

Analyzing Maternal Mortality For Eritrea Using The Double Exponential Smoothing Technique

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Abstract
This study uses annual time series data on MMR for Eritrea 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 0.9 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will continue to fall to levels around 60 deaths per 100 000 live births by 2035. Therefore, we encourage authorities to address local factors associated with maternal mortality and focus on quality improvement initiatives.

Keyword(s): - Exponential smoothing, Forecasting, Maternal Mortality Ratio

Introduction

Sustainable Development Goal 3.1 encourages all UN member countries to lower maternal mortality rate (MMR) to less than 70 per 100,000 live births by 2030 (UN, 2015). This can be achieved by effective utilization of locally available resources and implementation of targeted evidence-based health care interventions. The set UN target of below 70 maternal deaths per 100 000 live births by the end of 2030 has not been easy to achieve as available data indicates that the majority of low-middle income countries are still far away from reaching the target (Zewde, 2024). Even though the global maternal mortality rate fell from 442 to 211 per 100,000 live births within the past twenty years, the number of maternal deaths is still high in most developing countries. Sub-Saharan Africa countries bear the highest burden of maternal mortality contributing to 66%of the total maternal deaths reported globally (WHO, 2019). The high burden of adverse maternal outcomes in some resource-poor areas of the world is a clear indication of the inequalities in health service access, and highlights the gap between the rich and poor. The causes of maternal mortality are usually preventable. They include obstetric bleeding, infections, pre-eclampsia/eclampsia, and unsafe abortion) accounting for 80% of all maternal deaths (WHO, 2019). Most maternal deaths are avoidable since there are well-established healthcare solutions to prevent and manage obstetric complications (WHO, 2015). Unfortunately, the majority of maternal deaths that occur in developing countries are largely avoidable hence corrective measures must be put into place to control the scourge (Benimana et al. 2018; Liang et al. 2011).

The purpose of this paper is to model and forecast MMR for Eritrea using the double exponential smoothing technique. The findings of this paper will inform policy and allocation of resources to the health sector.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
Compaoré et al. (2025)	to determine the frequencies and causes of severe maternal outcomes (SMO: MNM + MD)	Between 1st February 2008 and 31st October 2010, we conducted an SMO incidence study in 36	-At the time of our study the burden of severe maternal outcomes was high in

	in regional and district hospitals in Benin, Burkina Faso and Niger	hospitals in the three countries	Benin, Burkina Faso and Niger. -most women had a near miss complication on admission to a participating hospital, indicating the need to facilitate access to obstetric care for women with high-risk pregnancies and complications
Kawuki et al. (2025)	examines the relationship between maternal mass media exposure and two critical child health indicators: morbidity and mortality	This secondary analysis of the 2017/2018 Benin Demographic and Health Survey (BDHS) included 13,851 women. Childhood morbidity (fever, cough, and diarrhea) and mortality were analyzed as outcomes. Bivariable and multivariable logistic regression and Cox regression models were applied, and results were expressed as odds ratios (OR), hazard ratios (HR), and their adjusted counterparts	Maternal exposure to mass media, particularly radio and television, was associated with increased childhood morbidity. This association could reflect heightened maternal health awareness, leading to increased reporting of symptoms or exposure to misleading health information through media content
Harsono et al. (2024)	to identify structural barriers to maternal care during the early adaptation of the mobile Medical Information Service via Telephone (mMIST) program in Cameroon	conducted in-depth interviews and focus groups with 56 key stakeholders including previously and currently pregnant women, primary healthcare providers, administrators, and representatives of the	Dynamic inter-relations among structural level factors create barriers to maternity care in Cameroon

		Ministry of Health, recruited by purposive sampling. Thematic coding and analysis via modified grounded theory approach were conducted using NVivo12 software	
Birabwa et al. (2024)	To describe the trends in IMMR between 2016 and 2021, and the causes and characteristics of maternal deaths in Kampala, Uganda	-retrospective study utilized routine data from all facilities in Kampala that provided childbirth services from 2016 to 2021. -conducted descriptive analysis and assessed time trends in IMMR	IMMR in Kampala increased from 2019-2021. Health infrastructure changes and maternal health initiatives potentially accounted for the observed trend by affecting data quality. Referral and facility readiness were underlying reasons for maternal deaths
Zewde (2024)	to identify determinants of SMO (severe maternal outcome) among women admitted to Keren Provincial Referral Hospital	unmatched case-control study	lack of ANC follow-up, caesarean section in the current pregnancy, referral from lower facilities, distance from nearest health facility, history of anemia and previous caesarean section were associated with SMO
Agballa et al. (2023)	to determine the hospital-based maternal mortality ratio and factors associated with maternal deaths	conducted a case-control study over two years from 1st January 2020 to 31 December 2021 in four Cotonou hospitals. It included 264 maternal deaths (case) matched to 264 controls by delivery mode. The dependent variable was the status at discharge. Independent variables	The hospital-based maternal mortality ratio was 1403 deaths per 100,000 live births. Age superior than or equal to 30 years old (OR= 3.09; 95% CI= 1.52 to 6.41; p=0.002), admission by a referral from public health facility (OR=4.26; 95% CI= 2.60-7.10; or private health facility (OR=

		included socio-demographic characteristics, gynecologic information, medical and gynecologic history as well as type of complications. Univariate and multivariate analysis were performed to identify the factors associated with maternal deaths	4.52; 95% CI= 2.49-8.38 ; gestational age less than or equal to 31 weeks (OR=3.77; 95% CI= 2.13 to 6.84 ; occurrence of non-infectious (OR= 1.94; 95% CI= 1.27 to 2.97; p= 0.002) and fetal complications (OR= 1.98; 95% CI= 1.13 to 3.54; p=0.018) were the factors associated to maternal deaths.
Ghebremeskel et al. (2023)	to explore maternal length of hospital stay (LOS) following childbirth and associated factors in a rural health facility in Eritrea	retrospective study	A substantial proportion of mothers stay too short post-VD to allow adequate postnatal care, which can have untoward consequences for maternal and child health
Touolak et al. (2023)	To analyze the factors associated with maternal mortality that occurred at the Gyneco-Obstetric and Pediatric Hospital of Yaounde (YGOPH) from the 1st January 2018 to the 31st December 2021.	conducted an analytical case control study with a retrospective data collection, using medical files of 210 participants (for 1 case, 2 survivors, totally 70 cases and 140 survivors). Data were collected using a questionnaire and analyzed with SPSS 25.0. A multivariate analysis was done to determine the independent factors associated with maternal mortality at YGOPH	Maternal mortality at YGOPH was explained by the following among other factors: Hypertensive disorders (AHR=3.304; P-value=0.019; 95%; CI=[1.401; 5.020]), Co-morbidities (AHR=3.01; P-value = 0.003; 95%; CI= [2.059; 3.900]), mode of delivery (AHR=2.900; P-value=0.002; 95%; CI=[4.652; 8.549]), Postpartum hemorrhage (AHR=3.700; P-value = 0.011; 95%; CI= [1.730; 4.002]), Infections

			(AHR=9.489; P-value=0.004; 95%; CI=[3.552; 12.519])
Musarandega et al. (2021)	to identify the leading causes of maternal deaths using the international classification of disease – 10th revision, for maternal mortality (ICD-MM)	Systematic literature review	Obstetric hemorrhage, hypertensive disorders in pregnancy, non-obstetric complications, and pregnancy-related infections are the leading causes of maternal deaths in SSA
Anya & Enaruna (2020)	to identify current and emerging causes of MM and to examine the recent trend in the etiology of MM University of Benin Teaching Hospital	-The case records of patients who suffered MM in the University of Benin Teaching Hospital, Benin City, Nigeria from 1st January, 2011 to 31st December, 2018 were retrospectively studied -Data on sociodemographic characteristics, clinical diagnosis, and primary cause of maternal death were extracted and analyzed	-A progressive decline in MMR was observed in the initial 5 years, with 58% reduction between 2012 (1.48%) and 2015 (0.61%). A further rise in MMR occurred in the last 3 years, climbing 53% from 2016 (0.81%) to 2018 (1.72%) -Maternal mortality occurred in 235 women during the study period, giving a MMR of 1.1% (1,114/100,000 live births). MMR among booked women of 161/100,000 live births was 6 times lower than MMR for referred women of 953/100,000 live births. Almost half (48%) of the MM occurred within 24 hours of admission to hospital, and 74.5% were postpartum. A teenager had 3-fold

			risk of mortality, age older than 35 years increased risk of dying 2-fold, and grand-multiparity conferred a 3-fold risk of mortality. Those in the lower socioeconomic class were 7 times more likely to suffer mortality
Meh et al. (2020)	To explore ratios and determinants of maternal mortality in women of childbearing age (15–49 years) and assessed differences between the North and South Cameroon	-used the Cameroon Demographic and Health Surveys (2004 and 2011) to extract a sample of 18,665 living or deceased women who had given birth -applied logistic regression	Maternal mortality ratios and determinants varied between women of childbearing age in the North and South of Cameroon
Wirsiy et al. (2019)	to assess the critical determinants of maternal mortality in Cameroon so as to facilitate inform decision making in regards to interventions on maternal health	Systematic review	Maternal age, parity, post-partum hemorrhage, unsafe abortion, domestic violence, hypertensive disorders of pregnancy, severe malaria, HIV/AIDS, inadequate antenatal care, pre-existing co-morbidities, place of delivery, education level, healthcare provider qualification, delays in arrival at health facilities, ectopic pregnancy, placenta previa, anemia, pneumonia, heart disease, number of prenatal visits
Yaya et al. (2018)	To comparatively explore the utilization	used data from two rounds of Benin	The results of multivariable logistic

	level of maternal health care, and examine disparities in the determinants of major maternal health outcomes.	Demographic and Health Survey (BDHS) to examine the utilization and disparities in factors of maternal health care indicators using logistic regression models	regression models showed disparities in maternal health care service utilization, including antenatal care, facility-based delivery, postnatal care and contraceptive use across selected maternal factors. The current BHDS showed age, region, religion was significantly associated with maternal health care services
Girum and Wasie (2017)	to identify correlates of maternal mortality in developing countries	Systematic review	Maternal mortality is correlated with multiples of socio-economic factors, health care system associated factors, disease burden and their complex interactions
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 Eritrea. 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 Eritrea 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	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	42.638999
Sum Square Error (SSE)	188088.967339
Mean Square Error (MSE)	4822.794034
Mean Percentage Error (MPE)	1.220910
Mean Absolute Percentage Error (MAPE)	5.050525

Residual Analysis for the Applied Model

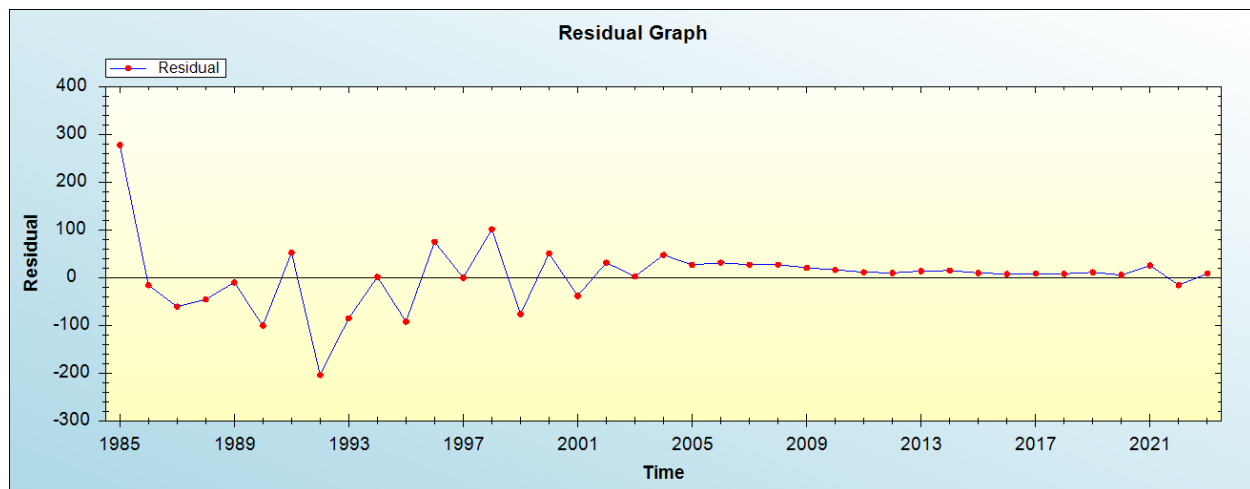


Figure 1: Residual analysis

In-sample Forecast for A

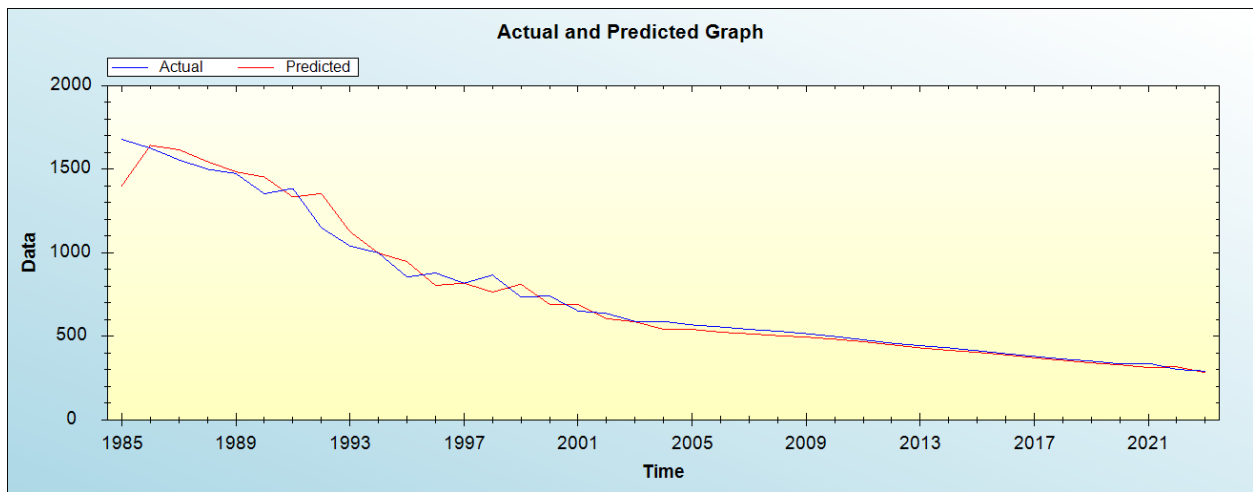


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

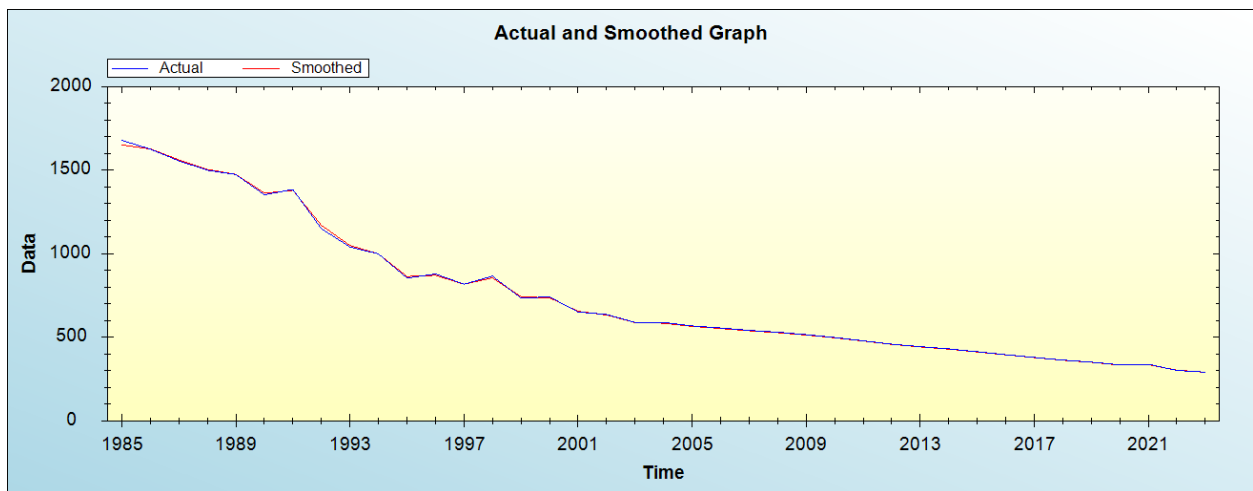


Figure 3: Actual and smoothed graph for A series

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

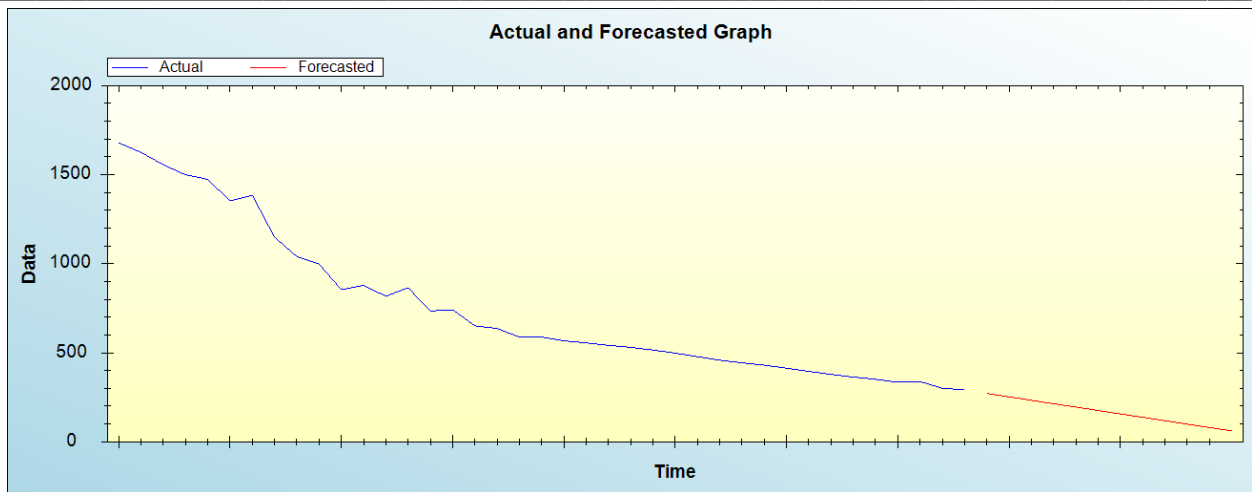


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	271.0679
2025	251.9600
2026	232.8521
2027	213.7441
2028	194.6362
2029	175.5283
2030	156.4204
2031	137.3125
2032	118.2046
2033	99.0967
2034	79.9887
2035	60.8808

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 drop to levels around 60 deaths per 100 000 live births by 2035.

Recommendations & Conclusion

Maternal mortality remains an important public health issue for developing countries. Deficiencies in the continuum of care have resulted in preventable maternal deaths. This study projects MMR for Eritrea using the double exponential smoothing method and results indicate that MMR will continue to drop to levels around 60 deaths per 100 000 live births by 2035. Therefore, we encourage health authorities to address local factors associated with maternal deaths and conduct routine quality improvement initiatives during antenatal, delivery and postnatal periods.

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