THE APPLICATION OF GREY SYSTEM THEORY IN PREDICTING THE NUMBER OF DEATHS OF WOMEN BY COMMITTING SUICIDE- A CASE STUDY

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Abstract:

Sexual harassment, dowry problem, torture, importation of girls, kidnapping, rape and other social problems are forced a woman to commit suicide. These risk factors include man dominated social structure, insecurity of woman, unequal priority level of man and woman, family problems, un-employment etc. Indian constitution offers equal rights for male and female. So the problem of woman suicide becomes a complicated one that restricts the development of country and threatens for the parallelism of male-female ratio. Considering the complexity and uncertainty of the influencing factors on woman suicides, suicide forecasting can be regarded as a grey system with unknown and known information, so it can be analyzed by grey system theory. Grey models require only a limited amount of data to estimate the behavior of unknown systems. In this paper, the original predicted values of woman suicides are separately obtained by the GM (1, 1) model, the Verhulst model and the GM (2, 1) model. The results obtained from these models on predicting woman suicide show that the forecasting accuracy of the GM (1, 1) is better than the Verhulst model and the GM (2, 1) model. Then, the GM (1, 1) model is proposed to predict woman suicide in Indian context.

Key words: Woman suicide, Grey system theory, GM (1, 1) model, Verhulst model, GM (2, 1) model, Forecasting

1. Introduction

Indian civilization is one of the greatest civilizations in the world history. Women suicide is found in the great epic like the Mahabharata and the Ramayana. Committing suicide is a multidimensional, multifaceted malaise. At present India is a developing nation. Indian constitution offers the same rights of man and woman. With the development of economy overall demands regarding all sphere of life of a woman are increasing day by day. Now, in urban life, women have to lead first life in order to meet the demand of her family and other reasons. As a result, they are affected both mentally and physically such as high blood pressure, high blood sugar, stress, hypertension, mental depression etc. In rural and urban sections, there have been an increasing number of cases such as sexual harassment, dowry problem, mental and physical torture, importation of girls, kidnapping, rape, divorce, love affairs, cancellation or the inability to get married (in accordance with the system of arranged marriages in India), illegitimate pregnancy, extra-marital affairs, family conflicts, family problems, illness high expectation, and other unknown problems. These factors are the main causes behind committing suicide. Many young girls lose their deep love affairs and take maximum decision of committing suicide [1][3]. Eight suicides per day are occurred due to poverty and dowry dispute [1]. One suicide out of every five suicides was committed by a housewife [1]. However, the occurrence of woman suicidal cases [1, 2] reflects a rising tendency as a result of the quick growing of alertness. Though the occurrence of woman suicidal case is occasional, it can be predicted scientifically based on the related statistical indexes. Accurate prediction of the woman suicide is important not only for government's policy, but also for social organizations that are devoted to deal with woman's problems.

Grey system theory proposed by Deng [3] in 1982 is a powerful theory for dealing with partially known and partially unknown information. The concept of the grey system theory is used in several fields such as rainfall prediction [4], industry [5], business [6] and geological systems studies [7], environmental studies [8], decision making [9], etc. As an essential part of grey system theory, grey forecasting models [10] are popularly used in time -series forecasting because of its simplicity and ability and high precision to characterize an unknown system by using a few data points [11, 12].

In recent years, the grey system theory has been widely used to forecast in various fields such as grey prediction model for traffic demand [13], electricity demand [14], and internet access population [15].

In review of literature, no prediction model for women suicide is still found. In this paper, the original predicted values of woman suicides are separately obtained by using the GM (1, 1) model [16], the Verhulst model [17] and the GM (2, 1) model [18]. The results of these models on predicting woman suicide are compared. Then, the GM (1, 1) model is proposed to predict woman suicide accidents in Indian context.

Rest of the paper is organized as follows: Section 2 presents mathematical presentation of three grey prediction models. Section 3 is devoted to present case study in Indian context. Section 4 presents concluding remarks.

2. Mathematical Presentation Of Prediction Models

2.1. The GM (1, 1) Model [16]

The most commonly used grey forecasting model is GM (1, 1), which indicates that one variable is employed in the model. The first order differential equation is adopted to match the data generated by the accumulation generating operation (AGO).

For the algorithm of GM (1, 1), the raw data sequences is presented as follows:

$$X^{(0)} = \left\{x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n)\right\} \quad (1)$$

Here n is the total number of modeling data. The AGO formation of $X^0(1)$ is defined as follows:

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

Here,

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

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

$$\frac{dX^{(1)}}{dt} + a X^{(1)} = u \quad (4)$$

Here, the parameters a, u are called the developing coefficient and grey input respectively.

In practical, the parameters a, u are not calculated directly from the equation (4). Therefore, the solution of the equation (4) can be obtained by using the least square method as follows:

$$\hat{x}^{(1)}(k+1) = \left[x^{(0)}(1) - \frac{u}{\hat{a}}\right] e^{-ak} + \frac{u}{\hat{a}} \quad (5)$$

Here $\hat{a} = [a, u]^T = (B^T B)^{-1} B^T Y$ and

$$B = \begin{bmatrix} -\frac{1}{2}\left(x^{(1)}(1) + x^{(1)}(2)\right) & 1 \\ -\frac{1}{2}\left(x^{(1)}(2) + x^{(1)}(3)\right) & 1 \\ \vdots & \vdots \\ -\frac{1}{2}\left(x^{(1)}(3) + x^{(1)}(4)\right) & 1 \end{bmatrix} \quad (6)$$

$$Y_N = \left(X^{(0)}(2), X^{(0)}(3), \cdots, X^{(0)}(n)\right)^T \quad (7)$$

Applying the inverse accumulated generation operation (IAGO), the obtained solution is presented by:

$$\hat{x}^{(0)}(k) = \left[x^{(0)}(1) - \frac{u}{a}\right](1 - e^{a}) e^{-a(k-1)} \quad (8)$$

Here $\hat{x}^{(1)}(1) = x^{(0)}(1)$ and k = 2, 3,..., n.

2.2 The Grey Verhulst Model [17]

The Verhulst model [17] was first introduced by a German biologist Pierre Franois Verhulst. The main purpose of Velhulst model is to restrict the whole development for a real system. For an initial time sequence,

$X^{(0)} = \{x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n)\}$, the initial sequence $X^{(0)}$ is used to construct the Verhulst model directly as follows:

$$\frac{dX^{(0)}}{dt} + a X^{(0)} = u\left(X^{(0)}\right) \quad (9)$$

Here a presents the development coefficient and u denotes the grey action quantity. The solution of the parameter vector $\hat{a}=[a,u]^T$ can be obtained by using the least square method.

Here $\hat{a}=\left[(A\vdots B)^T(A\vdots B)\right]^{-1}(A\vdots B)^T Y$

and,

$$A=\begin{bmatrix} -\frac{1}{2}(x^{(0)}(1)+x^{(0)}(2)) \\ -\frac{1}{2}(x^{(0)}(2)+x^{(0)}(3)) \\ \vdots \\ -\frac{1}{2}(x^{(0)}(n-1)+x^{(0)}(n)) \end{bmatrix};\ B=\begin{bmatrix} \left[\frac{1}{2}(x^{(0)}(1)+x^{(0)}(2))\right]^2 \\ \left[\frac{1}{2}(x^{(0)}(2)+x^{(0)}(3))\right]^2 \\ \vdots \\ \left[\frac{1}{2}(x^{(0)}(n-1)+x^{(0)}(n))\right]^2 \end{bmatrix} \quad (10)$$

$$Y=\left[x^{(0)}(2)-x^{(0)}(1),\ x^{(0)}(3)-x^{(0)}(2),\ \cdots,\ x^{(0)}(n)-x^{(0)}(n-1)\right]^T \quad (11)$$

The re-solution of (9) can be presented as follows:

$$\hat{x}^{(0)}(k+1)=\frac{ax^{(0)}(1)}{ux^{(0)}(1)+(a-ux^{(0)}(1))e^{ak}} \quad k = 0, 1, 2,\dots, n \quad (12)$$

2.3 The GM (2, 1) Model [18]

The GM (2, 1) model is a single sequence second-order linear dynamic model and is fitted by differential equations.

Let us assume that an original sequence $X^{(0)}$ be

$$X^{(0)} = \left\{x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n)\right\}.$$

A new sequence $X^{(1)}$ is generated by the AGO as follows:

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

$$X^{(1)}(k) = \sum_{j=1}^{k} x^{(0)}(j),\ k = 1, 2,\dots, n \quad (13)$$

Now the differential equation of GM (2, 1) model can be presented as follows:

$$\frac{d^2X^{(1)}}{dt^2}+a\frac{dX^{(1)}}{dt}=u \quad (14)$$

$$\hat{a}=[a,u]^T=\left(B^T B\right)^{-1}B^T Y$$

$$B=\begin{bmatrix} -x^{(0)}(2) & 1 \\ -x^{(0)}(3) & 1 \\ \vdots & \vdots \\ -x^{(0)}(n) & 1 \end{bmatrix};\ Y=\begin{bmatrix} (x^{(0)}(2)-x^{(0)}(1)) \\ (x^{(0)}(3)-x^{(0)}(2)) \\ \vdots \\ (x^{(0)}(n)-x^{(0)}(n-1)) \end{bmatrix} \quad (15)$$

From the equation (14), we have

$$\hat{x}^{(1)}(k+1)=\left(\frac{u}{a^2}-\frac{x^0(1)}{a}\right)e^{-ak}+\frac{u}{a}(k+1)+\left(x^0(1)-\frac{u}{a}\right)\left(\frac{1+a}{a}\right) \quad (16)$$

The prediction values of original sequence can be obtained by applying inverse AGO to $\hat{x}^{(1)}$ as follows:

$$\hat{x}^{(0)}(k+1)=\hat{x}^{(1)}(k+1)-\hat{x}^{(1)}(k),\ \text{here } k=1, 2,\dots, n \quad (17)$$

3. Case Study

In this section, the GM (1, 1) [16], the Verhulst model [17] and the GM (2, 1) [18] are used for comparison. The woman suicide data [1, 2] in India from 2008 to 2013 is used to demonstrate the effectiveness and practicability of the models. The data of women suicide in 2006-2010 is presented to form the three grey prediction models and the data of women suicide from 2011 to 2013 is used as data set to compare the accuracy of the three prediction models.

The evaluation criterion is the mean relative percentage error (MRPE), which measures the percentage of prediction errors. MRPE can be presented as follows:

$$\mathrm{MRPE} = \frac{1}{n}\sum_{k=1}^{n}\left[\left|x^{(0)}(k) - \hat{x}^{(0)}(k)\right| / x^{(0)}(k)\right] \tag{18}$$

In the GM (1, 1) model values of the essential terms are presented as follows:

$$B = \begin{bmatrix} -44488 & 1 \\ -44788 & 1 \\ -45193 & 1 \\ -45780 & 1 \\ -47601 & 1 \\ -49801 & 1 \\ -51048 & 1 \end{bmatrix};\ Y = \begin{bmatrix} 44750 \\ 44825 \\ 45560 \\ 46000 \\ 49201 \\ 50400 \\ 51695 \end{bmatrix};\ \hat{a} = [a, u] = [-0.02, -20]^T \tag{19}$$

In the Verhulst model values of the essential terms are presented as follows:

$$(A \vdots B) = \begin{bmatrix} -44488 & 1979182144 \\ -44788 & 2005964944 \\ -45193 & 2042407249 \\ -45780 & 209580840 \\ -47601 & 2265855201 \\ -49801 & 2480139601 \\ -51048 & 2605898304 \end{bmatrix} \quad Y = \begin{bmatrix} 525 \\ 75 \\ 735 \\ 440 \\ 3201 \\ 1199 \\ 1295 \end{bmatrix} \quad \hat{a} = [a, u] = [-0.01,\ 1/4428000]^T \tag{20}$$

In the GM (2, 1) model values of the essential terms are presented as follows:

$$B = \begin{bmatrix} -44750 & 1 \\ -44825 & 1 \\ -45560 & 1 \\ -46000 & 1 \\ -49201 & 1 \\ -50400 & 1 \\ -51695 & 1 \end{bmatrix},\ Y = \begin{bmatrix} 525 \\ 75 \\ 735 \\ 440 \\ 3201 \\ 1199 \\ 1295 \end{bmatrix} \quad \hat{a} = [a, u] = [-0.21, -9000]^T \tag{21}$$

The real and forecasted values are shown in 'Table1' to compare the three model accuracy and relative error. The corresponding calculated results (the mean error in the different stage) are shown in Table2.

Table1 indicates that the GM (1, 1) prediction model is smaller than the others by comparing the relative error. From Table2, it is seen that the MRPE of the GM (1, 1) model, the Verhulst model and the GM (2, 1) from 2011 to 2013 are 1.360%, 2.007% and 1.503%, respectively. The effectiveness and accuracy of GM (1, 1) model is higher than the Verhulst model and the GM (2, 1) model.

Table1. Model values and prediction error of the woman suicidal case in India

	Year	Real Value	GM(1,1)		Verhulst		GM(2,1)	
			Model value	**Error R (%)**	**Model value**	**Error R (%)**	**Model value**	**Error R (%)**
Model set up stage	2006	44225	44225	0	45128	-2.04	44225	0
	2007	44750	45098	-0.78	46067	-2.94	46103	-3.02
	2008	44825	45989	-2.6	47048	-4.96	46542	-3.83
	2009	45560	46898	-2.94	48071	-5.51	47084	-3.35
	2010	46000	47825	-3.97	49139	-6.82	47751	-3.81
Post set up stage	2011	49201	48771	0.87	50256	-2.14	48576	1.27
	2012	50400	49736	1.32	51424	-2.03	49592	1.60
	2013	51695	50721	1.88	52649	-1.85	50846	1.64

Table2. Error results for the different prediction models

Stage	GM(1,1)	Verhulst	GM(2,1)
	MRPE (%)	**MRPE (%)**	**MRPE (%)**
2008-2010	2.058	4.454	2.802
2011-2013	1.36	2.007	1.503

The comparison of Table1 and Table2 show that the GM (1, 1) model and the GM (2, 1) model have the better forecasting precision in 2006-2010, but the GM (1, 1) prediction model offers the lowest post-forecasting errors and it is more suitable to make a short-term prediction, so the GM (1, 1) model is used to predict women suicide for 2014 and 2015 in India. In Table 3, the comparison between the real values and predicted values obtained from GM (1, 1) model (see Figure1) for women suicides in India.

Table3. The result of forecasting

Year	2010	2011	2012	2013	2014	2015
Real values	46000	49201	50400	51695	---	---
GM (1, 1) Model values	47825	48771	49736	50721	51552	52253

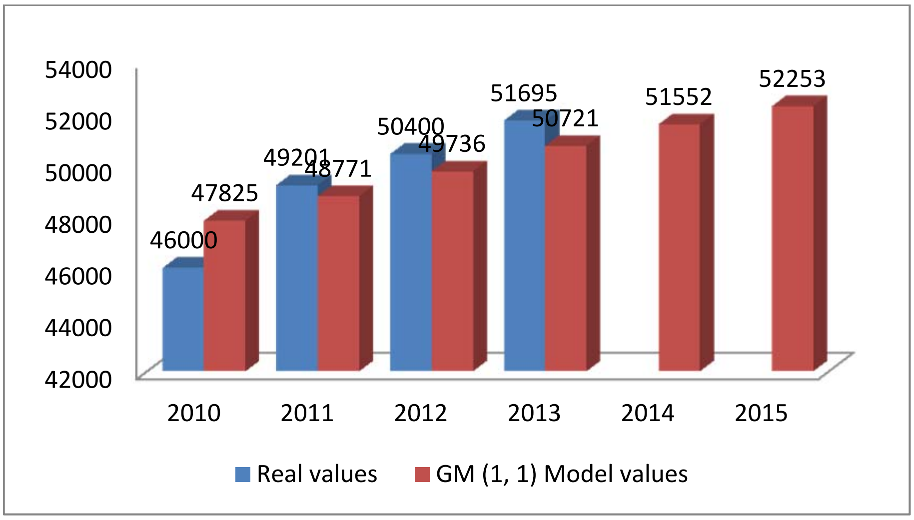

Figure 1. Comparison of real values and predicted values obtained from GM (1, 1) model

4. Conclusion

Committing suicide is an important issue in social context. This paper demonstrates how the grey system theory deals with prediction problem with incomplete or unknown information with large sample. In this paper, we compare the performance of the accuracy of the three grey forecasting models to predict women suicide in India. This paper demonstrates that performance of the GM (1, 1) model in prediction is better than the other two prediction models because it has the merits of both simplicity of application and high forecasting precision. Therefore, we suggest to using the GM (1, 1) model to predict the number of suicides in India and other countries for planning and other issues.

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