

PREDICTION OF EXPECTED FUTURE VALUES OF ANNUAL MATERNAL MORTALITY RATE FOR MAURITANIA USING HOLT'S LINEAR METHOD

Smartson. P. NYONI¹,

Thabani NYONI²

¹Independent Researcher & Medical Doctor, Harare, Zimbabwe

²Independent Researcher & Health Economist, Harare, Zimbabwe

ABSTRACT

This study uses annual time series data on MMR for Mauritania 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 but still remain very high over the out of sample period. Therefore, we encourage authorities to adopt the suggested 6-fold policy prescription.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

INTRODUCTION

Every day, close to 830 women die from avoidable causes associated with pregnancy or childbirth globally (WHO, 2018). The majority of maternal deaths are reported in developing countries (WHO, 2018), and 65% of these deaths are documented in sub-Saharan Africa (WHO, 2019). Achieving the third sustainable development goal (SDG-3.1) which focuses on lowering the global maternal mortality ratio to levels below 70 deaths per 100,000 live births by 2030 remains challenging in sub-Saharan Africa (WHO, 2019). Data indicates that maternal mortality ratios are highest where skilled birth attendance is the lowest (WHO, 2019). Most maternal deaths are reported during the intrapartum and peripartum periods (Ahmed et al. 2018; Merdad et al. 2018) highlighting the significance of early access to quality health services for birth and postpartum care. In addition, complications during childbirth and postpartum periods are best managed and treated in well-equipped and staffed health facilities. The objective of this paper is to model and forecast MMR for Mauritania using Holt's linear method. The findings of this paper will inform policy-making, planning and allocation resources to the maternal and child health program so as to further lower preventable maternal mortality across the country.

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
Dowou et al. (2024)	To examine the factors associated with health insurance coverage among women in Mauritania using a nationally representative survey dataset	analyzed secondary data from the 2019–2021 Mauritania Demographic and Health Survey	Health insurance coverage among the women in this study was low
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 Repeated measures one-way ANOVA in the 47 counties in Kenya	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
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	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

	Kenyatta National Hospital		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
El Hassen et al. (2022)	to measure and analyze the inequality in the use of skilled birth attendance services in Mauritania	used data from Mauritania Multiple Indicator Cluster Surveys (MICS) 2007 and 2015	The concentration index for skilled birth attendance services use dropped from 0.6324 ($p < 0.001$) in 2007 to 0.5852 ($p < 0.001$) in 2015. Prenatal care, household wealth level, and rural urban residence contributed most to socioeconomic inequality
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 Mauritania. 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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

M_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 Mauritania 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	M
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	14.622231
Sum Square Error (SSE)	16948.652585
Mean Square Error (MSE)	434.580836
Mean Percentage Error (MPE)	0.282666
Mean Absolute Percentage Error (MAPE)	2.238079

Residual Analysis for the Applied Model

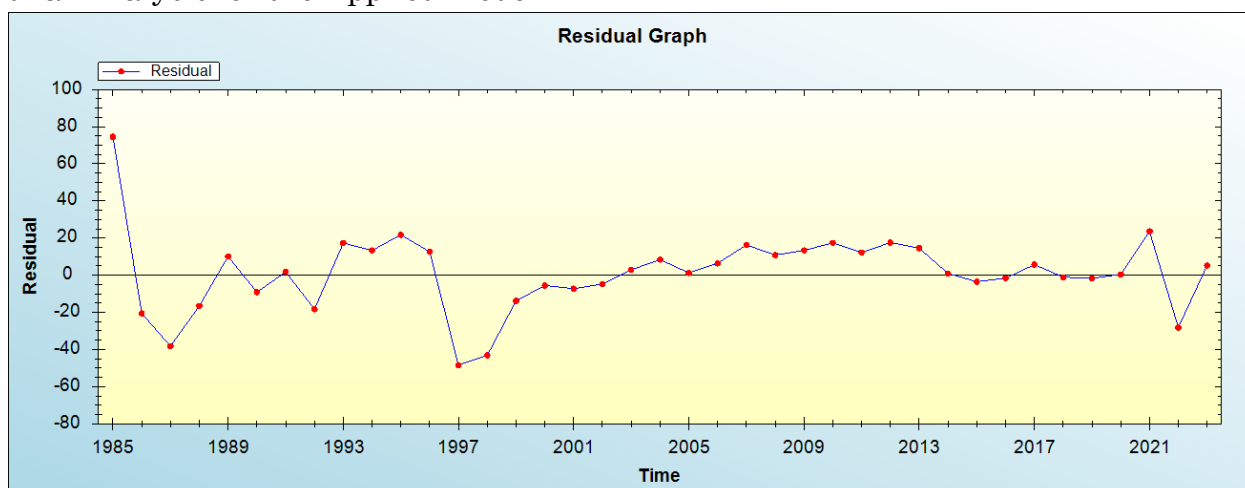


Figure 1: Residual analysis

In-sample Forecast for M

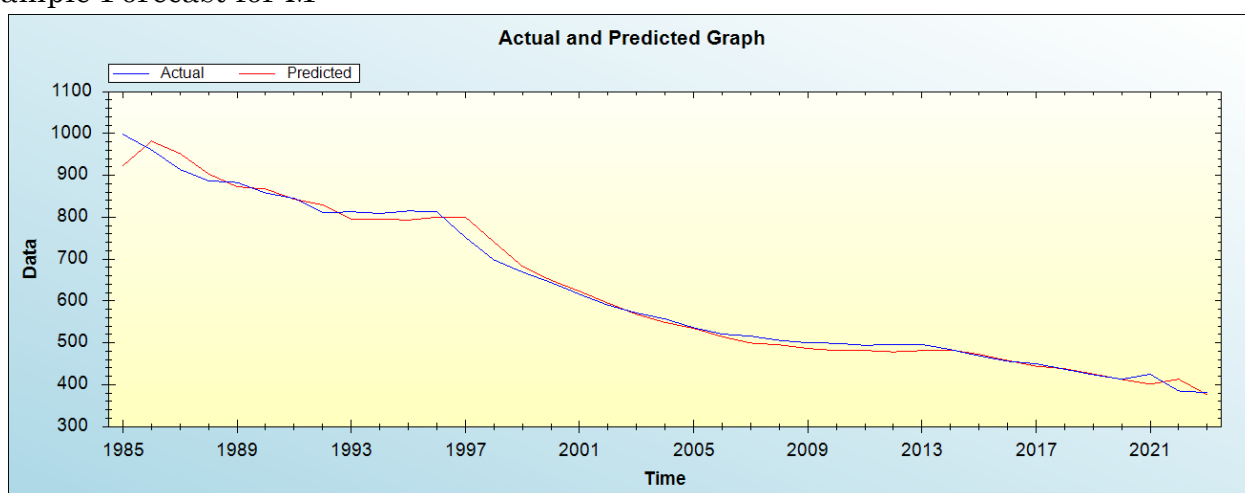


Figure 2: In-sample forecast for the M series

Actual and Smoothed graph for M series

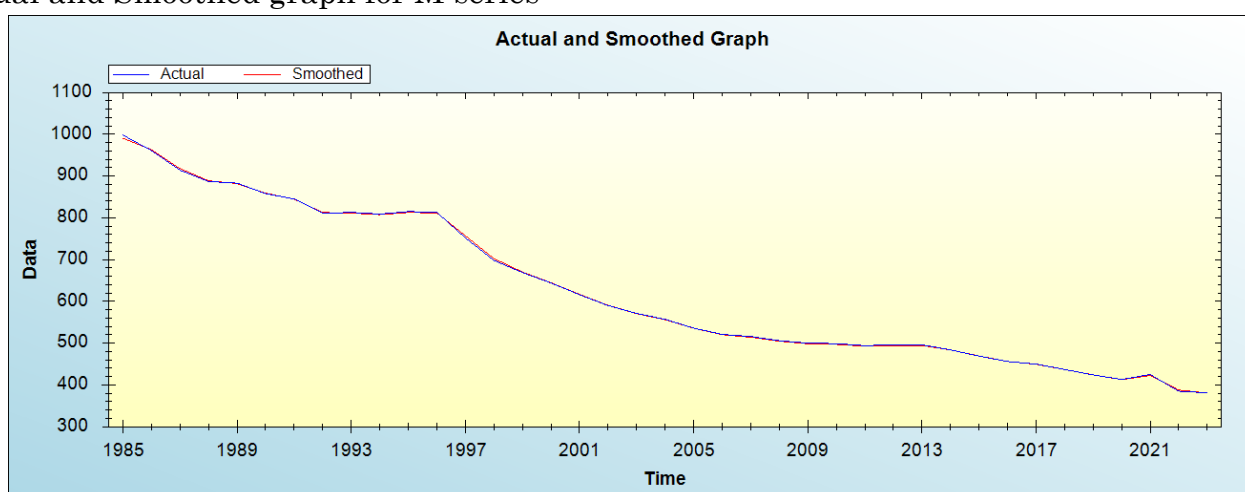


Figure 3: Actual and smoothed graph for M series

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

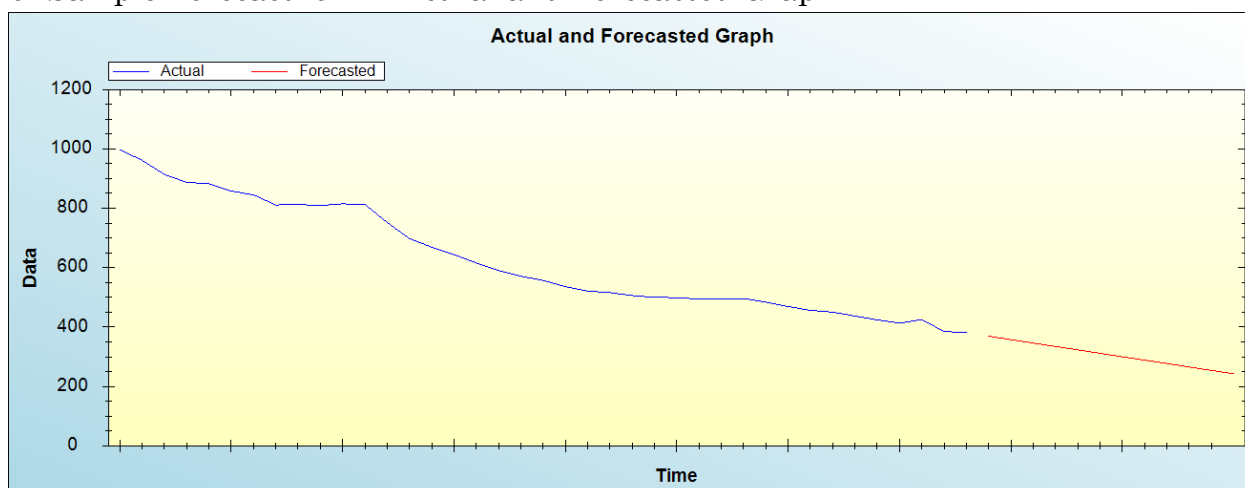


Figure 4: Out-of-sample forecast for M: actual and forecasted graph

Out-of-Sample Forecast for M: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	368.9777
2025	357.4704
2026	345.9632
2027	334.4559
2028	322.9486
2029	311.4413
2030	299.9340
2031	288.4268
2032	276.9195
2033	265.4122
2034	253.9049
2035	242.3976

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

RECOMMENDATIONS & CONCLUSION

This paper demonstrates the application of Holt's linear method to project MMR for Mauritania and results indicate that MMR will continue to drop but still remain very high over the out of sample period. Therefore, the government is encouraged to adopt the following recommendations : (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 (5) create 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 and (6) improvement of road infrastructure.

REFERENCES

1. Ahmed I., Ali S.M., Amenga-Etego S., Ariff S., Bahl R., and Baqui AH (2018). Population-based rates, timing, and causes of maternal deaths, stillbirths, and neonatal deaths in south Asia and sub-Saharan Africa: a multi-country prospective cohort study. *Lancet Glob Heal*. 6(12): e1297–308.
2. Merdad L and Ali M.M (2018). Timing of maternal death: Levels, trends, and ecological correlates using sibling data from 34 sub-Saharan African countries. *PLoS ONE*. 13(1):1–13.
3. World Health Organization (2018). Maternal mortality: Levels and trends 2000 to 2017. 2017. World Health Organization. Maternal mortality. Key facts. WHO. 2018. <https://www.who.int/news-room/fact-sheets/detail/maternal-mortality>.
4. World Health Organization (2019). The World Health Statistics 2019. Monitoring health for the SDGs. 2019. <https://apps.who.int/iris/bitstream/handle/10665/324835/9789241565707-eng.pdf?ua=1>
5. World Health Organization (WHO, 2019). SDG 3: Ensure healthy lives and promote wellbeing for all at all ages. WHO. 2019. <https://www.who.int/sdg/targets/en/>.