td>2005</td>
<td>94,375,576</td>
<td>90,934,142.93</td>
<td>6,558,567</td>
</tr>
<tr>
<td>2006</td>
<td>90,764,693</td>
<td>98,414,355.99</td>
<td>7,649,663</td>
</tr>
<tr>
<td>2007</td>
<td>103,756,571</td>
<td>95,957,473.91</td>
<td>-7,799,097</td>
</tr>
<tr>
<td>2008</td>
<td>95,957,473.91</td>
<td>108,454,669</td>
<td>-2,497,195</td>
</tr>
<tr>
<td>2009</td>
<td>84,593,315</td>
<td>91,226,185.03</td>
<td>-6,632,870</td>
</tr>
<tr>
<td>2010</td>
<td>88,018,045</td>
<td>88,948,753.63</td>
<td>930,709</td>
</tr>
<tr>
<td>2011</td>
<td>86,728,177.55</td>
<td>87,204,585</td>
<td>-476,407</td>
</tr>
<tr>
<td>2012</td>
<td>84,563,037.42</td>
<td>84,392,281</td>
<td>170,756</td>
</tr>
</tbody>
</table>

MAPE %: 4.566
Accuracy: (100-MAPE) (%): 95.434
Evaluation: Good

Following the same way, the outgoing cargo throughput of GM (1, 1) and FRMGM (1, 1) are calculated and summarized in Table 4.

Table 4. Forecasted outgoing cargo throughput in Kaohsiung port using GM (1, 1) and FRMGM (1, 1)

<table>
<thead>
<tr>
<th>Year</th>
<th>Actual value</th>
<th>GM(1,1)</th>
<th>FRMGM(1,1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forecasted Value</td>
<td>Residual Value</td>
<td>Error (%)</td>
</tr>
<tr>
<td>2003</td>
<td>37,916,190</td>
<td>37,916,190</td>
<td>0.00000</td>
</tr>
<tr>
<td>2004</td>
<td>44,013,275</td>
<td>46,060,508.5</td>
<td>2,047,233</td>
</tr>
<tr>
<td>2005</td>
<td>43,544,755</td>
<td>44,762,764.92</td>
<td>1,218,010</td>
</tr>
<tr>
<td>2006</td>
<td>44,317,320</td>
<td>43,501,584.95</td>
<td>-815,735</td>
</tr>
<tr>
<td>2007</td>
<td>45,468,455</td>
<td>42,275,938.41</td>
<td>-3,192,517</td>
</tr>
<tr>
<td>2008</td>
<td>44,402,957</td>
<td>41,084,824.17</td>
<td>-3,318,133</td>
</tr>
<tr>
<td>2009</td>
<td>38,976,947</td>
<td>39,927,269.28</td>
<td>950,322</td>
</tr>
<tr>
<td>2010</td>
<td>36,934,388</td>
<td>38,802,328.22</td>
<td>1,867,940</td>
</tr>
<tr>
<td>2011</td>
<td>36,727,315</td>
<td>37,709,082.09</td>
<td>981,767</td>
</tr>
<tr>
<td>2012</td>
<td>36,363,719</td>
<td>36,646,637.91</td>
<td>282,919</td>
</tr>
</tbody>
</table>

MAPE %: 3.47301
Accuracy: (100-MAPE) (%): 96.527
Evaluation: Good

It can be seen from the error of forecast model (table 3 and 4), the error of both forecasting model too small, more specifically, the MAPE of GM (1, 1) in and GM (1, 1) out is 4.566 and 3.473 while both of FRMGM (1, 1) in and FRMGM(1,1) out get zero error. This is indicated that both of GM(1,1) and FRMGM(1,1) models are suitable for forecasting the number of Incoming and outgoing cargo throughput but FRMGM (1, 1) models is better forecast model. Therefore, FRMGM (1, 1) was strongly recommended in this situation. The forecasted values of two models in 2013-2015 were illustrated as below table:

Table 5. Forecasted value of cargo throughput value from 2013 -2015

<table>
<thead>
<tr>
<th>Year</th>
<th>GM(1,1)</th>
<th>FRMGM(1,1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incoming (Unit: M.T.)</td>
<td>Outgoing (Unit: M.T.)</td>
</tr>
<tr>
<td>2013</td>
<td>82,451,949.3</td>
<td>35,614,127.8</td>
</tr>
<tr>
<td>2014</td>
<td>80,393,563.8</td>
<td>34,610,708.5</td>
</tr>
<tr>
<td>2015</td>
<td>78,386,565.2</td>
<td>33,635,560.2</td>
</tr>
</tbody>
</table>

Table 5 shows that the number of Incoming and Outgoing cargo throughput in 2015 will be 86,801,762.3 and 37,070,650.7 million tons, respectively. This will
provide a basis for the port to make the port development strategy in the future.

4. Conclusion

The study results suggest that applying FRMGM (1, 1) to forecast short-term cargo throughput can achieve excellent prediction.

The result of this study is important in forecast Cargo Throughput. Predicting the cargo throughput of the port is of great importance for state and local to formulate the port development strategy.

The accomplishment of this study can lead to the future research of more international commercial ports can be assessed by FRMGM (1, 1).

References