



FORECASTING MATERNAL MORTALITY FOR SOMALIA USING THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

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Abstract

This study uses annual time series data on MMR for Somalia 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 0.5 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will continue to fall but still remain very high over the out of sample period. Therefore, we encourage health authorities to adopt the suggested 5-fold policy prescription.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

The global maternal mortality ratio was reduced by nearly 50% from 515 per 100,000 live births in 1990 to 303 in 2015 (WHO, 2016). The 2014 annual global report by the Save the Children Fund, ranked Somalia at the very bottom out of 178 countries. The Maternal Mortality Rate in Somalia in 2016 stood at 732 maternal deaths per 100,000 live births, which is among the highest in the world. This maternal mortality had dropped from 1,044 in 2012 (UNICEF, 2016). According to UNICEF 2016 report Somalia has a high fertility rate of 6.6 per woman, this being the third highest rate in the world. Accordingly, the lifetime risk of maternal death in Somalia is among the world's highest, 1 in 22, exceeded by only Chad and Sierra Leone (UNICEF, 2016). Hemorrhage, eclampsia, sepsis and obstructed labor are important causes of direct obstetric deaths. Anemia is a



risk factor behind the indirect obstetric deaths. Patient factors such as delaying the decision to seek care when obstetric complications arise and health service factors were identified as common contributors to maternal death (Aden et al. 2019; De Silva et al. 2019; Sumankuuro et al. 2019; Sumankuuro et al. 2018; Yasuoka et al. 2018; Kyei-Nimakoh et al. 2017; Birmeta et al. 2013). The aim of this study is to model and forecast MMR for Somalia using the double exponential smoothing technique. The results of this study are expected to facilitate drafting and implementation of effective health interventions that will further reduce preventable maternal deaths across the country.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Osman et al. (2026)	to identify the prevalence and determinants of facility delivery among pregnant women in Somalia using data from the 2020 Somalia Demographic and Health Survey (SDHS)	cross-sectional study	Facility delivery remains low in Somalia. Wealth status, ANC attendance, and perceived distance to health facilities were key determinants of facility delivery, alongside residence type, parity, and early marriage
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.
Hussein et al. (2025)	to quantify the perinatal mortality rate (PMR) and identify key determinants within two major referral hospitals in Mogadishu	hospital-based, cross-sectional study	this study revealed a severe, localized crisis of perinatal mortality in Mogadishu, driven overwhelmingly by stillbirths
Singh & Swain (2025)	to explore the factors influencing CDMR and its effect on maternal and fetal outcomes	Prospective cohort study	The prevalence of CDMR was 21.35%, which was relatively higher than the World Health Organization's recommended guidelines
Aweis et al. (2024)	To shed light on the trends of the maternal mortality ratio (MMR) and obstetric transition in Somalia over the last two decades	This was a descriptive study comparing aggregate secondary data from the 2006 Multiple Indicator Cluster Survey and the 2020 Somali Health and Demographic Survey to show the transition	A 44% reduction of the MMR from 1044 to 692 per 100 000 live births was observed comparing the two surveys
Sheikh et al. (2024)	to investigate the factors hindering women from giving birth at healthcare facilities in major towns in Somalia, where most of the health facilities in the country are concentrated	-A community-based health survey was carried out in 11 major towns in Somalia between October and December 2021 -Applied logistic regression	The study found that home delivery is high in major towns in Somalia and is associated with a lack of understanding of the importance of health facility delivery, not using ANC, and not receiving consultancy about where to give birth



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Manamo et al. (2023)	to examine the socio-economic differentials of under-five mortality in Botswana within the framework of equality and equity	The was based on the data from 2001 and 2011 Botswana Population and Housing Censuses and the 2017 Botswana Demographic Survey. One census method was used to indirectly estimate under five mortalities for different socio-economic groups using Princeton west model life tables.	socio-economic disparities in under-five mortality disfavoring the worse-off exist in all the selected socio-economic variables
Chacha et al. (2022)	review the current cardiac obstetrics practice, gaps, and potential areas of improvement.	Systematic review	With an increasing number of women with pre-existing cardiac conditions becoming pregnant, the contribution of CVD to maternal mortality is also growing. Consequently, there is a need for accurate diagnosis and appropriate care of pregnant women with CVD to minimize adverse outcomes
Isaacson et al. (2021)	to evaluate the prevalence and outcome of twin pregnancies in Botswana	Quantitative analysis	Adverse birth outcomes are common among twins in Botswana, and are often severe
Mohamed et al. (2021)	to determine whether the health crisis in Comoros is attributable to the consequences of the chronic political instability	semi-structured interviews with key informants	political instability and lack of proper leaders' hip from the Government undermine the establishment of health policies which contributed dramatically to the



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			decline in health performance
Aden et al. (2019)	To explore and describe causes and contributing factors concerning maternal deaths in the Bosaso District, Puntland State of Somalia	Data was collected using an adapted Verbal Autopsy tool. In 2017 30 cases of maternal deaths occurring in 2016 in the Bosaso District were reviewed. Information was assessed by three independent reviewers who classified the cause of death and the contributing factors	Direct obstetric deaths accounted for 28 cases. Among these, hemorrhage was the leading cause, followed by eclampsia, sepsis and obstructed labor. Two cases were indirect obstetric deaths, caused by anemia. All three types of delay were frequent among the studied cases. Delay in deciding to seek care was found in 25 cases, delay in reaching care in 22 cases and delay in receiving health care in 24 cases
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
Oyekale et al. (2018)	To analyze the effect of maternal education and fertility on child survival in the Islands of Comoros	The 2012 Demographic and Health Survey (DHS) data were used. A two-stage probit regression method was used for data analysis	The results showed that about 75% of the children's mothers had given birth to between one and five children, while more than half did not have any form of formal education
Madzimbamuto et al. (2014)	To determine the underlying causes of maternal deaths reported in 2010, to	Case-notes for maternal deaths were reviewed by a panel of five clinicians, initially independently then discussed	The high number of contributory factors demonstrates poor quality of care even



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	categorize contributory factors and to prioritize appropriate interventions based on the identified causes, to prevent further deaths.	together to achieve consensus on assigning contributory factors, cause of death and whether each death was avoidable or not at presentation to hospital. Factors contributing to maternal deaths were categorized into organizational/management, personnel, technology/equipment/supplies, environment and barriers to accessing healthcare	where deaths were not avoidable: 14/23 (61%) of direct deaths were considered avoidable compared to 12/32 (38%) indirect deaths. Highest ranking categories were: failure to recognize seriousness of patients' condition (71% of cases); lack of knowledge (67%); failure to follow recommended practice (53%); lack of or failure to implement policies, protocols and guidelines (44%); and poor organizational arrangements (35%). Half the deaths had some barrier to accessing health services
Alvarez et al. (2009)	to describe and determine different factors associated with the maternal mortality ratio in Sub Saharan countries	An ecological multi-group study compared variables between many countries in Sub Saharan Africa using data collected between 1997 and 2006. The dependent variable was the maternal mortality ratio, and Health care system-related, educational and economic indicators were the independent variables. Information sources included the WHO, World Bank, UNICEF and UNDP	Education and an effective and efficient health system, especially during pregnancy and delivery, are strongly related to maternal death



Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Somalia. 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

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

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 Somalia 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	0.500
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	32.608236
Sum Square Error (SSE)	74166.105339
Mean Square Error (MSE)	1901.695009
Mean Percentage Error (MPE)	-0.450551
Mean Absolute Percentage Error (MAPE)	3.396981

Residual Analysis for the Applied Model

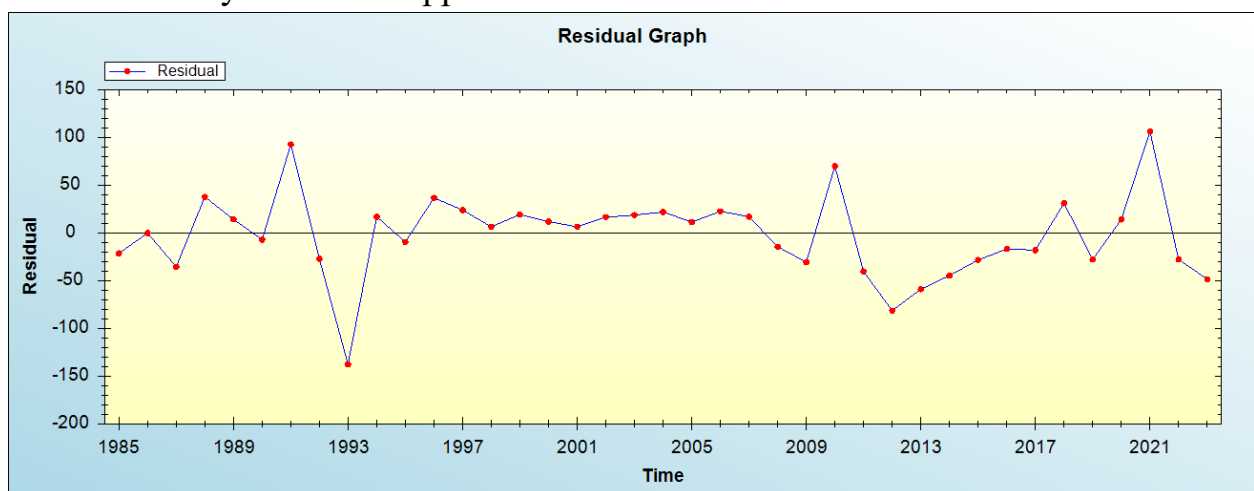


Figure 1: Residual analysis



In-sample Forecast for A

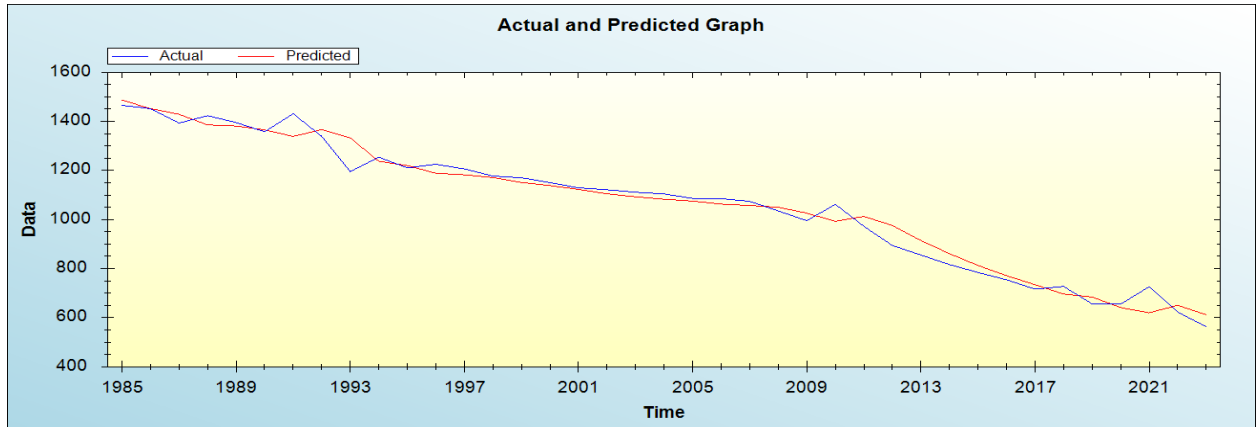


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

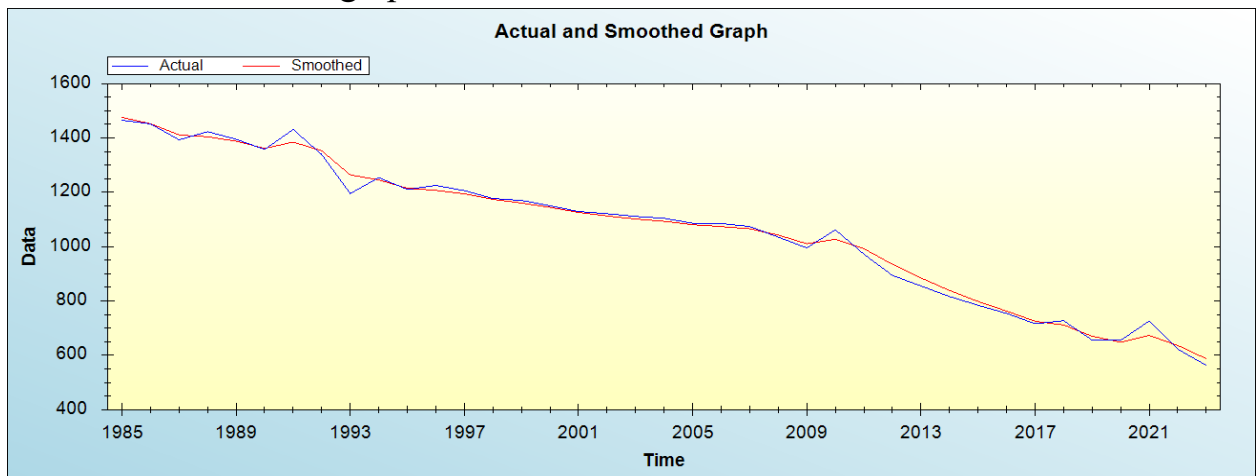


Figure 3: Actual and smoothed graph for A series

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

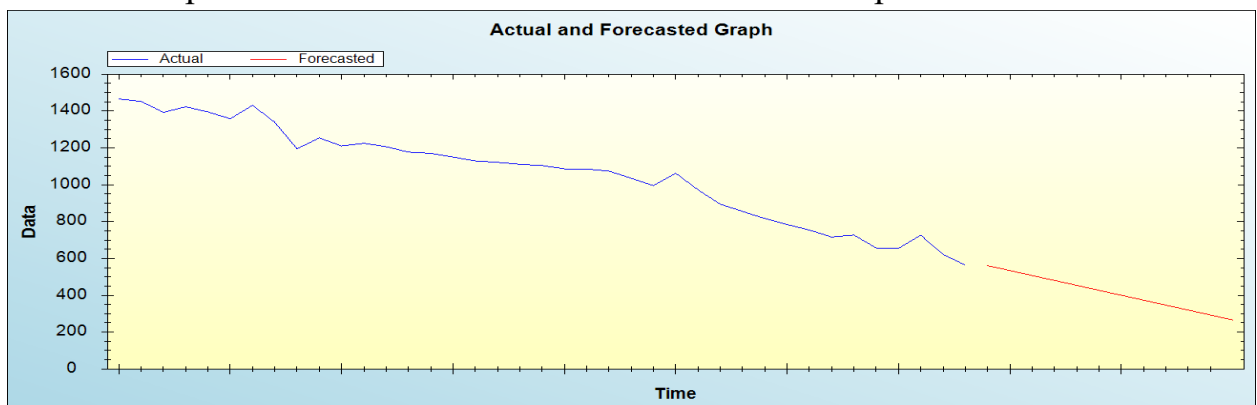


Figure 4: Out-of-sample forecast for A: actual and forecasted graph



Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	560.5411
2025	533.7691
2026	506.9972
2027	480.2253
2028	453.4533
2029	426.6814
2030	399.9094
2031	373.1375
2032	346.3655
2033	319.5936
2034	292.8216
2035	266.0497

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 to fall but still remain very high over the out of sample period.

Recommendations & Conclusion

High maternal mortality rates in Somalia indicate the presence of unattended challenges along the continuum of care. Patient factors such as delaying the decision to seek care when obstetric complications arise and health service factors were identified as common contributors to maternal death. In this study we applied the double exponential smoothing technique to model and forecast MMR and findings indicate that MMR will continue to fall but still remain very high over the out of sample period. Hence, we implore health authorities to adopt the following policy prescription: (1) end teenage pregnancy by enforcing laws that prohibit early child marriage, promote female education and comprehensive sexual and reproductive health education in schools (2) Improve coverage of maternal and child health services across the country (3) conduct routine quality improvement activities (4) ensure availability of adequate medical supplies and



medical staff in all medical facilities and (5) creating posts for obstetricians at government general or district hospitals particularly at high volume sites so that specialist services are accessed at the first referral level. Alternatively, Registrars undergoing Obstetrics & Gynecology training can be attached at high volume district hospitals under the supervision of provincial consultants.

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