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Application of Holt's model to predict future maternal mortality in India

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Abstract

The technique this study established helps forecast data from Holt's method of double exponential smoothing (DES), which is used for univariate time series.Time series data on the maternal mortality rate (MMR) were obtained for this study from 2000 to 2020 (21 years). To determine the most accurate model for predicting future MMR in India, a specific model was used: Holt's model.The following predicting errors, namely mean absolute percentage error (MAPE), mean absolute deviation (MAD), and mean square deviation (MSD) were used as model selection criteria. This study shows the better performance and accuracy of the Holt model with the lowest values of MAPE = 6.172, MAD = 13.164, MSD = 244.499.Holt's model predicted India's MMR for the next 10 years. The data shows that the MMR in India will decrease in the next 10 years, from 2000 to 2030.The analysis's conclusions can help develop evidence-based plans for lowering maternal death rates and enhancing systems for maternity healthcare.

Keywords:MMR; Holt's model, MAPE, MAD, MSD.

1. Introduction

The Sustainable Development Goals (SDGs) of the United Nations, to which the Indian government is a signatory, aim to reduce the worldwide maternal mortality rate (MMR) to fewer than 70 deaths per 100,000 live births by 2030. At these regions and the national level, accurate determination of maternal mortality is required, including ensuring that Sample

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Registration System results are published on causes of mortality promptly. Unfortunately, the last Million Death Study incidence data was published in 2014. More studies are needed in Empowered Action Group states plus Assam (EAGA)states to identify maternal risk factors and effective interventions. By ensuring improvements in the EAGA states, India can accelerate overall reductions in MMR and ensure that all governments reach the 2030 SDG target and continue to improve besides that day (Meh, *et al*., 2022). Despite progress, nearly a quarter of maternal deaths worldwide occur in India. Currently, India tracks maternal mortality in 18 of its 36 states using Sample Registration Register (SRS) data. There is no reliable national data on maternal mortality in sub-countries and regions. And this is a major obstacle in local health policies and planning to prevent preventable maternal deaths. For the first time, we use triangulation of maternal mortality records under Health Management Information System, Census of India and SRS, current MMR for all states and territories of India. We also examined the social and health care correlates of MMR using quantitative and qualitative statistical tools. The findings show that 70% of districts (448 out of 640 districts) in India reported MMR of more than 70 deaths - a target set in Sustainable Development Goal 3. According to SRS, only Assam shows MMR above 200, our assessment based on HMIS shows that 6 states (and two union territories) and 128 districts with MMR above 200. There is variation in MMR across regions of the country, with a spatial clustering of high MMR in the northeast, east, and central regions and low MMR in the southern and western regions. Better states like Kerala, Tamil Nadu, Andhra Pradesh, Karnataka and Gujarat have medium to high MMR range. In terms of importance, fertility levels, sex ratio at birth, health infrastructure, years of education, postnatal care, maternal age and nutrition, and lack of socioeconomic status has emerged as a major correlate of MMR (Goli, *et al*., 2022). Maternal and newborn health has been a priority for the Tamil Nadu government for more than a decade. This case study shows the various initiatives and initiatives taken by the government to improve maternal health, which resulted in the MMR dropping from 380 in 1993 to 90 in 2007 (Padmanaban, *et al*., 2009).

Holt's method, also known as Holt's linear trend model, is a widely used forecasting technique in time series analysis. It extends simple exponential smoothing to capture linear trends in data. This method has been further developed and adapted for various applications, including handling irregular time intervals, seasonal data, and intermittent demand.Holt's method, particularly the Holt-Winters exponential smoothing technique, is a widely used time series

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forecasting method. It is often applied to predict various types of data, including mortality rates and disease spread. This synthesis examines the effectiveness of Holt's method in forecasting deaths. When applied to forecast the spread of Covid-19 in Indonesia, the Holt-Winters method showed varying levels of accuracy. For positive cases, it produced a mean absolute percentage error (MAPE) of 9.21%, indicating good performance. However, for forecasting deaths, the MAPE was higher at 17.97%, suggesting less reliability in predicting mortality compared to other case types (Pangestu, and Andayani, 2023). This study shows that Holt's method and Single Exponential Smoothing (Bas *et al*., 2021; Wright, D. J. 1986) are statistically very effective in the case of irregularly spaced data. The main objective is to determine which method can provide a more accurate prediction between simple linear regression and linear trend (Holt *et al*., 2004). Different exponential smoothing methods were developed and evaluated to find that which is useful in predicting the population of Malaysia. (Nazem and Aftanurhan, 2014).

The primary goal of this work is to make future predictions about the MMR in India. Future MMR using Holt's model is presently receiving more and more attention and has various practical applications. Holt's model predicted India's MMR for the next 10 years. The data shows that the MMR in India will decrease in the next 10 years, from 2000 to 2030.The analysis's conclusions can help develop evidence-based plans for lowering maternal death rates and enhancing systems for maternity healthcare.

2. Methods

The current study used secondary data (time series data) on India's MMR, which was acquired from https://data.worldbank.org/indicator/SH.STA.MMRT?locations=INduring the years 2000 to 2020 (21 years). The Minitab version 16 software, and MS-Excel were used to do the data analysis.

Holt's method

Charles Holt and Peter Winters created the Holt-Winters forecasting approach for time series forecasting (Chatfield (1978)), which involves smoothing time series data before using it for prediction. Exponential smoothing is a technique of time series data, that assigns an exponentially dropping fertility rate in contrast to historical data to minimize fertility rates in the past. Apart from that, a trend change is smoothed using the α and γ smoothing parameters. Additive and multiplicative trends exist. Linear trend analysis is provided by the additive trend,

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and exponential trend analysis is provided by the multiplicative trend (Gardner 1985). Before modelling with Holt's method approach, Smoothing variables were automatically calculated with Minitab version 16 software. Simple exponential smoothing (SES) is a simpler option for data with no discernible pattern or seasonality. The SES model sits in comparison to the average prediction of past values and the technique prediction (where the future estimate is simply equal to the series' last observed value). Let the accurately assess values of the series be $Y_1, Y_2, \ldots, Y_t$. Then the prediction for

$$Y_{t+1} = \alpha Y_t + \alpha(1-\alpha)Y_{t-1} + \alpha(1-\alpha)^2 Y_{t-2} + \ldots$$

where $0 \leq \alpha \leq 1$ is the smoothing parameter. Flat predictions (all predictions following the final observation have the same value) are the result of this model. This research uses this simpler scenario as a baseline. (Holt, 2004) improved on this SES model by allowing for a trend in data (DES model). Two smoothing equations are used in this model to correct for the level and trend, respectively, and one forecast equation.The prediction is $Y_{t+h/t} = L_t + hB_t$, where the level at time t is

$$L_t = \alpha Y_t + (1-\alpha)(L_{t-1} + B_{t-1})$$

with the level's time-smoothing parameter $0 \leq \alpha \leq 1$ and trend is

$$B_t = \beta(L_t - L_{t-1}) + (1-\beta)B_{t-1}$$

with $0 \leq \beta \leq 1$ to act as the trend's smoothing parameter the latest predicted h times level the h step ahead prediction is made up of the most recent trend value that has been predicted.

3. The Accuracy Measures

The purpose of using two forecasting methods is to compare the estimates and determine which forecasting method best fits the data based on three appropriate criteria. These precision measures include the mean absolute percent error (MAPE), the mean absolute deviation (MAD), and the mean square deviation (MSD). Smaller values for all these criteria indicate a better model, and the better model has the lowest prediction error (Karim *et al*., 2010, Rani and Raza,

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2012).

The most popular method for predicting error is called the mean absolute percentage error (MAPE), perhaps because the units of the variable are scaled to percentages, which makes them simpler to comprehend. If the data do not have any extremes, it works best (and without zeros). In the evaluation of models and regression analyses, it is commonly utilized as a loss function.

$$MAPE = \frac{1}{N}\sum_{i=1}^{N} \left| \frac{y_i - \hat{y}_i}{y_i} \right| *100$$

Where

N= is the number of observations

$\hat{y}_i$= Predicted value of y

y_i = The actual value of y

MAD is the average value of the absolute difference between the actual value and the prediction of the data set is represented by the mean absolute deviation. Theresiduals of the data set are averaged out in this measurement.

$$MAD = \frac{1}{N}\sum_{i=1}^{N} |y_i - \hat{y}_i|$$

The squared difference between the data set's original and forecasted values is averaged out to get the term MSD. It computes a residual's variance.

$$MSD = \frac{1}{N}\sum_{i=1}^{N} (y_i - \hat{y}_i)^2$$

The most popular method for predicting error is called the mean absolute percentage error (MAPE), perhaps because the units of the variable are scaled to percentages, which makes them simpler to comprehend. If the data don't have any extremes, it works best (and no zeros). In the evaluation of models and regression analyses, it is commonly utilized as a loss function.

4. Results and Discussion

The problem of forecasting is to assess the accuracy of forecasts by determining key performance indicators. However, measures such asMAPE, MAD and MSD are used for prediction accuracy, as shown in [Table 1]. The model with the lowest values of these criteria is good for MMR in India.

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Table 1. lists the accurate measurements forHolt's model.

Model	Holt's method
Best parameters	**α =0.3, β =0.7**
MAPE	6.172
MAD	13.164
MSD	244.499

Table 2. shows the MMRactual and predicted made using Holt's method.

Year	MMR	Predicted MMR
2000	384	351.0087
2001	371	353.681
2002	329	355.2886
2003	315	338.2934
2004	301	317.3051
2005	286	294.9892
2006	248	272.9804
2007	234	240.9283
2008	221	212.8369
2009	207	190.9872
2010	179	174.8551
2011	170	156.033
2012	162	143.0907
2013	154	135.602
2014	135	131.8235
2015	128	124.1456
2016	121	117.4805
2017	119	111.454
2018	116	108.2202
2019	116	106.6902
2020	103	107.5743

This table shows India's actual and projected MMR using Holt's method, based on data values from 2000 to 2020.

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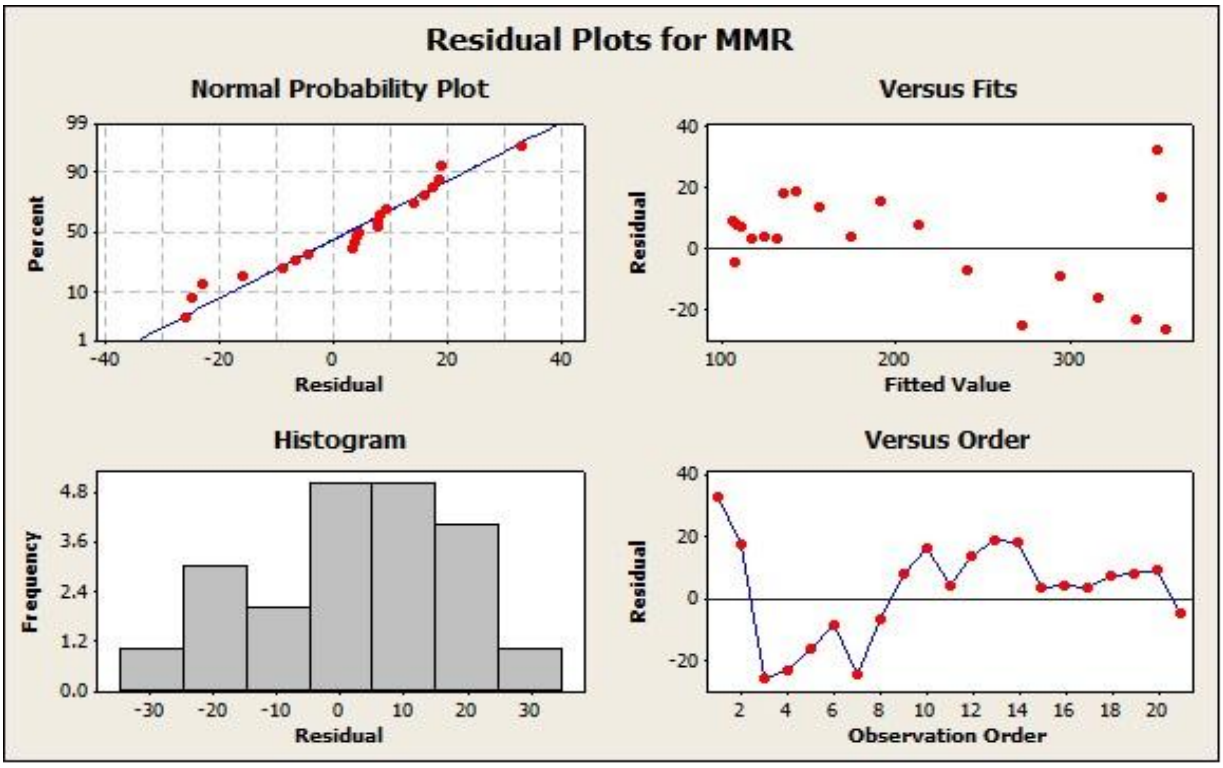

Figure. 1. Holt's model Residuals plots.

Figure.1 show that the distribution of residuals for the Holt model is statistically significant, indicating the normality of the residuals.

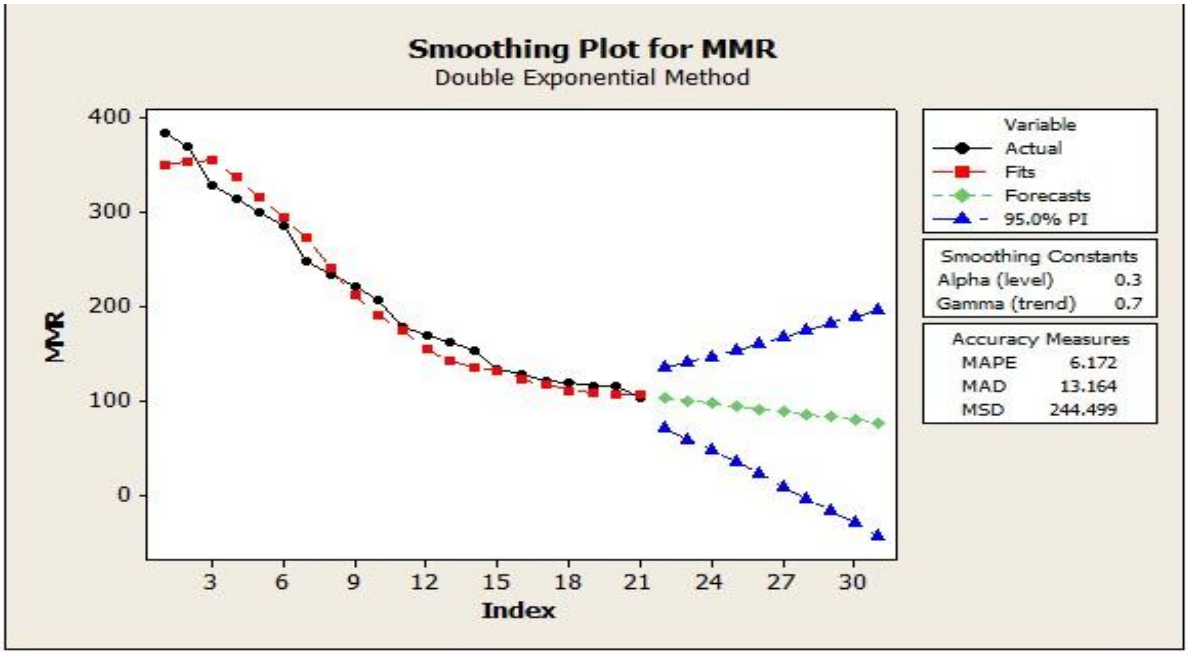

Figure. 2. MMR actual, Predicted, and future prediction plot using Holt's model in India (1950-2040).

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From [Figure 2], the predicted MMR in the model from 2000 to 2020 from the Holt model was close to the predicted and historical rates. The future prediction line (green) extends from the end of the actual line (black) and the prediction line (red) to the future of MMR in India. 10-year MMR future prediction plot [Figure 2]. Over the next decade, Holt's model predicts that India's MMR will continue to decline from 2021 to 2030.

Table 3. shows the MMR made for the next 10 years using Holt's model.

Year	Point Forecast	Lower 95% Confidence Interval	Upper 95% Confidence Interval
2021	103.3326	71.08058	135.5846
2022	100.4631	59.74456	141.1817
2023	97.59368	47.67328	147.5141
2024	94.72423	35.20681	154.2416
2025	91.85478	22.50902	161.2005
2026	88.98534	9.665858	168.3048
2027	86.11589	-3.27403	175.5058
2028	83.24644	-16.2813	182.7742
2029	80.37699	-29.3373	190.0912
2030	77.50755	-42.4295	197.4446

According to Table 3, Holt's model predicted India's MMR in the next 10 years. The data shows that the MMR in India will decrease in the next 10 years, from 2000 to 2030.

5. Conclusion

The primary goal of this work is to make future predictions about the MMR in India. Future MMR using Holt's model is presently receiving more and more attention and has various practical applications. Holt's model predicted India's MMR for the next 10 years. The data shows that the MMR in India will decrease in the next 10 years, from 2000 to 2030. The analysis's conclusions can help develop evidence-based plans for lowering maternal death rates and enhancing systems for maternity healthcare.

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References

1. Bas, E., Egrioglu, E., & Yolcu, U. (2021). Bootstrapped Holt Method with Autoregressive Coefficients Based on Harmony Search Algorithm. *Forecasting*, *3*(4), 839-849.
2. Chatfield, C. (1978) 'The Holt-winters forecasting procedure', Applied Statistics, Vol. 27, No. 3, pp.264– 279.
3. Gardner, E. S. (1985) 'Exponential smoothing: The state of the art', Journal of Forecasting, Vol. 4, pp.1-28.
4. Goli, S., Puri, P., Salve, P. S., Pallikadavath, S., & James, K. S. (2022). Estimates and correlates of district-level maternal mortality ratio in India. *PLOS global public health*, *2*(7), e0000441.
5. Holt, C. C. (2004). Forecasting seasonals and trends by exponentially weighted moving averages. *International journal of forecasting*, *20*(1), 5-10.
6. Karim, M. R., Awal, M. A., & Akter, M. (2010). Forecasting of wheat production in Bangladesh. *Bangladesh Journal of Agricultural Research*, *35*(1), 17-28.
7. Meh, C., Sharma, A., Ram, U., Fadel, S., Correa, N., Snelgrove, J. W., ... & Jha, P. (2022). Trends in maternal mortality in India over two decades in nationally representative surveys. *BJOG: An International Journal of Obstetrics & Gynaecology*, *129*(4), 550-561.
8. Nazim, A., & Afthanorhan, A. (2014). A comparison between single exponential smoothing (SES), double exponential smoothing (DES), holt's (brown) and adaptive response rate exponential smoothing (ARRES) techniques in forecasting Malaysia population. *Global Journal of Mathematical Analysis*, *2*(4), 276-280.
9. Padmanaban, P., Raman, P. S., & Mavalankar, D. V. (2009). Innovations and challenges in reducing maternal mortality in Tamil Nadu, India. *Journal of health, population, and nutrition*, *27*(2), 202.

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10. Pangestu, A. I., & Andayani, P. (2023). Implementation of Holt-Winter Exponential Smoothing Method to ForecastThe Spread of Covid-19. *Indonesian Journal of Mathematics and Applications*, *1*(2), 13-24.
11. Rani, S., & Raza, I. (2012). Comparison of trend analysis and double exponential smoothing methods for price estimation of major pulses in Pakistan. *Pakistan Journal of Agricultural Research*, *25*(3).
12. WHO. Strategies toward ending preventable maternal mortality (EPMM) [Internet]. Geneva, Switzerland: World Health Organization; 2015[http://www.who.int/reproductivehealth/ topics/maternal_perina tal/epmm/en/]. Accessed 24 September 2020.
13. Wright, D. J. (1986). Forecasting data published at irregular time intervals using an extension of Holt's method. *Management science*, *32*(4), 499-510.