

CALCULATION OF FUTURE VALUES OF ANNUAL MATERNAL MORTALITY RATE FOR KENYA USING HOLT'S LINEAR METHOD

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ABSTRACT

This study uses annual time series data on MMR for Kenya 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 0.8 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will decline from around 143 in 2024 to about 71 deaths per 100 000 live births in 2035. Therefore, we encourage health authorities to adopt the suggested 5-fold policy prescription.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio

INTRODUCTION

Maternal mortality is a worldwide public health problem. Nearly 800 women die each day from preventable causes related to pregnancy or childbirth (WHO, 2023). This scourge affects low-middle countries more than developed countries. Hemorrhage, hypertensive disorders, and sepsis are responsible for over 50% of maternal deaths worldwide (Khan et al. 2006). Direct obstetric causes, which are preventable, account for 73-80% of maternal deaths, with indirect causes contributing to the remaining 28% (Wamalwa, 2015). According to the WHO, at the global level, the maternal mortality ratio in 2020 was estimated at 233 per 100,000 live births (WHO, 2020). However, during the recent years, a significant decline of maternal mortality ratio at the global level was noted, with a reduction of 34.3% between 2000 and 2020, an average rate of reduction of 2.9% per year (WHO, 2023; WBG, 2023; WHO, 2020). Kenya continues to experience a high MMR, despite government commitments to address the issue. Between 1990 and 2015, Kenya witnessed a minimal decrease in MMR, from 687 to 510 maternal deaths per 100,000 live births (Kenya, 2020). County-wise data is limited, but a 2014 survey estimated a lower MMR of 362 per 100,000 live births and a lifetime risk of 1 in 67 (Kenya, 2020; WHO, 2019). The objective of this paper is to model and forecast MMR for Kenya using Holt's linear method. The findings of this paper are expected to inform policy, planning and allocation of resources to the health sector.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Main finding(s)
Fatuma et al. (2025)	to determine factors associated with maternal mortality among women of reproductive age seeking care in Wajir County, Kenya	The study employed a retrospective analytical cross-sectional study design where a systematic random sampling approach was utilized to recruit respondents into the study. The Yamane formula of sample size calculation was used to recruit 359 study partakers for this study	The prevalence of maternal mortality in Wajir County was 4.2%. From this study, not utilizing emergency obstetric and newborn care services, unavailability of skilled birth attendants, and study partakers aged 18-23 years increased the odds of maternal mortality rate
Masaba et al. (2025)	to investigate the causes and determinants of maternal mortality in rural Kenya	A four-year retrospective, cross-sectional study was conducted in three tertiary hospitals within Migori county in Kenya. Data were extracted from 101 maternal mortality records from January 1, 2016 to December 31, 2019	Leading complications were hemorrhage 34.70%, eclampsia 20.80%, and sepsis 15.80%. Mothers who were unmonitored using partograph, had reactive HIV status, were in the postpartum period, were referred from periphery facilities, and low socioeconomic levels were most vulnerable
Mwaura et al. (2024)	To develop a novel model to predict maternal mortality rates in Kenya	-utilized DHS surveys from several Sub-Saharan African countries to estimate parameters for predicting Kenya's maternal mortality rate (MMR) in the absence of recent Kenya Demographic and Health Survey (KDHS) data -Researchers then developed a multiple linear regression model using supervised machine learning using the R-programming suite	Although MMR in Kenya displayed a general downward trend, the new model's estimates for DHS 2022 indicated an increase compared to the 2019 National Census and Housing Survey estimate of 355 deaths per 100,000 live births
Awe et al. (2023)	to fill a crucial gap in understanding the dynamics of maternal mortality in Kenya, post-devolution	The study spans all the 47 counties of the Republic of Kenya, using county as the unit of analysis. Maternal Mortality Ratio (MMR) data was extracted from the District Health Information Software (DHIS), which was created to evaluate the level of progress in coverage of RMHCAH service in Kenya. Changes in the MMR Indicator was modelled over time using	There was an average reduction in the MMR, which decreased from approximately 170 to 130 per 100,000 live births between 2012 and 2018. There was a steady decrease in MMR in Garisa, Mombasa, Busia, Elgeyo, Samburu and Uasin

		Repeated measures one-way ANOVA in the 47 counties in Kenya	
Masaba and Mmusi-Phetoe (2023)	to develop a strategy for reducing the maternal mortality ratio (MMR) in Migori, Kenya	An explanatory sequential mixed methods design was utilized	The strategy for implementation considered three strategic areas, namely, interventions targeting first delays, interventions targeting second delays, interventions targeting third delays
Nduati (2023)	to determine the factors associated with severe maternal morbidity and its prevalence at Kenyatta National Hospital	analytical cross-sectional quantitative study	The prevalence of severe maternal morbidity during the one month of this study was at 36.1%. The factors that were associated with the occurrence of a severe maternal morbidity were: husband's education; being married; being referred from another facility; having a pre-existing condition; experiencing a complication postnatally; stillbirth outcome and delivery via caesarean section
Masaba et al. (2022)	to explore and describe the experiences of midwives on maternal deaths that are associated with the healthcare system and client failures in Migori, Kenya	An explanatory, qualitative approach method was adopted. In-depth interviews were conducted with the purposively selected midwives working in peripartum units of the three sampled hospitals within Migori County in Kenya	Identified sub-themes: sub-optimal care, staff inadequacy, theatre delays, lack of blood and essential drugs, non-adherence to protocols, staff shortage, inadequate equipment and supplies, unavailable ICU wards, clients' ANC non-adherence
Yaya et al. (2021)	To examine the spatial distribution of maternal mortality in Africa and explored the influence of SDoH on the spatial distribution.	used country-level secondary data of 54 African countries collected between 2006 and 2018 from three databases namely, World Development Indicator, WHO's Global Health Observatory Data and Human Development Report. We performed descriptive analyses, presented in tables and maps	the average prevalence of maternal mortality ratio (MMR) in Africa was 415 per 100 000 live births. Findings from the spatial analyses showed clusters (hotspots) of MMR with seven countries (Guinea-Bissau, Guinea, Sierra Leone, Cote d'Ivoire, Chad and Cameroon, Mauritania), all within the Middle and West Africa

METHODOLOGY

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

K_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 Kenya 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	K
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.800
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	56.565562
Sum Square Error (SSE)	685718.511299
Mean Square Error (MSE)	17582.525931
Mean Percentage Error (MPE)	3.007074
Mean Absolute Percentage Error (MAPE)	11.263606

Residual Analysis for the Applied Model

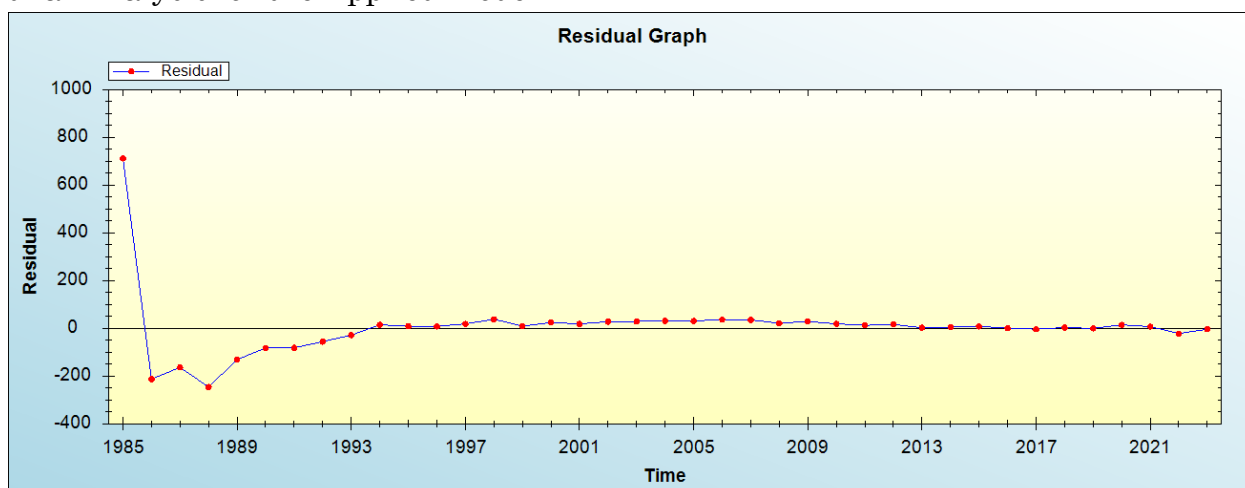


Figure 1: Residual analysis

In-sample Forecast for K

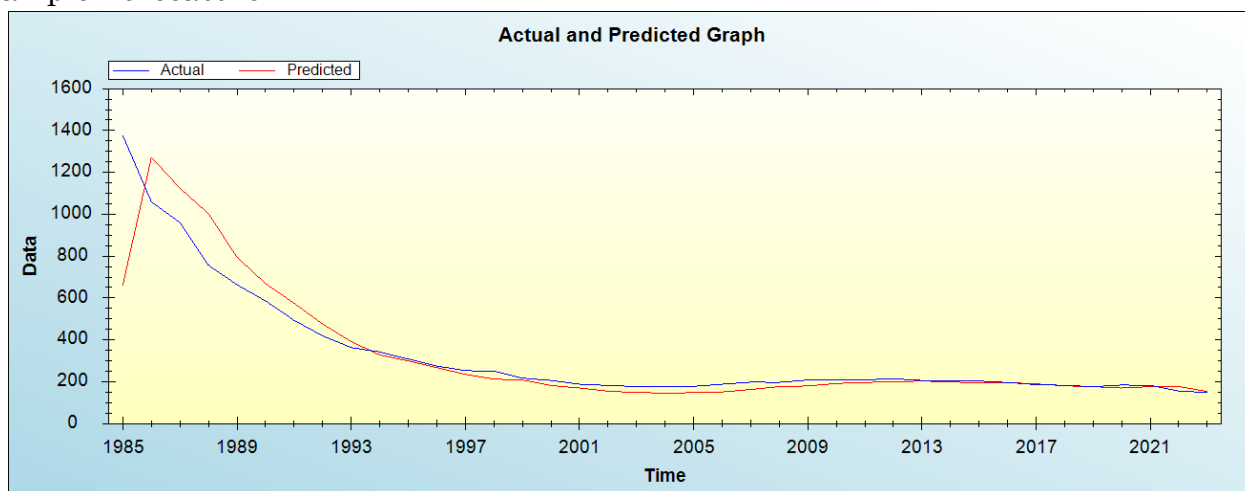


Figure 2: In-sample forecast for the K series

Actual and Smoothed graph for K series

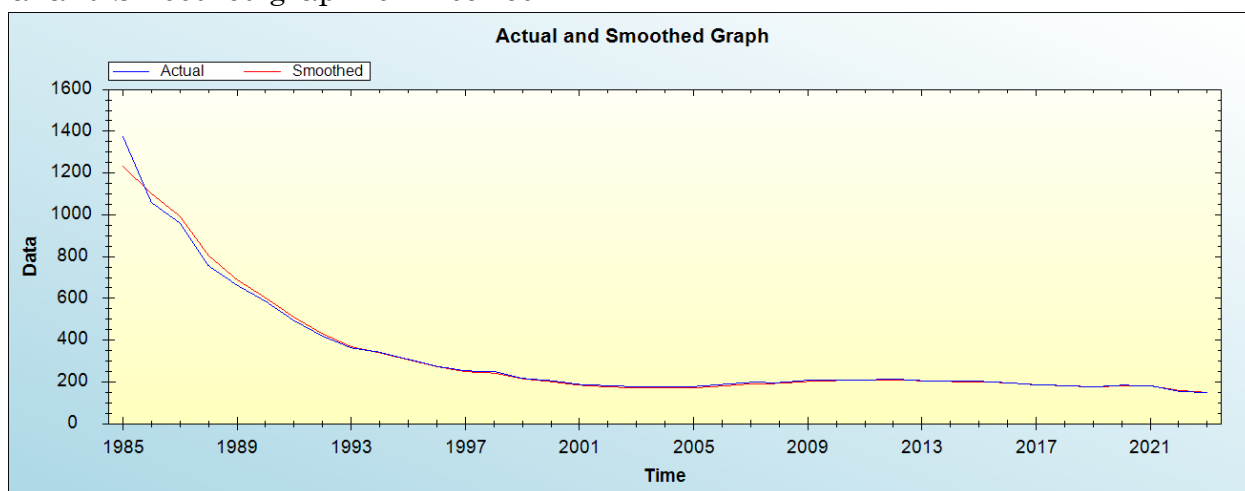


Figure 3: Actual and smoothed graph for K series

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

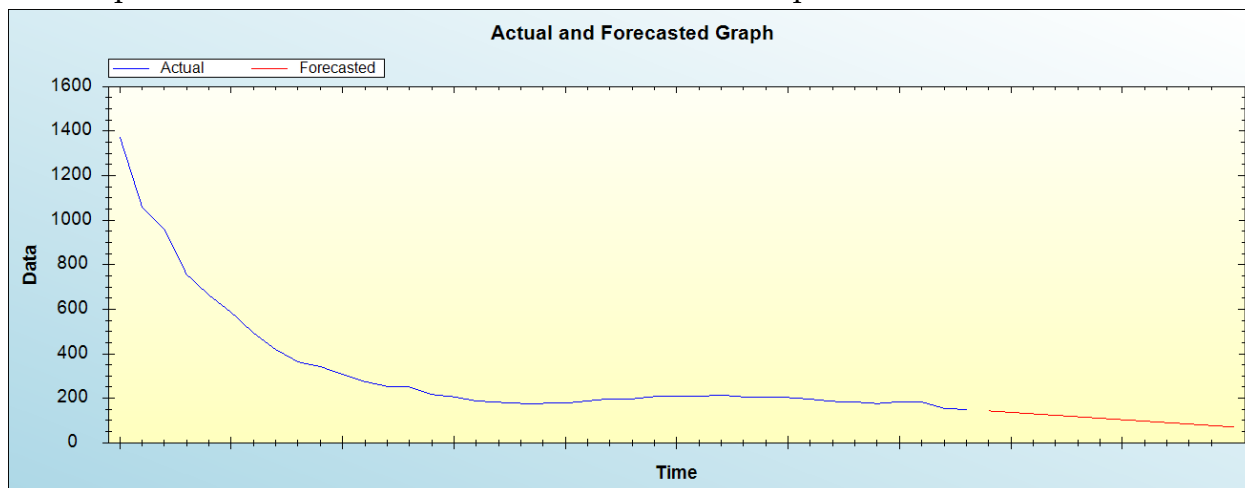


Figure 4: Out-of-sample forecast for K: actual and forecasted graph

Out-of-Sample Forecast for K: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	143.2659
2025	136.6924
2026	130.1190
2027	123.5455
2028	116.9720
2029	110.3986
2030	103.8251
2031	97.2517
2032	90.6782
2033	84.1048
2034	77.5313
2035	70.9578

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 decline from around 143 in 2024 to about 71 deaths per 100 000 live births in 2035.

RECOMMENDATIONS & CONCLUSION

Kenya continues to bear a huge burden of maternal mortality. This paper utilized Holt's linear method to forecast MMR and findings suggest that MMR will decline from around 143 in 2024 to about 71 deaths per 100 000 live births by 2035. Therefore, we implore Kenyan health authorities to adopt the following policy prescription: (1) end adolescent 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) improve quality of maternity services (4) ensure availability of adequate medical supplies and medical staff in all medical facilities and (5) Establish 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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