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# Forecasting the number of deaths from cerebrovascular diseases in Thailand using grey systems theory

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## Abstract

Due to uncertainties in life, a forecasting system that can accept variables and generate an acceptable predictive function needs to be developed. The grey system theory works with poor, incomplete or uncertain past data in time series forecasting. According the Public Health Statistics, the number of deaths from cerebrovascular diseases in Thailand were S-shaped with an overall upward trend from 1996 to 2015; with deaths rising from 6,300 to 8,200 during 1996-2000 (V-shape), 11,309 up to 19,265 and down to 15,719 during 2001 to 2005(/\-shape ), rose from 12,921 to 17,540 during 2006 to 2010, and rose again from 19,283 to 28,146 in 2011 to 2015. The data are arranged in 4 sets from the past to the most current year 2015: there are 5, 10, 15, and 20 years as the input to 5 grey models: Grey Model First Order One Variable (GM(1,1)), expanded forms of GM(1,1) (GM(1,1)E), and expanded forms of GM(1,1) with residuals correction (GM(1,1)E&C), the grey Verhulst model (VGM), and the grey Verhulst model with improvement (VGMI). From the 20 solutions from 4 sets of input and 5 models, the forecasts from GM(1,1)E&C show minimum errors with high correlation efficiencies. The different shape and number of past data also affect the forecast values. The forecast number of deaths from cerebrovascular in 2016 will be 25,991 persons, if the S-shape in the past will be repeated.

***Keywords*****:** *Cerebrovascular disease, Forecasting, Grey Systems Theory*

## 1. Introduction

Cerebrovascular diseases are included as a group of disorders of the heart and blood vessels, the cardiovascular diseases (CVDs) (WHO, 2016). In 2012, an estimated 17.5 million people died from CVDs (7.4 million and 6.7 million were due to coronary heart disease and stroke, respectively) that were approximately 31% of all global deaths and were the highest cause of deaths worldwide (WHO, 2016).

When the blood, which supplies oxygen and nutrients, is not able to flow to some specific region of the brain, it can cause a particular part of the body under the control of that region of the brain to not function as it should. This is called a stroke. There are 3 types of strokes, which are defined by the causes of the interruptions of blood flow. An ischemic stroke is caused by a clot obstruction. If the clot is temporary, it is a mini stroke, or transient ischemic attack (TIA). If a blood vessel is ruptured, it can cause a hemorrhagic stroke (American Heart Association/American Stroke Association, 2016). Sudden weakness or numbness of the face, arm or leg, most often on one side of the body is a common symptom of a stroke. Other symptoms include lack of understanding, uncertainty, difficulty in communication, difficulty in vision with one or both eyes, difficulty of movement, unsteadiness, loss of balance or coordination; severe headache with no known cause, and fall due to fainting or loss consciousness. The severely injured parts of the brain show different stroke effects. Sudden death can be caused from a very severe stroke.

Using The International Classification of Diseases, Tenth Edition (ICD-10), cerebrovascular diseases have the ICD-10 Code I60-I69. The number of deaths from Cerebrovascular diseases in Thailand appeared in the annual report from Ministry of Public Health (MOPH) - "Public Health Statistics" - Table 2.3.2 Number and Mortality Rates per 100,000 population by Sex and Causes of Death - According to ICD General Mortality Tabulation List 1, Revision 10 (Bureau of policy and strategy, 2015). The number of deaths from cerebrovascular diseases increased 4.47 times within two decades from 6,297 in 1996 to 28,146 in 2015.

In Thailand, the Bureau of Non Communicable Diseases, using data from 2001 to

2011, predicted the mortality rate during 2012 to 2016 for the deaths caused by ICD-10 Code I60-I69 cerebrovascular diseases by using exponential smoothing with simple, Holt, and Damped methods. The forecasted number of deaths from Damped method had the lowest Mean Absolute Percentage Error (MAPE) criteria, the forecasts were 30.56, 30.72, 30.77, 30.78, and 30.56 per 100,000 population for 2012 to 2016, respectively (Manosoontorn, n.d.). Public Health Statistics A.D. 2015 reported the number of deaths at 31.7, 35.9, 38.7, and 43.3 per 100,000 population for the years 2012 to 2015 (Bureau of Policy and Strategy, 2015). There are many existing models to forecast pending deaths based on diseases and disease models. They can be delineated based on their use of time, artificial intelligence, other intelligent methods and the hybrids which exist therein. Among time series predictions, statistical models AR (Autoregressive), MA (Moving Average), ARMA (Autoregressive Moving Average), and ARIMA (Autoregressive Integrated Moving Average) are the most popular. The artificial intelligence-based approach (neural network (NN)), and other intelligent approaches (linear regression, Kalman filtering, fuzzy systems, hidden Markov model, support vector machines, and many hybrid models), may be too complex to be used in predicting the future values of a time series (Kayacan, Ulutus, & Kaynak, 2010).

Grey system theory was initiated by Jurong Deng in 1982; the methodology solves the problem of generally incomplete and inadequate information with a group of differential equations. A system that has both known and unknown information is defined as a grey system. In real life, every system can be considered as a grey system, because there are always uncertainties. Due to noise from both inside and outside of the system, the information of the system is always uncertain and limited in scope. The focus of grey system theory is on the uncertainty problems of small samples and poor information that are difficult for probability and fuzzy mathematics to handle (Liu & Lin, 2010). Grey model (GM) uses a minimum of 4 data sets to build a differential model for a grey process (a stochastic process whose amplitudes vary with time). Grey series forecasting is applicable for the life sciences, including health and disease prediction (Modal & Pramanik, 2015, Shen et al., 2013; Zhang & Xu, 2012). The procedure in a grey system starts from creating the accumulated series, estimating parameters using the least square method, projecting the accumulated series, and an inverse accumulated generating operation to predict the original series.

In forecasting practice, the forecasters generally compare the results from various quantitative technical forecasting techniques, and then choose the one solution with their final logical qualitative judgment. Grey system theory focuses on the study of grey problems and has been well accepted from scientific practitioners around the world (Liu & Lin, 2010). In Thailand, the published grey system theory in forecasting was infrequent and directed towards rice export, price of the stock market, and levels of air pollution. Based on a thorough review of existing literature, there are no prediction models for the number of deaths from diseases. Grey series forecasting will be the new challenger among other existing forecasting techniques in Thai public health diseases prediction.

## 2. Objectives

The purpose of this study is to apply the grey system theory for forecasting the number of deaths from cerebrovascular diseases in Thailand. The number of deaths from cerebrovascular diseases (ICD-10 Code I60-I69) during 1996 to 2015 from Public Health Statistics (Bureau of policy and strategy, 2015) are arranged into 4 data period, 5 years (2011-2015), 10 years (2006-2015), 15 years (2001-2015), and 20 years (1996-2015) in order to evaluate the forecasting results when different numbers and combinations of patterns of data are used. Section 3 represents the input data and describes the methods from GM(1,1), expanded form of GM(1,1), modification of GM(1,1) model using Fourier series of error residuals, the grey Verhulst model, and the grey Verhulst improvement model, including model accuracy evaluation. Sections 4, 5, and 6 show results, conclusion, and discussion, respectively.

## 3. Materials and methods

### 3.1 The number of deaths from cerebrovascular diseases from 1996 to 2015

The number of deaths from cerebrovascular diseases during 1996 to 2015 from Bureau of Policy and Strategy, Ministry of Public Health (2015) were shown in Table 1 (real values column).

**Table 1** Real and Model Values - Number of deaths from cerebrovascular diseases in Thailand during 1996 to 2015

| Year | Real values | GM(1,1) | GM(1,1)E | GM(1,1)E&C | VGM | VGMI |
|---|---|---|---|---|---|---|
| 1996 | 6,297 | 6,297 | 6,297 | 6,297 | 6,297 | 6,297 |
| 1997 | 5,962 | 7,841 | 439 | 5,929 | 1,154 | 1,220 |
| 1998 | 4,283 | 8,384 | 852 | 4,330 | 1,362 | 1,452 |
| 1999 | 6,631 | 8,966 | 1,149 | 6,571 | 1,607 | 1,726 |
| 2000 | 8,260 | 9,587 | 1,609 | 8,330 | 1,893 | 2,050 |
| 2001 | 11,309 | 10,252 | 2,182 | 11,230 | 2,228 | 2,430 |
| 2002 | 13,427 | 10,963 | 2,966 | 13,513 | 2,619 | 2,877 |
| 2003 | 18,332 | 11,723 | 3,898 | 18,242 | 3,073 | 3,398 |
| 2004 | 19,265 | 12,535 | 5,169 | 19,357 | 3,599 | 4,003 |
| 2005 | 15,719 | 13,404 | 6,505 | 15,627 | 4,206 | 4,703 |
| 2006 | 12,921 | 14,334 | 7,596 | 13,010 | 4,902 | 5,507 |
| 2007 | 12,995 | 15,328 | 8,492 | 12,912 | 5,697 | 6,422 |
| 2008 | 13,133 | 16,390 | 9,393 | 13,208 | 6,597 | 7,454 |
| 2009 | 13,353 | 17,527 | 10,304 | 13,287 | 7,610 | 8,606 |
| 2010 | 17,540 | 18,742 | 11,230 | 17,594 | 8,736 | 9,874 |
| 2011 | 19,283 | 20,041 | 12,447 | 19,242 | 9,977 | 11,249 |
| 2012 | 20,368 | 21,431 | 13,784 | 20,395 | 11,324 | 12,711 |
| 2013 | 23,222 | 22,916 | 15,197 | 23,210 | 12,764 | 14,232 |
| 2014 | 25,114 | 24,505 | 16,807 | 25,110 | 14,276 | 15,773 |
| 2015 | 28,146 | 26,204 | 18,549 | 28,165 | 15,829 | 17,282 |

Source: Real values from Bureau of Policy and Strategy, Ministry of Public Health, 2015

3.2 Grey system theory for time series forecasting

*3.2.1 The Grey Model First Order One Variable - GM(1,1) model*

Grey Model First Order One Variable - GM(1,1) is a basic model with its computational efficiency among GM($r,m$) (a grey model, where $r$ is the order of difference equation and $m$ is the number of variables). GM(1,1) is most widely used in various fields, i.e. agriculture, ecology, medicine, environment, etc. and also in the time series forecasting model. The Accumulation Generating Operation (AGO) applies to the primitive data in order to smooth the randomness, the differential equation is solved and the Inverse Accumulated Generating Operation (IAGO) is applied to find the predicted values of original data (Deng, 1989).

Consider that $X^{(0)}$ denotes the number of deaths from cerebrovascular diseases of non-negative sequence and $n$ is the sample size of the data. After applying AGO to $X^0$ using Eq. (3), $X^{(1)}$ the monotonic increasing sequence is obtained. $Z^{(1)}$ is the mean sequence that is generated from $X^{(1)}$ using Eq. (5). The least square estimate sequence of the grey difference equation of GM(1,1) is defined in Eq. (6) The whitening equation is shown in Eq. (7). $[a,b]^T$ is a sequence of parameters that can be found in Eq. (8). According to Eq. (7), the solution of $X^{(1)}(t)$ at time $k$ is in Eq. (11), and by IAGO, the original sequence can be expressed in Eq. (12) (Liu and Lin, 2010). $X^{(0)}$ and $X^{(1)}$ are the forecast values of the individual values and the accumulated values, respectively.

$$X^{(0)} = \left(x^{(0)}(1),...,x^{(0)}(n)\right) \quad (1)$$

$$X^{(1)} = \left(x^{(1)}(1),...,x^{(1)}(n)\right) \quad (2)$$

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

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

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

$$x^{(0)}(k)+az^{(1)}(k)=b \tag{6}$$

The first order ordinary differential equation of $X^{(1)}$ as:

$$\frac{dX^{(1)}}{dt}+aX^{(1)}=b \tag{7}$$

*a* and *b* are called the developing coefficient and grey input, respectively.

$$\begin{bmatrix} a \\ b \end{bmatrix}=\left(B^T B\right)^{-1}B^T Y \tag{8}$$

where

$$B=\begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \cdots & \cdots \\ -z^{(1)}(n) & 1 \end{bmatrix} \tag{9}$$

$$Y=\left(x^{(0)}(2),x^{(0)}(3),...,x^{(0)}(n)\right)^T \tag{10}$$

$$x^{(1)}(k+1)=\left(x^{(0)}(1)-\frac{b}{a}\right)e^{-ak}+\frac{b}{a} \tag{11}$$

$$x^{(0)}(k+1)=\left(1-e^{a}\right)\left(x^{(0)}(1)-\frac{b}{a}\right)e^{-ak},k=1,2,...,n \tag{12}$$

*3.2.2 Expanded forms of GM(1,1) model*

Expanded forms of GM(1,1) model (GM(1,1)E) provide better simulation accuracies than the difference model $x^{(0)}(k)=\beta-\alpha x^{(1)}(k-1)$ by transforming GM(1,1) into Eqs. (13)-(14) (Liu and Lin, 2010, pp. 109-116).

$$x^{(0)}(k)=\beta-\alpha x^{(1)}(k-1) \tag{13}$$

where

$$\beta=\frac{b}{1+0.5a} \text{ and } \alpha=\frac{a}{1+0.5a}$$

$$x^{(0)}(k)=\beta-\alpha x^{(0)}(1)e^{-a(k-2)} \tag{14}$$

*3.2.3 GM(1,1) expanded with periodic correction model*

Improved forecasting precision using error modification of Grey models has been shown as an error correction model (Lin et al., 2013), modification of GM(1,1) model using Fourier series of error residuals (Kayacan, Ulutus, & Kaynak, 2010), and residual modification of Grey Verhulst model on times series error correction (Guo, Song, & Ye, 2005).

The error residuals in Eq. (15) can be expressed in Fourier series as Eq. (16).

$$\varepsilon^{(0)}(k) = x^{(0)}(k) - \hat{x}^{(0)}(k) \tag{15}$$

$$\varepsilon^{(0)}(k) \cong \frac{1}{2}a_0 + \sum_{i=1}^{z}\left[a_i \cos\left(\frac{2\pi i}{T}k\right) + b_i \sin\left(\frac{2\pi i}{T}k\right)\right], \quad k = 2,3,...,n. \tag{16}$$

$T = n-1$ and $z = \frac{(n-1)}{2} - 1.$

$T$ will be an integer number and $z$ will be selected as an integer number (Guo, Song, & Ye, 2005). Eq. (16) can be rewritten as Eq. (17) where $P$ and $C$ matrixes can be defined as Eqs. (18)-(20). Fourier series correction can be obtained as Eq. (21).

$$\varepsilon^{(0)} \cong PC \tag{17}$$

$$P = \begin{bmatrix} 1/2 & \cos\left(2\frac{2\pi}{T}\right) & \sin\left(2\frac{2\pi}{T}\right) & \cos\left(2\frac{2\pi 2}{T}\right) & \sin\left(2\frac{2\pi 2}{T}\right) & ... & \cos\left(2\frac{2\pi z}{T}\right) & \sin\left(2\frac{2\pi z}{T}\right) \\ 1/2 & \cos\left(3\frac{2\pi}{T}\right) & \sin\left(3\frac{2\pi}{T}\right) & \cos\left(3\frac{2\pi 2}{T}\right) & \sin\left(3\frac{2\pi 2}{T}\right) & ... & \cos\left(3\frac{2\pi z}{T}\right) & \sin\left(3\frac{2\pi z}{T}\right) \\ ... & ... & ... & ... & ... & ... & ... & ... \\ 1/2 & \cos\left(n\frac{2\pi}{T}\right) & \sin\left(n\frac{2\pi}{T}\right) & \cos\left(n\frac{2\pi 2}{T}\right) & \sin\left(n\frac{2\pi 2}{T}\right) & ... & \cos\left(n\frac{2\pi z}{T}\right) & \sin\left(n\frac{2\pi z}{T}\right) \end{bmatrix} \tag{18}$$

$$C = \begin{bmatrix} a_0 & a_1 & b_1 & a_2 & b_2 & ... & a_n & b_n \end{bmatrix}^T \tag{19}$$

$$C \cong \left(P^T P\right)^{-1} P^T \varepsilon^{(0)} \tag{20}$$

$$\hat{x}_r^{(0)}(k) = \hat{x}^{(0)}(k) - \varepsilon^{(0)}(k) \tag{21}$$

*3.2.4 The Grey Verhulst model*

The German biologist Verhulst first introduced the Grey Verhulst model (VGM). This model is effective in describing some increasing processes, such as S-curves which have a saturation region in the phenomenon of population increase, living creature bleeding and its individual growth (Kayacan, Ulutas, and Kaynak, 2010; Liu and Lin, 2010; Guo, Song, & Ye, 2005)). The Grey Verhulst model can be constructed just as the GM(1,1) by establishing the first order differential equation for $X^{(1)}(k)$ as:

$$\frac{dX^{(1)}}{dt} + aX^{(1)} = b\left(X^{(1)}\right)^2 \tag{22}$$

and

$$\begin{aligned} x^{(0)}(k) + az^{(1)}(k) &= b\left(z^{(1)}(k)\right)^2 \\ x^{(0)}(k) &= -az^{(1)}(k) + b\left(z^{(1)}(k)\right)^2 \end{aligned} \tag{23}$$

where

$$\begin{bmatrix} a \\ b \end{bmatrix} = \left(B^T B\right)^{-1} B^T Y \tag{24}$$

and

$$B = \begin{bmatrix} -z^{(1)}(2) & \left(z^{(1)}(2)\right)^2 \\ -z^{(1)}(3) & \left(z^{(1)}(3)\right)^2 \\ \cdots & \cdots \\ -z^{(1)}(n) & \left(z^{(1)}(n)\right)^2 \end{bmatrix} \tag{24}$$

$$Y = \left(x^{(0)}(2), x^{(0)}(3), \ldots, x^{(0)}(n)\right)^T \tag{26}$$

$$x^{(1)}(k+1) = \frac{ax^{(0)}(1)}{bx^{(0)}(1) + \left(a + bx^{(0)}(1)\right)e^{ak}} \tag{27}$$

$X^{(1)}$ can be obtained from Eq. (27). $X^{(0)}$ be the fitted and predicted the series.

$$\begin{aligned} x^{(0)}(k) = &\frac{ax^{(0)}(1)\left(a - bx^{(0)}(1)\right)}{bx^{(0)}(1) + \left(a - bx^{(0)}(1)\right)e^{a(k-1)}} \\ &\times \frac{(1-e^a)e^{a(k-2)}}{bx^{(0)}(1) + \left(a - bx^{(0)}(1)\right)e^{a(k-2)}} \end{aligned} \tag{28}$$

*3.2.5 The Grey Verhulst Improvement model*

The Grey Verhulst improvement model (VGMI) was presented by Zhang (2012) to reduce simulation error of VGM. The improved grey derivative is in Eqs. (29)-(30).

$$x^{(0)}(k)^* = \frac{dx^{(1)}(k)}{dk} \tag{29}$$

$$\begin{aligned} x^{(0)}(k)^* = &\frac{x^{(0)}(k)x^{(0)}(k+1)x^{(1)}(k)}{x^{(1)}(k-1)x^{(0)}(k+1) - x^{(0)}(k)x^{(1)}(k+1)} \\ &\times \ln \frac{x^{(0)}(k+1)x^{(1)}(k-1)}{x^{(0)}(k)x^{(1)}(k+1)} \end{aligned} \tag{30}$$

3.3 Model accuracy evaluation

The error is the difference of the forecast value from the real value. The accuracy evaluation terms that are used to examine the accuracy of the models in this study are as follows.

The mean absolute percentage error (MAPE) is the average of the absolute value of relative percentage errors.

The root mean square error (RMSE) is the root of the average sum squares of the error.

The closer the correlation coefficient (CC) is to 1, the better the prediction.

The closer the coefficient of efficiency (CE) is to 1, the more the prediction matches the actual situation.

MAPE, RMSE, CC, and CE are shown in Eqs. (31)-(34), respectively (Lin, et al., 2013).

$$MAPE = \left( \frac{1}{n-1} \sum_{k=1}^{n} \left| \frac{x(k) - x^{(0)}(k)}{x^{(0)}(k)} \right| \right) \times 100\% \quad (31)$$

$$RMSE = \sqrt{\frac{\sum_{k=1}^{n} \left( x(k) - x^{(0)}(k) \right)^2}{n-1}} \quad (32)$$

$$CC = \frac{\sum_{k=2}^{n} \left( x^{(0)}(k) - \bar{x}(k) \right) \left( x(k) - \bar{x}(k) \right)}{\sqrt{\sum_{k=2}^{n} \left( x^{(0)}(k) - \bar{x}(k) \right)^2 \sum_{k=2}^{n} \left( x(k) - \bar{x}(k) \right)^2}} \quad (33)$$

$$CE = 1 - \frac{\sum_{k=2}^{n} \left( x^{(0)}(k) - x(k) \right)^2}{\sum_{k=2}^{n} \left( x^{(0)}(k) - \bar{x}(k) \right)^2} \quad (34)$$

3.4 The input data and different grey models in this study

In order to evaluate the effect from past data pattern in the future value prediction, the number of deaths from cerebrovascular diseases in Thailand during 1996 to 2015 (as shown in Table 1) were designated to four input periods :

- Last 5 years (2001-2015) (/ shape)
- Last 10 years (2006-2015) (u and / shape)
- Last 15 years (2001-2015) (/\, u, and / shape)
- Last 20 years (1996-2015). (v, /\, u, and / shape)

The five different grey models to test the accuracies in this study are:

- GM(1,1)
- GM(1,1)E
- GM(1,1)E&C
- VGM
- VGMI

All models in this study are designed in MATLAB using custom scripts.

## 4. Results

Only the predicted values from the 5 models using 20 years of input are shown in Table 1. The accuracy evaluation by MAPE, RMSE, CC, and CE of the models: GM(1,1), GM(1,1)E, GM(1,1)E&C, VGM, and VGMI for the 4 periods input data (5,10, 15, 20 years from the past to the most current 2015) are shown in Table 2. The GM(1,1)E&C shows minimum errors with high correlation efficiencies, and the model accuracy from the 20 years data input is the lowest error with the highest correlation. The forecast values for those 5 models of 4 input data periods are shown in Table 3. The number of deaths from cerebrovascular diseases from 1996 to 2015 and projected GM(1,1)E&C values for the year 2016 are shown in Fig. 1.

**Table 2** Model accuracy

| Errors | GM(1,1) | GM(1,1)E | GM(1,1)E&C | VGM | VGMI |
|---|---|---|---|---|---|
| MAPE | | | | | |
| Last 5 years (2011-2015) | 0.92% | 77.24% | 0.93% | 10.94% | 11.86% |
| Last 10 years (2006-2015) | 3.80% | 60.14% | 0.75% | 25.58% | 22.07% |
| Last 15 years (2001-2015) | 15.58% | 66.81% | 1.15% | 53.22% | 48.81% |
| Last 20 years (1996-2015) | 21.24% | 62.02% | 0.64% | 68.68% | 65.22% |
| RMSE | | | | | |
| Last 5 years (2011-2015) | 249.09 | 18,450.85 | 222.44 | 3,008.02 | 3,204.41 |
| Last 10 years (2006-2015) | 757.40 | 10,810.89 | 136.82 | 4,637.33 | 4,147.54 |
| Last 15 years (2001-2015) | 3,061.73 | 12,274.24 | 194.92 | 9,722.74 | 9,062.67 |
| Last 20 years (1996-2015) | 3,008.14 | 8,075.33 | 74.84 | 9,174.07 | 8,751.64 |
| CC | | | | | |
| Last 5 years (2011-2015) | 0.9976 | -0.2249 | 0.9983 | 0.8719 | 0.7200 |
| Last 10 years (2006-2015) | 0.9908 | 0.7957 | 0.9997 | 0.9508 | 0.9480 |
| Last 15 years (2001-2015) | 0.7946 | 0.5349 | 0.9993 | 0.7097 | 0.7182 |
| Last 20 years (1996-2015) | 0.8924 | 0.8467 | 1.0000 | 0.8283 | 0.8354 |
| CE | | | | | |
| Last 5 years (2011-2015) | 0.9952 | -25.4485 | 0.9962 | 0.2970 | 0.2023 |
| Last 10 years (2006-2015) | 0.9816 | -2.7470 | 0.9994 | 0.3106 | 0.4485 |
| Last 15 years (2001-2015) | 0.6300 | -4.9463 | 0.9985 | -2.7311 | -2.2417 |
| Last 20 years (1996-2015) | 0.7962 | -0.4564 | 0.9999 | -1.0452 | -0.7564 |

**Table 3** Forecast values for 2016

| Past data used | GM(1,1) | GM(1,1)E | GM(1,1)E&C | VGM | VGMI |
|---|---|---|---|---|---|
| Last 5 years (2011-2015) | 31,167 | 12,759 | 31,229 | 21,624 | 15,910 |
| Last 10 years (2006-2015) | 31,257 | 20,532 | 32,283 | 26,009 | 24,024 |
| Last 15 years (2001-2015) | 25,969 | 14,216 | 27,228 | 20,307 | 21,143 |
| Last 20 years (1996-2015) | 28,021 | 20,501 | 25,991 | 17,383 | 18,701 |

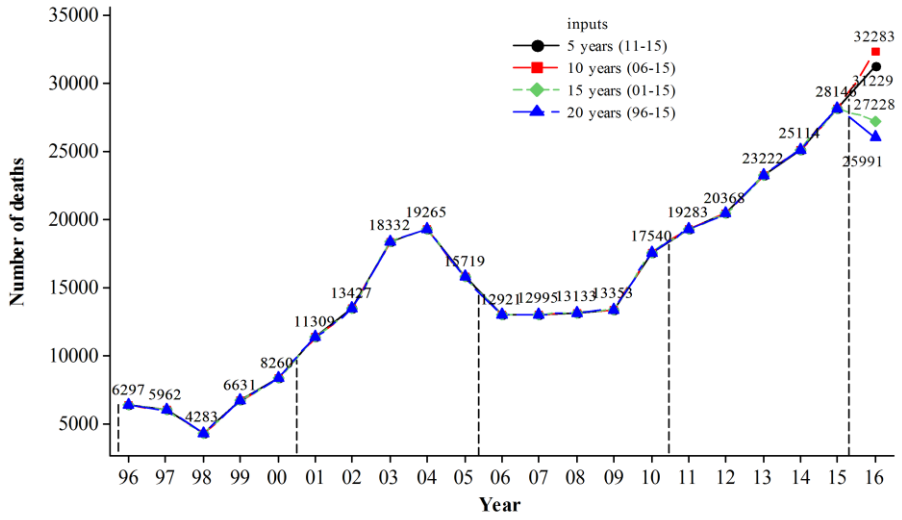


**Figure 1** Real values from 1996 to 2015 and GM(1,1)E&C values of 4 period inputs in 2016

## 5. Discussion

The GM(1,1) E&C of 4 period input data show the forecast values from 25,991 to 32,283. The forecast values have 2 groups, for long term input data of 15 years and 20 years. The forecasts are lower than the number of deaths in 2015 at 27,228 and 25,991 with the effect of S-shape from the past, while in short term input data of 5 years and 10 years, they are in rising patterns which is higher than the number of deaths in 2015 at 31,229 and 32,283. The narrow band width in predicting the number of deaths in 2016 will be in between 27,228 to 31,229. From a quantitative side, the GM(1,1)E&C with 20 years input shows minimum errors with high correlation efficiencies and if the S-shape pattern continues to occur as previously seen, then the 25,991 deaths from GM(1,1)E&C with 20 years input is an interesting figure to predict the number of deaths from cerebrovascular diseases in 2016.

## 6. Conclusion

The grey system model can be fitted with the past data and projected to the future with the information from the system, the number of past data including with size and direction or pattern or shape of data inherent to the forecast value. The precision of the 2016 forecasted value will be observed in Public Health Statistics 2017.

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## 8. References

American Heart Association, Inc. (2016). About stroke. Retrieved November 18, 2016, from http://www.strokeassociation.org/STROKEORG/AboutStroke/About-Stroke_UCM_308529_SubHomePage.jsp

Bureau of policy and strategy. (2015). Table 2.3.2 Number and Mortality Rates per 100,000 population by Sex and Causes of Death (According to ICD General Mortality Tabulation List 1, Revision 10). *Public Health Statistics A.D. 2015.* [In Thai/English]. Ministry of Public Health. Thailand.

Deng, J. (1989). Introduction to grey system theory. *The Journal of grey system, 1989*,1-24.

Guo, Z., Song, X., & Ye, J. (2005). A Verhulst model on time series error corrected for port throughput forecasting. *Journal of the Eastern Asia Society for Transportation Studies*, *6*, 881-891. DOI: http://doi.org/10.11175/easts.6.881

Hui, S., Yang, F., Li, Z., Liu, Q., & Dong, J. (2009). Application of grey system theory to forecast the growth of larch. *International Journal of Information and Systems Sciences, 5*(3-4), 522-527.

Kayacan, E., Ulutas, B., & Kaynak O. (2010). Grey system theory-based models in time series prediction. *Expert Systems with Applications, 37* (2010), 1784-1789. DOI: 10.1016/j.eswa.2009.07.064

Lin, Y. H., Chiu, C. C., Lin, Y. J., & Lee, P. C. (2013). Rainfall prediction using innovative grey model with the dynamic index. *Journal of Marine Science and Technology, 21*(1), 63-75. DOI: 10.6119/JMST-011-1116-1.

Liu, S., & Lin, Y. (2010). *Grey systems theory and application.* Verlag: Springer.

Manosoontorn, S. (n.d.) Cerebrovacular diseases forecasting report. [in Thai]. Retrieved December 9, 2016, from www.interfetpthailand.net/forecast/files/.../report_2014_no20.pdf

Modal, K., & Pramanik, S. (2015). The application of Grey System Theory in predicting the number of deaths of women by commiting suicide - A case study. *Journal of Applied Quantitative Methods. 10*(1), 48-55.

Mohammadi, A., Moradi, L., Talebnejad, A., & Nadaf, A. (2011). The use of Grey System Theory in predicting the road traffic accident in Fars province in Iran. *Australian Journal of Business and Management Research*, *1*(9),18-23.

Shen, X., Ou, L., Chen, X., Zhang, X., & Tan, X. (2013). The Application of the grey disaster model to forecast epidemic peaks of typhoid and paratyphoid fever in China. *Plos ONE, 8*(4), e60601, 1-6. DOI: https://doi.org/10.1371/journal.pone.0060601

The Math WorksTM. (2009). MATLAB 7.6.0(R2009a). License Number 350306, February 12, 2009.

World Health Organization, WHO. (2016). Cardiovascular diseases (CVDs) Fact sheet. Retrieved December 6, 2016, from http://www.who.int/mediacentre/factsheets/fs317/en/

Zhang, Y. (2012). Improved grey derivative of grey Verhulst model and its application. *International Journal of Computer Science*, *9*(6), 3, 443-448.

Zhang, Z., & Xu, F. (2012). Measles trends dynamic forecasting model based on grey system theory. *Management Science and Engineering*, *6*(4), 71-74. DOI: http://dx.doi.org/10.3968/j.mse.1913035X20120604.ZRXZ2