

ANNUAL MATERNAL MORTALITY RATE CALCULATION FOR LIBYA USING THE DOUBLE EXPONENTIAL SMOOTHING MODEL

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ABSTRACT

This study uses annual time series data on MMR for Libya 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 0.5 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will decline from around 65 in 2024 to about 58 deaths per 100 000 live births by 2035. Therefore, we encourage authorities to relentlessly address local causes of maternal deaths.

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). Hemorrhage, hypertensive disorders, and sepsis are responsible for over 50% of maternal deaths worldwide (Khan et al. 2006). In Sub-Saharan Africa, 65% of maternal deaths from hemorrhage occur following delivery (Campbell et al. 2006; Li et al, 1996). Maternal mortality 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 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). The objective of this paper is to model and forecast MMR for Libya using the double exponential smoothing technique. The results of this piece of work are envisioned to highlight future trends of MMR for Libya. This is crucial for policy making, planning and allocation of resources to the maternal and child program so as to further reduce preventable maternal mortality

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 comparison areas in three provinces	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

			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 significant 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 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
Saeed et al. (2022)	to find out the status of postpartum depression and the associated factors among postnatal mothers at the first, fourth and sixth month in Libya	This study is a prospective descriptive study, carried out in three major health facilities in Misurata, Libya	the prevalence of depression is 60.0% and 22.0% are suffering from borderline depression. Development of depression was strongly correlated with sleeping disturbances, the state of the neonate after birth, excess consumption of stimulants, less weight acceptance by mothers during pregnancy and infant illness
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 Libya. 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 Libya 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	0.500
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	5.483168
Sum Square Error (SSE)	2630.600714
Mean Square Error (MSE)	67.451300
Mean Percentage Error (MPE)	-1.295959
Mean Absolute Percentage Error (MAPE)	7.711626

Residual Analysis for the Applied Model

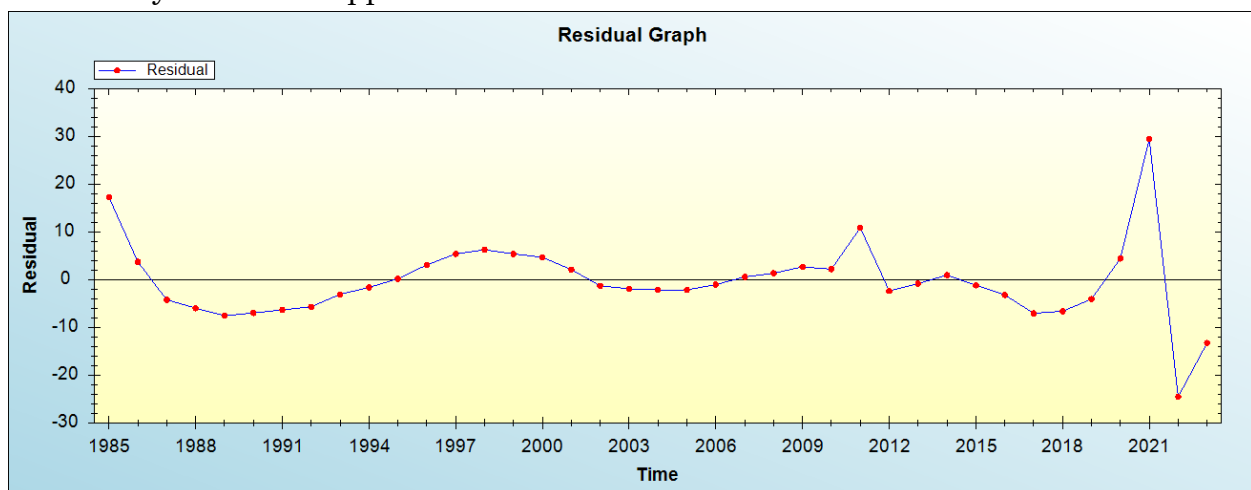


Figure 1: Residual analysis

In-sample Forecast for A

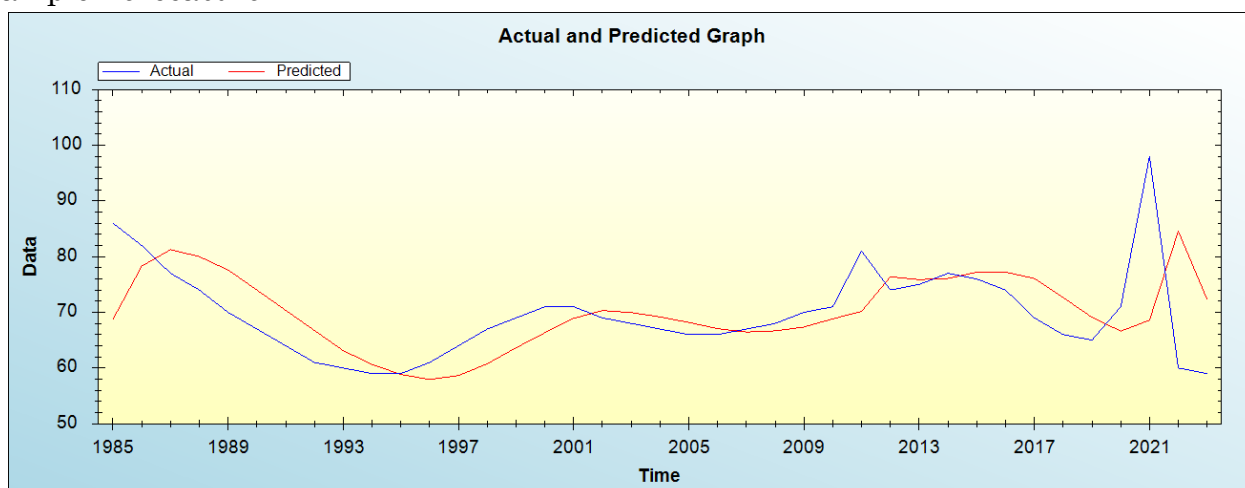


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

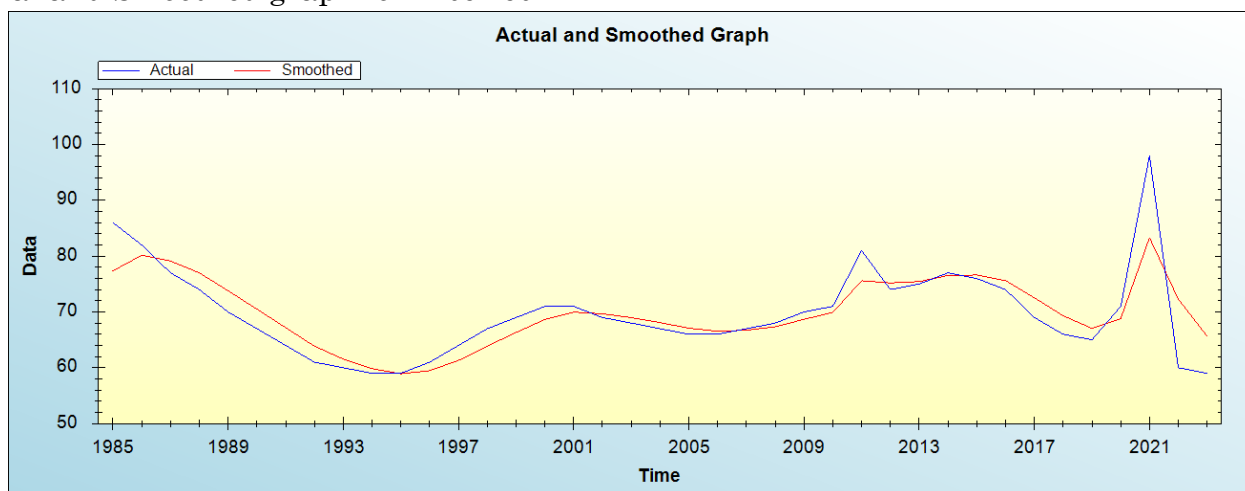


Figure 3: Actual and smoothed graph for A series

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

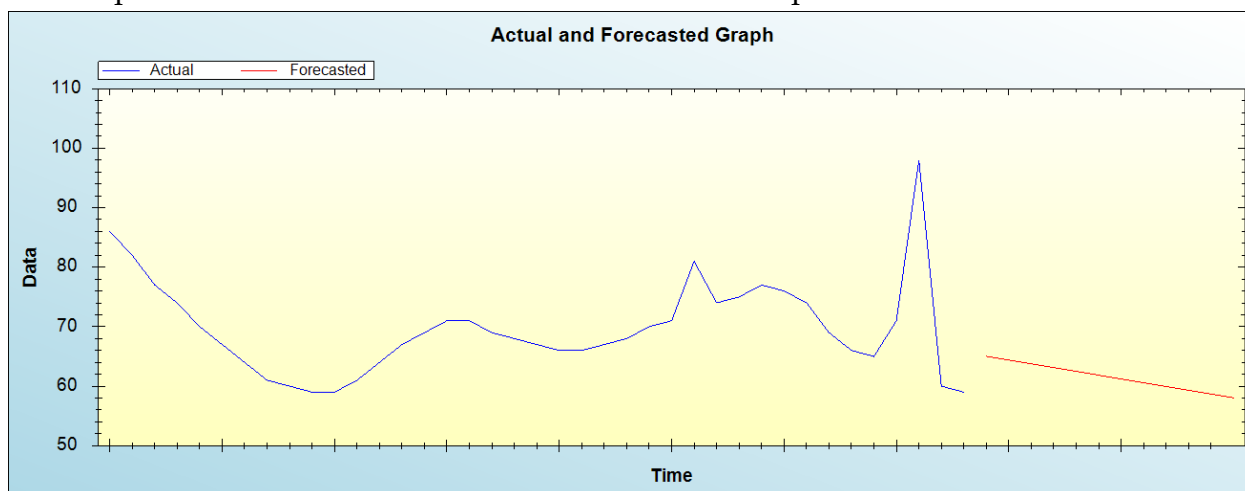


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	65.0204
2025	64.3859
2026	63.7514
2027	63.1169
2028	62.4824
2029	61.8479
2030	61.2134
2031	60.5789
2032	59.9444
2033	59.3099
2034	58.6754
2035	58.0409

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 65 in 2024 to about 58 deaths per 100 000 live births in 2035.

CONCLUSION

This study utilized the double exponential smoothing method to forecast MMR for Libya and findings indicate that MMR will decline from around 65 in 2024 to about 58 deaths per 100 000 live births in 2035. Therefore, we implore health authorities to address local causes of maternal deaths.

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