

APPLICATION OF HOLT'S LINEAR METHOD IN THE CALCULATION OF FUTURE VALUES OF ANNUAL MATERNAL MORTALITY RATE FOR INDIA

Smartson. P. NYONI ¹,

Thabani NYONI ²

¹Independent Researcher & Medical Doctor, Harare, Zimbabwe

²Independent Researcher & Health Economist, Harare, Zimbabwe

ABSTRACT

This study uses annual time series data on MMR for India from 1985 to 2023 to predict future trends of MMR over the period 2024 to 2035. The study utilizes Holt's double exponential smoothing model. The optimal values of smoothing constants α and β are 0.7 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will drop to levels below 10 deaths per 100 000 live births by 2035. Therefore, we encourage authorities to attend to the major drivers of avoidable maternal deaths.

Keywords: -Exponential smoothing, Forecasting, Maternal Mortality Ratio.

INTRODUCTION

The United Nations' Agenda 2030 for sustainable development, SDG 3.1 aims to reduce global maternal mortality ratio (MMR) to less 70 deaths per 100 000 live births by 2030 (WHO, 2015). The UN revealed that approximately 24 million children were born in 2017 in India, and about 35 000 mothers died during childbirth or shortly thereafter, giving an MMR of 145 per 100 000 live births (WHO, 2019). This rate accounted for 12% of global maternal deaths. According to the World Health Organization (WHO), the worldwide MMR has declined substantially from 342 in the year 2000 to 211 in 2017, reducing global maternal deaths from 451 000 to 295 000 during this period (WHO, 2019). About 40% of this absolute decline was derived from fewer maternal deaths in India (Register General India). The Sample Registration System (SRS) of India data revealed that MMR has significantly declined from 400 per 100,000 live births in the early 1990s to 230 in 2008 and 130 in 2016 (Office of the Registrar General, 2020; India Ministry of Health, 2018). Recent estimates of SRS have witnessed a steady decline in the MMR from 130 to 113 per 100,000 live births, with the highest rate in the state of Assam (215 per 100,000 live births) and lowest in the state of Kerala (43 per 100,000 live births) (Office of the Registrar General of India). In addition, available data indicates that even though the overall MMR of India has drastically fallen, the rate of decline in MMR is not uniform across the states (Horwood et al. 2020; Office of the Registrar General of India, 2020; Montgomery et al. 2014; Government of India, 2015; Jat et al. 2015; Barros et al. 2012). Empowered Action Group (EAG) states including Bihar, Madhya Pradesh, Rajasthan, Uttar Pradesh, and Assam contributed around 75% of the total estimated maternal deaths in India and Uttar Pradesh alone has above 30% of the maternal deaths (Office of Registrar General India). The objective of this paper is to model and forecast MMR for India using the double exponential smoothing technique. The findings of this paper are expected to inform policy and allocation of resources to the maternal and child health program in order to further reduce avoidable maternal deaths.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Ara et al. (2025)	to summarize the frequencies of sociodemographic characteristics, parity distribution, antenatal care patterns, and causes of death among maternal mortality	Conducted a retrospective study which analyzed maternal mortality at Rangpur Medical College Hospital, Bangladesh, in 2024, reviewing 4,741 birth records with 83 maternal deaths.	-Among 83 maternal deaths, majority of deaths occurred among women aged 16–25 (41%) and those from low socioeconomic backgrounds (72.2%). -Parity distribution showed 49.39% had 1–2 children, while 73.4% received no antenatal care (ANC), highlighting gaps in healthcare access. - Eclampsia (37.35%) and obstetric hemorrhage (26.50%) were the predominant cause of maternal deaths.
Bakshi et al. (2025)	-to review national trends in maternal mortality, using data from the Sample Registration System (SRS) and National Family Health Survey (NFHS) - to explore the relationship between improvements in the utilization of maternal healthcare services and their impact on reducing maternal mortality	Researchers examined trends in maternal mortality using nationally available datasets such as the SRS, NFHS, National Sample Survey, and government administrative records. These publicly available sources provide insight into maternal healthcare utilization patterns over time. Key indicators analyzed include antenatal care (four or more visits), skilled birth attendance, and postnatal care utilization	-India has achieved a remarkable decline in MMR over the past three decades, dropping from 570 maternal deaths per 100,000 live births in 1990 to 103 in 2019–2020 and further to 97 in 2023 - Concurrently, maternal healthcare utilization demonstrated significant improvement, with upward trends in antenatal care, institutional deliveries, and postnatal care across the country
Feng et al. (2025)	-to analyze trends (1990–2021) and projected (to 2050) MMR in Southeast Asia using the Global Burden of Disease (GBD) 2021 database and addressing gaps in regional granularity	-Data GBD 2021, covering MMR and age-standardized MMR (ASMR) for 1990–2021, stratified by country, age group, and cause -Trend assessment was conducted using the estimated annual percentage change (EAPC), while 30-year projections were generated via an autoregressive integrated moving average (ARIMA) model	The ASMR in Southeast Asia fell by 59%, dropping from 255.88 in 1990 to 104.56 per 100,000 live births by 2021. This decline was primarily driven by reduced rates of maternal hemorrhage and hypertensive disorders. Progress slowed during the 1997 Asian financial crisis yet picked up pace after 2000
Hossain et al. (2023)	To report the current level and major causes of maternal deaths in Bangladesh, focusing on care-	-analyzed data from the 2016 Bangladesh Maternal Mortality and Health Care Survey (BMMS), conducted with nationally representative	Nineteen per cent of the maternal deaths occurred at home, another 19% in-transit, almost half (49%) in a public facility, and 13% in a private hospital. Hemorrhage

	seeking practices, timing, and place of deaths	sample of 298 284 households -adapted the World Health Organization's 2014 verbal autopsy (VA) questionnaire. Trained physicians reviewed the responses and assigned the cause of death based on the International Classification of Diseases (ICD-10)	contributed to 31% and eclampsia to 23% of the maternal deaths. Twenty-one per cent of the maternal deaths occurred due to indirect causes
Jabeen et al. (2023)	To examine the current levels, trends, time of death, and care-seeking practices for hemorrhage-related maternal deaths in Bangladesh	-conducted a secondary analysis with data from the nationally representative 2001, 2010, and 2016 Bangladesh Maternal Mortality Surveys (BMMS) -The cause of death information was collected through verbal autopsy (VA) interviews using a country-adapted version of the standard World Health Organization VA questionnaire	Postpartum hemorrhage remains the primary cause of maternal mortality in Bangladesh
Singh et al. (2022)	to inform on potential options for measuring maternal mortality	Applied a case study approach to compare methodologies and estimates of pregnancy-related mortality ratio (PRMR)/maternal mortality ratio (MMR) obtained from four different data sources from similar time periods in Bangladesh, Mozambique, and Bolivia—national population census; post-census mortality survey; household sample survey; and sample vital registration system (SVRS)	For Bangladesh, PRMR from the 2011 census falls closely in line with the 2010 household survey and SVRS estimates, while SVRS' MMR estimates are closer to the PRMR estimates obtained from the household survey. Mozambique's PRMR from household survey method is comparable and shows an upward trend between 1994 and 2011, whereas the post-census mortality survey estimated a higher MMR for 2007. Bolivia's DHS and post-census mortality survey also estimated comparable MMR during 1998–2003
Goli et al. (2021)	examined socio demographic and health care correlates of MMR using large-sample and robust statistical tools	Robust statistical tools were applied	The findings suggest that 71% of districts (456 out of 640 districts) in India have reported MMR above 140 deaths-a target set under Sustainable Development Goal-3
Meh et al. (2021)	To assess national and regional trends and causes specific distribution of	Researchers analyzed trends in the maternal mortality ratio (MMR) from 1997 through 2020, estimated absolute	India could achieve the UN 2030 MMR goals if the average rate of reduction is maintained. However, without further

	maternal mortality in India	maternal deaths and examined the causes of maternal death using nationally representative data sources	intervention, the poorer states will not
Akhter, & Alam. (2019)	-to present the trends of maternal and neonatal mortality - to explain the maternal and neonatal mortality rate by background characteristics and the causes of maternal and neonatal deaths in Bangladesh on the basis of South Asian perspective	The main source of data collection and analysis was the secondary sources, from different journals and project reports published between the years 2001 to May 2018	In Bangladesh, 35% maternal deaths occurred as indirect causes and 9% causes of deaths are still remaining unidentified. hemorrhage (31%) and pre-eclampsia-eclampsia (20%) are found two vital causes of maternal deaths with two more causes which are due to obstructed labor (7%), and termination of pregnancy (1%)
Akhter et al. (2018)	to present, analyze and interrelate recent data to find barriers to achieving set MDG 5 targets by 2015	literature review has been done as a main method of data collection from Elsevier, Lancet, WHO, UNICEF, BBMS, NIPORT published from 2001 to May 2018	approximately 80% of maternal deaths could be averted if women had access to essential maternity and basic health care services

METHODOLOGY

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for India. In exponential smoothing forecasts are generated from the smoothed original series with the most recent historical values having more influence than those in the more distant past as more recent values are allocated more weights than those in the distant past. This study uses the Holt's linear method (Double exponential smoothing) because it is an appropriate technique for modeling linear data.

Holt's linear method is specified as follows:

Model equation

$$A_t = \mu_t + \rho_t t + \varepsilon_t$$

Smoothing equation

$$S_t = \alpha A_t + (1-\alpha) (S_{t-1} + b_{t-1})$$

$$0 < \alpha < 1$$

Trend estimation equation

$$b_t = \beta (S_t - S_{t-1}) + (1-\beta)b_{t-1}$$

$$0 < \beta < 1$$

Forecasting equation

$$f_{t+h} = S_t + hb_t$$

A_t is the actual value of MMR at time t

ε_t is the time varying **error term**

μ_t is the time varying mean (**level**) term

ρ_t is the time varying **slope term**

t is the trend component of the time series

S_t is the exponentially smoothed value of MMR at time t

α is the exponential smoothing constant for the data

β is the smoothing constant for trend

f_{t+h} is the h step ahead forecast

b_t is the trend estimate (slope of the trend) at time t

b_{t-1} is the trend estimate at time $t-1$

Data Issues

This study is based on annual MMR in India for the period 1985– 2023. The out-of-sample forecast covers the period 2024 – 2035. All the data employed in this research paper was gathered from the World Bank online database.

Findings of the study

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	A
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.700
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	10.039744
Sum Square Error (SSE)	13331.396170
Mean Square Error (MSE)	341.830671
Mean Percentage Error (MPE)	1.221462
Mean Absolute Percentage Error (MAPE)	5.400132

Residual Analysis for the Applied Model

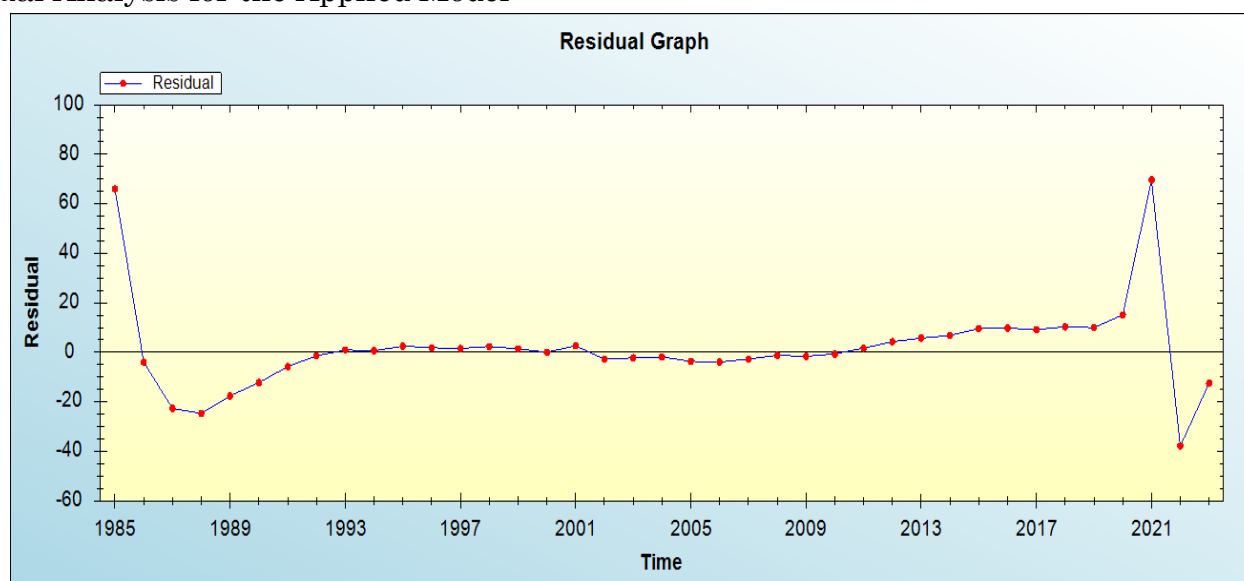


Figure 1: Residual analysis
In-sample Forecast for A

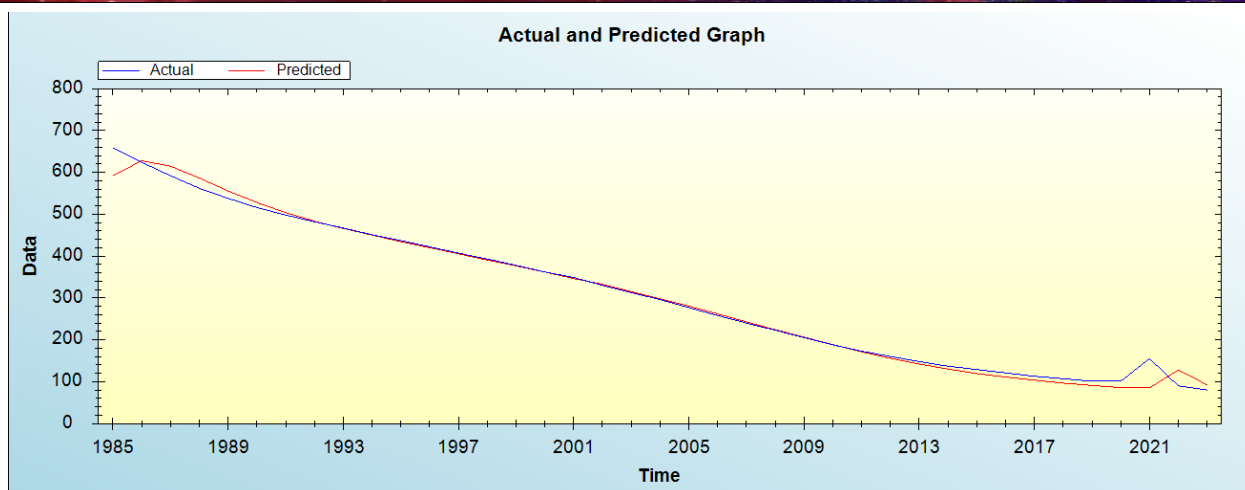


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

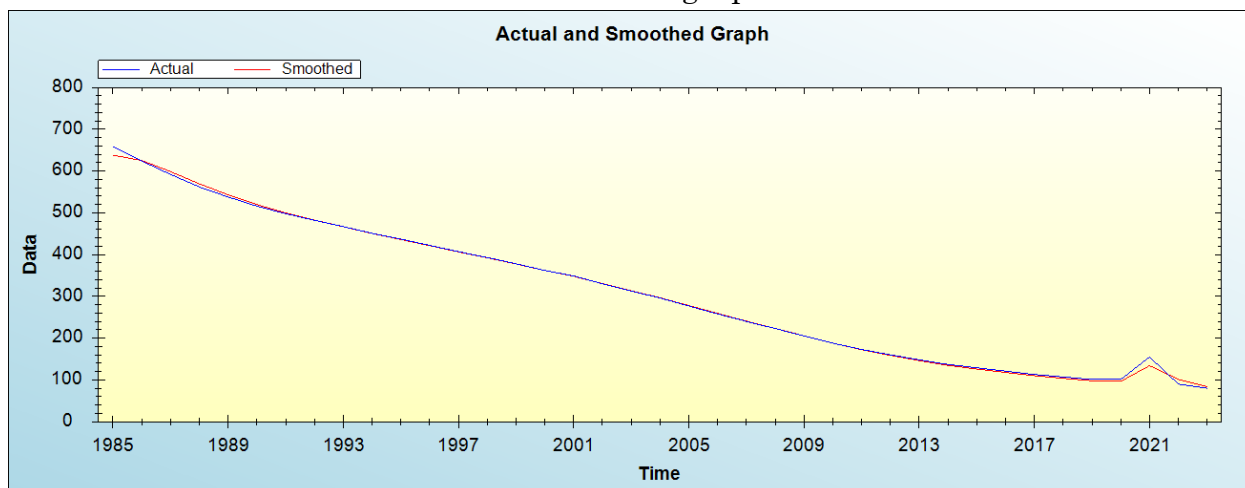


Figure 3: Actual and smoothed graph for A series

Out-of-Sample Forecast for A: Actual and Forecasted Graph

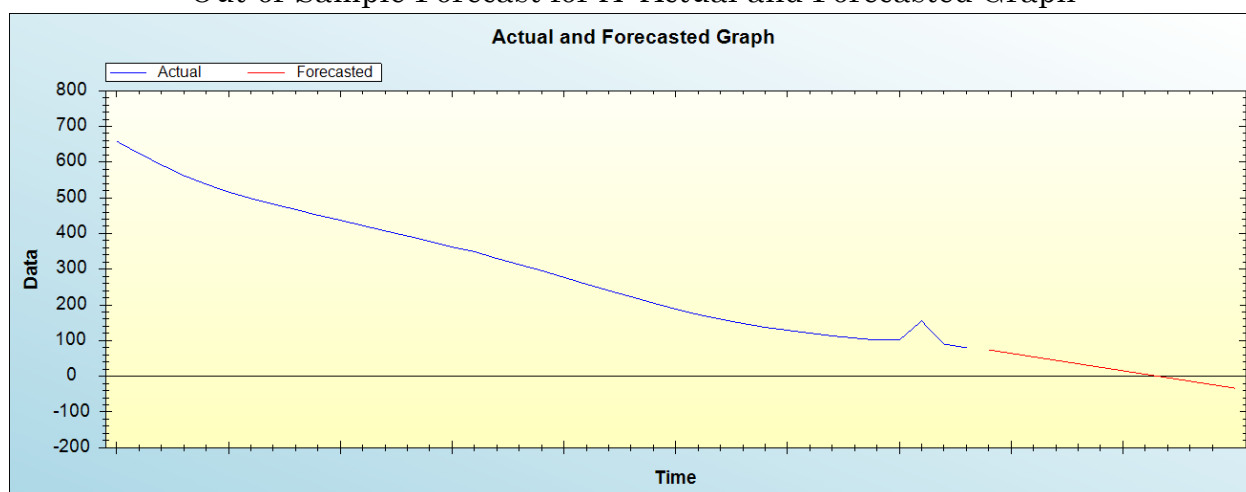


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	73.9920
2025	64.2389
2026	54.4857
2027	44.7325
2028	34.9794
2029	25.2262
2030	15.4730
2031	5.7199
2032	-4.0333
2033	-13.7865
2034	-23.5396
2035	-33.2928

The main results of the study are shown in table 1. It is clear that the model is stable as confirmed by evaluation criterion as well as the residual plot of the model shown in figure 1. It is projected that annual MMR will continue on a downward path to reach levels below 10 deaths per 100 000 live births by 2035.

RECOMMENDATIONS & CONCLUSION

The Indian government has made tremendous progress in the reduction of maternal mortality across the country. However, the reduction is not uniform some areas are still reporting high maternal mortality rates. These disparities indicate the differences in socio-economic status of different regions. In this paper, we applied the double exponential smoothing model to forecast MMR for India and the results indicate that MMR is expected to drop to levels below 10 deaths per 100 000 live births by 2035. Therefore, we implore Indian authorities to address local drivers of maternal mortality and ensure availability of medical supplies & staff at all levels of healthcare.

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