

MATERNAL MORTALITY PROJECTION FOR LIBERIA USING HOLT'S LINEAR APPROACH

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ABSTRACT

This study uses annual time series data on MMR for Liberia 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 remain very high throughout the out of sample period. Therefore, we encourage health authorities to adopt the suggested 6-fold policy recommendations.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio

INTRODUCTION

Liberia is reportedly among the countries in the world with the highest maternal mortality ratios (MMR), with an unacceptable rate of over 725 deaths per 100,000 live births (WHO, 2016). Neonatal, infant and under-five mortality have gradually fallen over the previous decades, but the rates are still very high for infants and under-five children (Liberia DHS 2013). Like other post-war countries, Liberia is experiencing numerous supply side barriers such as inadequate infrastructure, lack of skilled health personnel, and medical equipment (Kentoffio et al. 2016). Low utilization of contraceptive methods and high teenage pregnancies are major drivers of maternal and neonatal deaths. Nearly 60% of neonatal deaths occur among adolescent mothers compared to about 6% for those above 19years, which highlights the need to delay child birth through access to improved sexual and reproductive health care services (Liberia, 2020). The health sector has made continuous efforts to improve overall access to health services in Liberia. In 2007, Liberian government started a widespread campaign to prioritize access to basic health care and rebuild the health care system (Loevinsohn & Harding, 2005). The objective this paper is to model and forecast MMR for Liberia using double exponential smoothing technique. The findings of this paper will guide policy making, planning and allocation of resources to the maternal and child health program.

LITERATURE REVIEW

Author (s)	Objective(s)	Methodology	Main finding(s)
Hotchkiss et al. (2025)	To assess the impact of a large, complex health systems strengthening program on maternal health care utilization in the DRC.	A difference-in-differences approach was applied using population-based household survey data at base line (2014) and endline (2017) from treatment and matched	The health systems strengthening program significantly increased the probability of facility-based delivery, but had no significant impact on receiving at least four ANC visits. Qualitative findings suggest that uptake of ANC was constrained by travel

		comparison areas in three provinces	distance, time burdens, limited community outreach, and cultural norms discouraging early ANC initiation
Yah (2025)	to examine the relationship between women's place of residence, women's earnings spending autonomy, and maternal health care utilization of women ages 15–49 in Liberia	secondary quantitative data analysis study	Logistic regression analysis revealed statistically significantly odds of maternal health care utilization by women with high school education (Grades 10–12) (OR = 2.465, $p < .001$), women who make contraceptive use decisions with their partners (OR = .628, $p < .032$) and women's place of residence (OR = 0.313, $p < .001$)
Matongo et al. (2024)	to determine the frequency of serious maternal morbidity at the Ruashi military hospital (DRC) with a view to ensuring good care and monitoring of pregnant women	descriptive study	The incidence of maternal morbidity was 24.2%, of which 32.4% had anemia followed by hemorrhage with 27% and finally sepsis and uterine subinvolution with 5.4% each
Mwene-Batu et al. (2024)	to describe the trends as well as the epidemiological profile and causes of reported institutional maternal deaths between 2013 and 2022 in Eastern DRC	retrospective descriptive study	Overall, 62,6% of the deaths were reported from secondary hospital. Most deaths were of married women in their thirties (93.5%). Almost half (47.8%) had not completed four antenatal consultations. The main direct causes of death were, in decreasing order of frequency: post-partum hemorrhage (55.2%), uterine rupture (14.0), hypertensive disorders (8.4%), abortion (7.7%) puerperal infections (2.8%) and placental abruption (0.7%)
Lee et al. (2023)	to better classify the contextual factors leading up to maternal deaths and to develop a list of recommendations to prevent future similar deaths in Bong County, Liberia	retrospective mixed method study was conducted examining 35 maternal deaths in Bong County, Liberia using verbal autopsy reports from 2019	This study identified three contextual causes: limited resources (materials, transportation, facility, staff), inadequate skills and knowledge (staff, community, family, patient), and ineffective communication (between providers, between health facilities and hospitals, and between provider and patient/family). Of these, inadequate patient education (54.28%), inadequate staff education and training (51.42%), ineffective communication between health facilities and hospitals (31.42%), and inadequate

			materials (28.57%) were most frequently mentioned
King et al. (2022)	To analyze quality in terms of readiness for emergency care and referral, staffing, and volume of births in Liberia	assessed the readiness of the Liberian health system to provide safe care during childbirth use using three data sources: Demographic and Health Surveys (DHS), Service Availability and Readiness Assessments (SARA), and the Health Management Information System (HMIS)	Overall, 63% of facility births were in places without full basic emergency readiness. 60% of facilities could not make emergency referrals, and 54% had fewer than one birth every two days
Zhang et al. (2021)	To explore the relationship between self-reported insecurity of mothers and maternal health-seeking behaviors and diseases in children in the DRC	Applied logistic regression	Conflicts increase mothers' insecurities and negatively affect children's development
Yaya et al. (2019)	explored the changes in maternal healthcare services utilization between 2007 and 2016 in Liberia	used 2007 and 2013 Liberia Demographic and Health Survey (LDHS) and the 2016 Malaria Indicator Survey (MIS)	key maternal healthcare utilization indicators have improved substantially, especially facility-based delivery. However, a large proportion of women remain deprived of these life-saving health services in the post-war era
Shon et al. (2018)	to evaluate the costs and benefits of the MCH project	conducted a cost-benefit analysis (CBA) using a benefit-cost ratio (BCR)	The benefits of reduced maternal mortality and the mortality of infants and children aged under 5 years were estimated as USD 681,416, USD 4,332,376, and USD 1,710,184, respectively, in monetary terms
Odette et al. (2017)	to analyze the etiologies of maternal deaths occurring in a tertiary hospital in DRC	This is a descriptive cross-sectional study with retrospective data collection of maternal deaths that occurred in the reference provincial hospital Jason Sendwe from 2013 to 2015. All cases of maternal deaths in line with the definition of World Health Organization have been included.	Bleeding with 61.04% was the leading cause of maternal death followed by eclampsia (31.58%). Indirect causes were dominated by heart disease (30.0%)

METHODOLOGY

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

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

Z_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 Liberia 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	0.800
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	85.648122
Sum Square Error (SSE)	827472.635676
Mean Square Error (MSE)	21217.247069
Mean Percentage Error (MPE)	1.180152
Mean Absolute Percentage Error (MAPE)	7.796409

Residual Analysis for the Applied Model

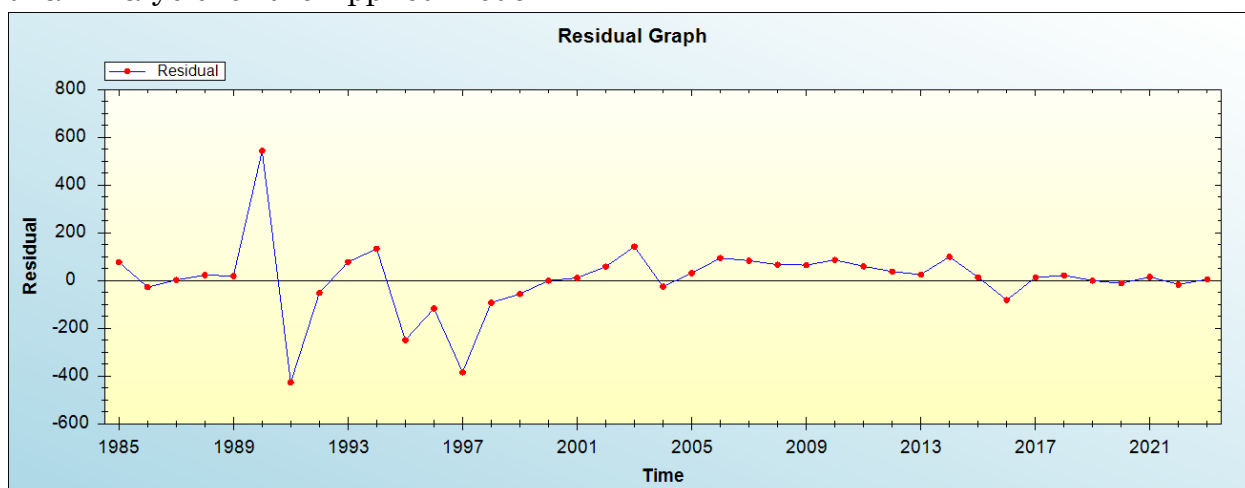


Figure 1: Residual analysis

In-sample Forecast for A

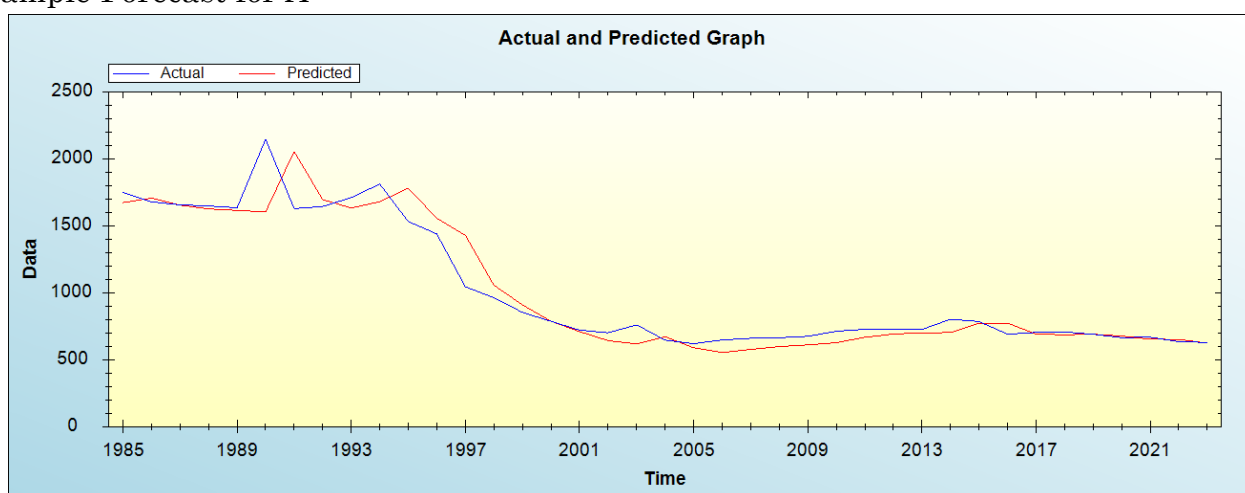


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

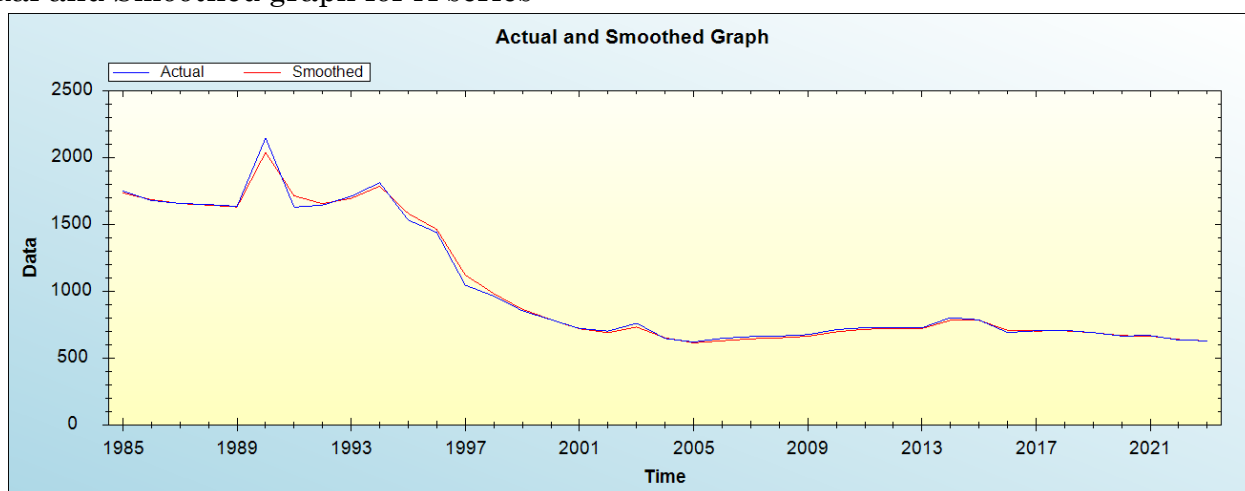


Figure 3: Actual and smoothed graph for A series

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

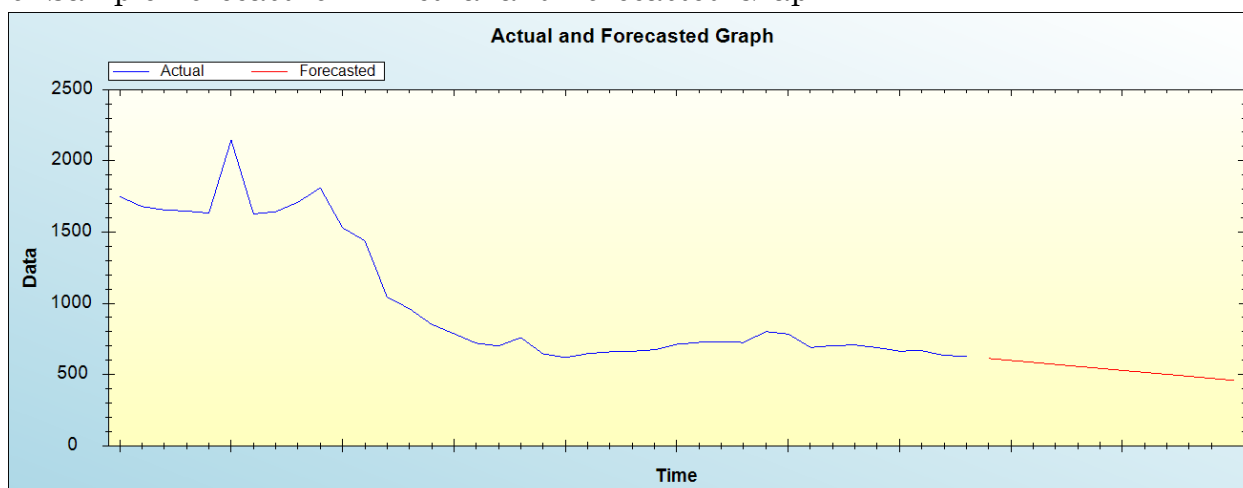


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	613.0087
2025	599.0160
2026	585.0233
2027	571.0306
2028	557.0379
2029	543.0452
2030	529.0525
2031	515.0598
2032	501.0670
2033	487.0743
2034	473.0816
2035	459.0889

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 remain very high over the out of sample period.

RECOMMENDATIONS & CONCLUSION

Maternal mortality rates in Liberia are unacceptably high indicating gross deficiencies in the continuum of care. This high maternal mortality is associated with factors such as high teenage pregnancies, shortage of skilled healthcare workers, inadequate supply of commodities and delapidated and inadequate healthcare infrastructure. This paper applies the double exponential smoothing model to forecast MMR for Liberia and results indicate that MMR will remain very high in the out of sample period. Therefore, we encourage 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) improve quality of maternity services (4) ensure

availability of adequate medical supplies and medical staff in all medical facilities (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 and (6) build new health infrastructure and also refurbish existing facilities.

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