International Journal of Business and Economics Research
2014; 3(1): 1-5
Published online January 10, 2014 (http://www.sciencepublishinggroup.com/j/ijber)
doi: 10.11648/j.ijber.20140301.11

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)

To cite this article:

Chia- Nan Wang, Van- Thanh Phan. An Improvement the Accuracy of Grey Forecasting Model for Cargo Throughput in International Commercial Ports of Kaohsiung. *International Journal of Business and Economics Research.* Vol. 3, No. 1, 2014, pp. 1-5.
doi: 10.11648/j.ijber.20140301.11

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

$$x^{(0)} = x^{(0)}(1), x^{(0)}(2), ... x^{(0)}(n)), n \geq 4 \qquad (1)$$

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:

$$x^{(1)} = (x^{(1)}(1), x^{(1)}(2), ... x^{(1)}(n)), n \geq 4 \qquad (2)$$

Where, $x^{(1)}(1) = x^{(0)}(1)$ and

$$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), k = 2,3....., n \qquad (3)$$

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

$$z^{(1)} = (z^{(1)}(1), z^{(1)}(2), ... z^{(1)}(n)) \qquad (4)$$

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

$$z^{(1)}(k) = 0.5x^{(1)}((k) + (k-1)), k = 2,3,...., n \qquad (5)$$

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

$$\frac{dx^{1}(k)}{dk} + ax^{(1)}(k) = b \qquad (6)$$

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

$$\hat{x}^{(1)}(k) = \left[x^{(0)}(1) - \frac{b}{a}\right] e^{-a(k-1)} + \frac{b}{a} \qquad (7)$$

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:

$$[a,b]^T = (P^T P)^{-1} P^T Y \qquad (8)$$

In that

$$Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ .... \\ .... \\ x^{(0)}(n) \end{bmatrix} \qquad (9)$$

and

$$P = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ .... & \vdots \\ .... & \vdots \\ -z^{(1)}(n) & 1 \end{bmatrix} \qquad (10)$$

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:

$$\hat{x}^{(0)}(k) = \left[x^{(0)}(1) - \frac{b}{a}\right] e^{-a(k-1)} (1 - e^{a}) \qquad (11)$$

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

$$\hat{x}^{(0)} = \hat{x}^{(0)}(1), \hat{x}^{(0)}(2), ..., \hat{x}^{(0)}(n) \quad and \quad \hat{x}^{(0)}(1) = x^{(0)}(1) \qquad (12)$$

Where:

$$\hat{x}^{(0)}(1), \hat{x}^{(0)}(2), ..., \hat{x}^{(0)}(n)$$

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

$$\hat{x}^{(0)}(n+1), \hat{x}^{(0)}(n+2), ...,$$

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 $\hat{x}^{(0)}(k)$ and original residual sequence $r^{(0)}(k)$
2) Transfer $r^{(0)}(k)$ into Fourier series form

$$r^{(0)}(k) \cong \frac{1}{2}a_{(0)} + \sum_{i=1}^{z}\left(a_i \cos(\frac{2\pi i}{T}(k)) + b_i \sin(\frac{2\pi i}{T}(k))\right) \quad (13)$$

Where $k = 2,3,4,..,n, T = n-1$ and $z = (\frac{n-1}{2}) - 1$

3) From $Y = PC$ to find the value of $C = \left(P^T P\right)^{-1} P^T Y$, which use least square method,

Where

$$P=\begin{bmatrix} \frac{1}{2} & \cos\left(2\frac{2\pi}{T}\right) & \sin\left(2\frac{2\pi}{T}\right) & \cos\left(2\frac{2\pi 2}{T}\right) & \sin\left(2\frac{2\pi 2}{T}\right) & ... & \cos\left(2\frac{2\pi z}{T}\right) & \sin\left(2\frac{2\pi z}{T}\right) \\ \frac{1}{2} & \cos\left(3\frac{2\pi}{T}\right) & \sin\left(3\frac{2\pi}{T}\right) & \cos\left(3\frac{2\pi 2}{T}\right) & \sin\left(3\frac{2\pi 2}{T}\right) & ... & \cos\left(3\frac{2\pi z}{T}\right) & \sin\left(3\frac{2\pi z}{T}\right) \\ .... \\ \frac{1}{2} & \cos\left(n\frac{2\pi}{T}\right) & \sin\left(n\frac{2\pi}{T}\right) & \cos\left(n\frac{2\pi 2}{T}\right) & \sin\left(n\frac{2\pi 2}{T}\right) & ... & \cos\left(n\frac{2\pi z}{T}\right) & \sin\left(n\frac{2\pi z}{T}\right) \end{bmatrix},$$

$$C = \left[a_0, a_1, b_1, a_2, b_2, ..., a_n, b_n,\right]^T,$$

$$Y = \left[r^{(0)}(2), r^{(0)}(3), r^{(0)}(4), ..., r^{(0)}(n)\right]^T, \quad k = 2,3,4,...,n$$

4) Substitute all data into the Fourier series to get the value of $\hat{r}^{(0)}(k)$.

5) The final prediction value is show in equation (14)

$$\begin{cases} \hat{x}_f^{(0)}(1) = \hat{x}^{(0)}(1) \\ \hat{x}_f^{(0)}(k) = \hat{x}^{(0)}(k) + \hat{r}^{(0)}(k), \quad k = (2,3,4,..,n) \end{cases} \quad (14)$$

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:

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

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 1.** The grade of MAPE*

MAPE	≤ 1%	1% - 5%	5% - 10%	> 10%
Grade level	Excellent	Good	Qualified	Unqualified

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 2.** The number of cargo throughput in Kaohsiung port*

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

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:

$$\hat{x}^{(1)}(k) = -4146598213.42 \times e^{-0.025281(k-1)} + 4247514231.42$$

and

$$\hat{x}^{(1)}(k) = -1634814823.74 \times e^{-0.0285793(k-1)} + 1672731013.74$$

, 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)*

Year	Actual value	GM(1,1) Forecasted Value	Residual Value	Error (%)	FRMGM(1,1) Forecasted Value	Residual Value	Error (%)
2003	100,916,018	100,916,018	0	0.000	100,916,018	0.00000	0.00000
2004	108,454,669	103,518,446.55	-4,936,222	4.551	108,454,669	0.00000	0.00000
2005	94,375,576	100,934,142.93	6,558,567	6.949	94,375,576	0.00000	0.00000
2006	90,764,693	98,414,355.59	7,649,663	8.428	90,764,693	0.00000	0.00000
2007	103,756,571	95,957,473.91	-7,799,097	7.517	103,756,571	0.00000	0.00000
2008	102,325,923	93,561,927.46	-8,763,996	8.565	102,325,923	0.00000	0.00000
2009	84,593,315	91,226,185.03	6,632,870	7.841	84,593,315	0.00000	0.00000
2010	88,018,045	88,948,753.63	930,709	1.057	88,018,045	0.00000	0.00000
2011	87,204,585	86,728,177.55	-476,407	0.546	87,204,585	0.00000	0.00000
2012	84,392,281	84,563,037.42	170,756	0.202	84,392,281	0.00000	0.00000
MAPE %				4.566			0
Accuracy= (100-MAPE) (%)				95.434			100
Evaluation				Good			Excellent

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)*

Year	Actual value	GM(1,1) Forecasted Value	Residual Value	Error (%)	FRMGM(1,1) Forecasted Value	Residual Value	Error (%)
2003	37,916,190	37,916,190	0	0.00000	37,916,190	0.00000	0.00000
2004	44,013,275	46,060,508.5	2,047,233	4.65140	44,013,275	0.00000	0.00000
2005	43,544,755	44,762,764.92	1,218,010	2.79714	43,544,755	0.00000	0.00000
2006	44,317,320	43,501,584.95	-815,735	1.84067	44,317,320	0.00000	0.00000
2007	45,468,455	42,275,938.41	-3,192,517	7.02139	45,468,455	0.00000	0.00000
2008	44,402,957	41,084,824.17	-3,318,133	7.47277	44,402,957	0.00000	0.00000
2009	38,976,947	39,927,269.28	950,322	2.43816	38,976,947	0.00000	0.00000
2010	36,934,388	38,802,328.22	1,867,940	5.05746	36,934,388	0.00000	0.00000
2011	36,727,315	37,709,082.09	981,767	2.67313	36,727,315	0.00000	0.00000
2012	36,363,719	36,646,637.91	282,919	0.77803	36,363,719	0.00000	0.00000
MAPE %				3.47301			0
Accuracy= (100-MAPE) (%)				96.527			100
Evaluation				Good			Excellent

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*

Year	GM(1,1) Incoming (Unit: M.T.)	GM(1,1) Outgoing (Unit: M.T.)	FRMGM(1,1) Incoming (Unit: M.T.)	FRMGM(1,1) Outgoing (Unit: M.T.)
2013	82,451,949.3	35,614,127.8	76,509,482.4	34,638,691.9
2014	80,393,563.8	34,610,708.5	72,127,801.1	35,183,869.6
2015	78,386,565.2	33,635,560.2	86,801,762.3	37,070,650.7

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 result suggest that applying FRMGM (1, 1) to forecast short term of the number of 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 with more international commercial ports can be assessed by FRMGM (1, 1).

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