

PROJECTION OF ANNUAL MATERNAL MORTALITY RATE FOR LESOTHO USING THE DOUBLE EXPONENTIAL SMOOTHING 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 Lesotho 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 0.9 respectively based on minimum MSE. The results of the study indicate that MMR will continue on a downward trend but still remain high throughout 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

Maternal mortality is a global public health problem. Nearly 800 women die each day from preventable causes related to pregnancy or childbirth (WHO, 2023). This problem affects low-middle countries more than the developed countries. 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 observed, with a decline of 34.3% between 2000 and 2020, an average rate of reduction of 2.9% per year (WHO, 2023; WBG, 2023; WHO, 2020). Lesotho's maternal mortality ratio is among the highest in the Southern region at 566 per 100 000 live births (WHO) 2023). A huge proportion of these preventable deaths were from pregnancy and childbirth complications (WHO 2024). Timely antenatal care attendance within the first 16 weeks of pregnancy offers opportunity for early detection of health problems, early treatment and health education (Seidu 2021). Regardless of the knowledge about the significance of early antenatal care, only 24% of women in Lesotho attend antenatal care early (Mkandawire et al. 2021). The purpose of this study is to model and forecast future trends of MMR for Lesotho using the double exponential smoothing technique. The study findings are envisioned to inform policy making and allocation of resources to the maternal and child health program in order to further lower preventable maternal deaths across the country.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Main finding(s)
Lenkoane et al. (2025)	to explore and describe the factors motivating women to attend antenatal care services before 16 weeks gestation	qualitative, exploratory and descriptive design study	Six themes were identified as the factors motivating early antenatal attendance in Lesotho, namely 1) confirmation of pregnancy, 2) concern for fetal well-being, 3) optimizing maternal well-being, 4) awareness raising through health education, 5) motivation from family and friends and 6) cultural and social expectations
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
Nonyane et al. (2024)	To identify and describe determinants associated with avoidable perinatal deaths at a district hospital in Lesotho and strategies to curb their occurrence.	A retrospective descriptive study was conducted using 142 anonymized obstetric records from January 2018 to December 2020.	A concerning number of perinatal deaths were secondary to avoidable patient factors, namely a delay in seeking medical care, inappropriate responses to antepartum hemorrhage, and inadequate responses to poor fetal movements. Medical personnel factors are also worth observing, namely incorrect use of partograph, insufficient notes to comment on avoidable factors and 'other' medical personnel problems
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
Mohale & Nyangu (2023)	To describe the psychological experiences of midwives regarding maternal deaths at two selected public hospitals in Lesotho	A qualitative, phenomenological inquiry was employed to collect data from a purposively selected sample of 10 midwives through face-to-face interviews	Psychological experiences such as trauma, shock, fear, stress, depression, loss of trust, helplessness, bad dreams, and insomnia were reported by the midwives after the occurrence of maternal deaths. They resorted to individual coping strategies such as crying, alcohol and other substance-related use, and recreational activities
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

Teasdale et al. (2021)	To implement a rapid quality improvement project to improve ANC retention at seven health facilities in Eswatini (October-December 2017)	anonymous tablet-based audio assisted computer self-interview (ACASI) surveys	The type of rapid quality improvement intervention implemented may be useful in improving patient-provider relationships although whether it can improve retention remains unclear
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
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
Madzimbamuto et al. (2014)	To determine the underlying causes of maternal deaths reported in 2010, to categorize contributory factors and to prioritize appropriate interventions based on the identified causes, to prevent further deaths.	Case-notes for maternal deaths were reviewed by a panel of five clinicians, initially independently then discussed 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	The high number of contributory factors demonstrates poor quality of care even 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 Lesotho. 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 Lesotho 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	0.900
Forecast performance measures	
Mean Absolute Error (MAE)	57.344483
Sum Square Error (SSE)	254127.295870
Mean Square Error (MSE)	6516.084509
Mean Percentage Error (MPE)	1.198262
Mean Absolute Percentage Error (MAPE)	8.822914

Residual Analysis for the Applied Model

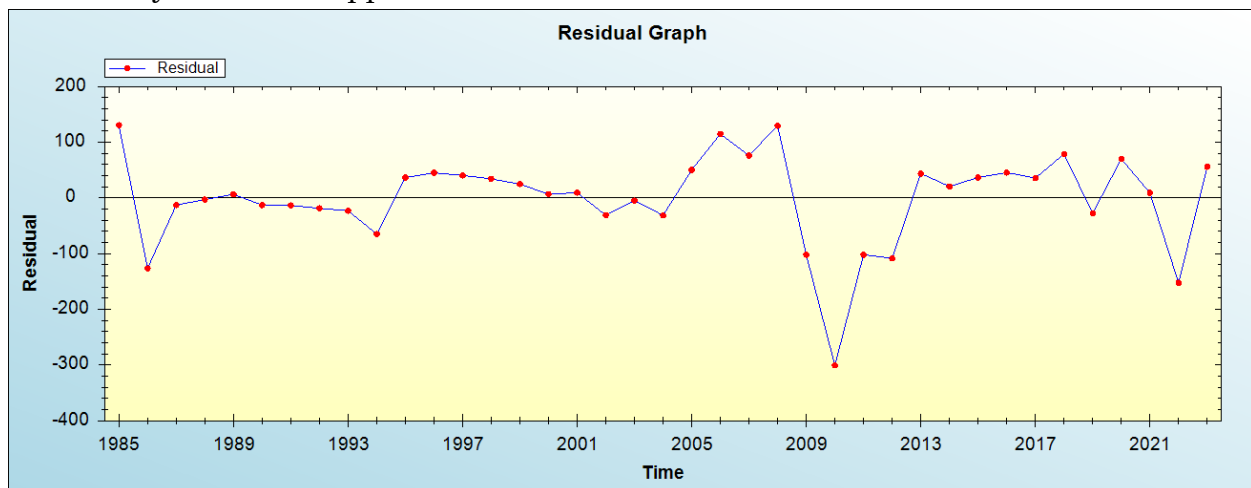


Figure 1: Residual analysis

In-sample Forecast for A

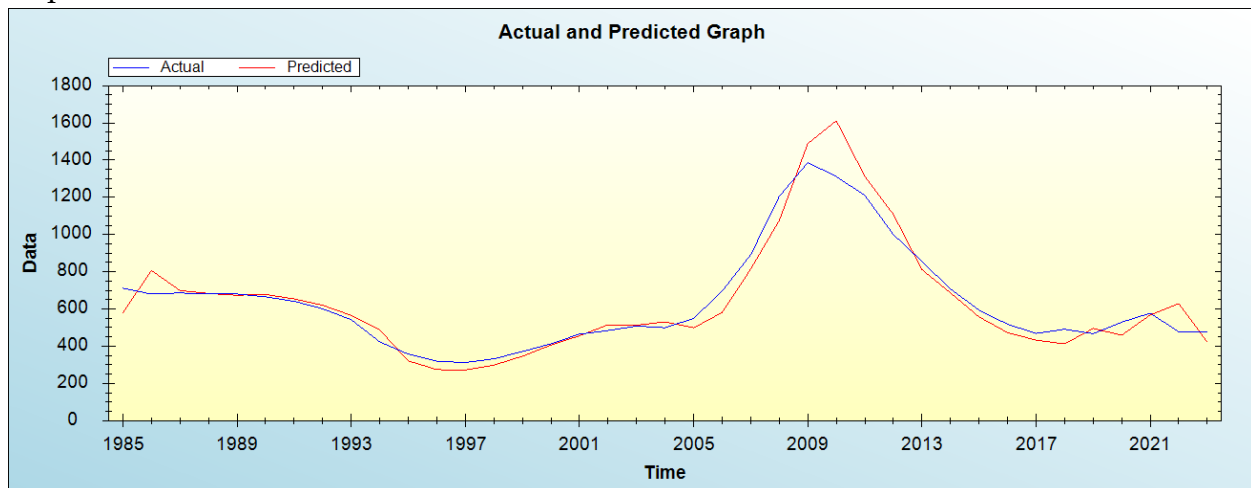


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

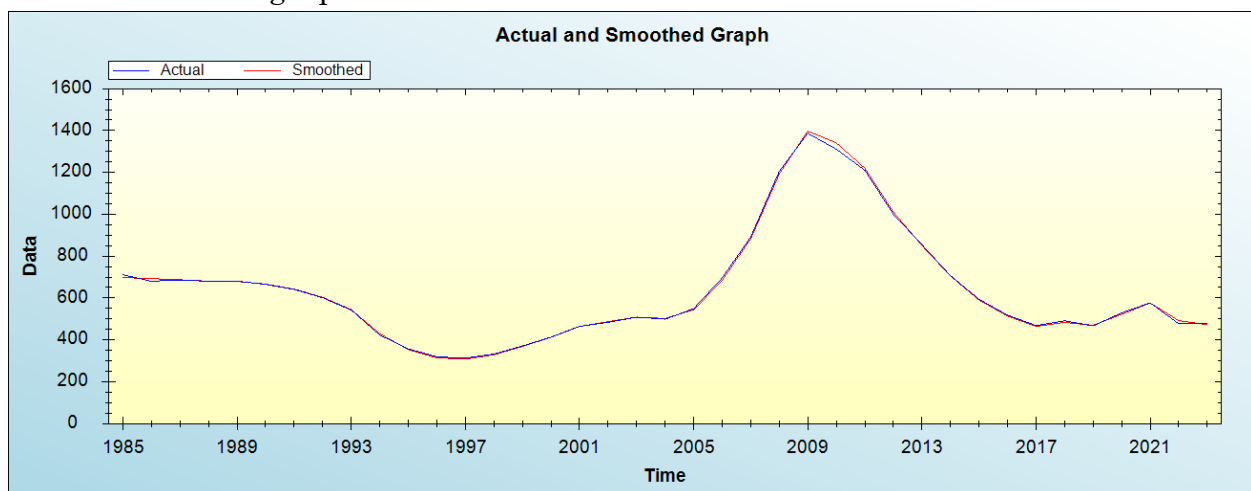


Figure 3: Actual and smoothed graph for A series

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

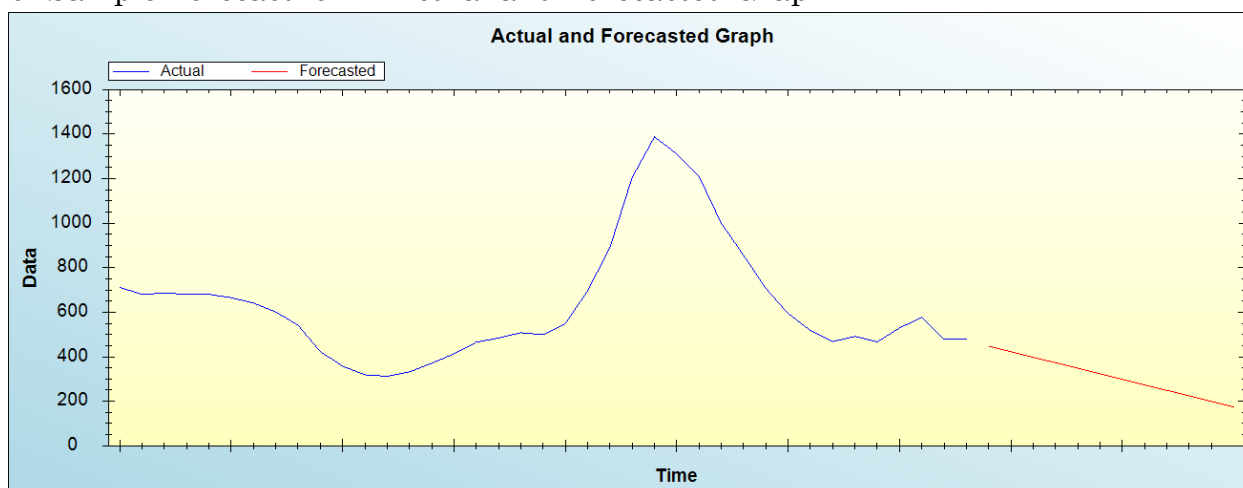


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	447.5511
2025	422.6925
2026	397.8339
2027	372.9753
2028	348.1167
2029	323.2581
2030	298.3995
2031	273.5409
2032	248.6823
2033	223.8237
2034	198.9651
2035	174.1065

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

RECOMMENDATIONS & CONCLUSION

Lesotho has a very high burden of maternal mortality reflecting existence of gaps and deficiencies in the continuum of care. Late antenatal care bookings coupled with relatively lower antenatal care coverage rates contribute significantly to avoidable maternal deaths. In this paper we apply the double exponential smoothing model to forecast MMR for Lesotho and findings indicate that MMR will continue on a downward trend but still remain high in the out of sample period. Therefore, we encourage 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) promote early antenatal bookings and 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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