

ESTIMATION OF EXPECTED FUTURE VALUES OF ANNUAL MATERNAL MORTALITY RATE FOR LEBANON 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 Lebanon 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 0.6 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will hover around 19 deaths per 100 000 live births in the out of sample period. Therefore, we encourage authorities to address local causes of maternal mortality.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

INTRODUCTION

Lowering preventable maternal mortality continues to be on the global agenda for sustainable development (WHO, 2014). The etiology of maternal mortality includes poorly performing health systems, lack of referral systems for high- risk pregnancies, shortage of medications and resources, and limited clinical skills or experience to provide the appropriate level of care (UNFPAA, 2021; Miller et al. 2016). Furthermore, lack of evidence based clinical protocols, non- adherence to guidelines and inadequate contextualization of guidelines can compromise the quality of care from being given to women during pregnancy (WHO, 2019; Miller et al. 2016). Worldwide, maternal mortality was reduced by 38% from 2000 to 2017 (WHO, 2019). The burden of maternal mortality is highly distributed among vulnerable populations in conflict settings and among those who face health inequalities based on gender, ethnicity, and socioeconomic status (WHO, 2023; Campbell et al. 2016). However, maternal death remains preventable in most settings. The objective of this paper is to model and project MMR for Lebanon using Holt's linear method. The study findings are expected to guide policy, planning and allocation of resources to the maternal and child health program in order to further reduce preventable maternal deaths across the country.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Main finding(s)
Tsushima et al. (2026)	To determine the long-term incidence of dysglycemia and dyslipidemia after GDM and evaluated whether postpartum changes in body mass index (BMI) independently predicted these outcomes.	Prospective cohort study	Postpartum BMI increase was independently associated with new-onset dysglycemia. No independent predictor of T2DM progression was identified. Dyslipidemia was independently associated with higher pre-pregnancy BMI and multiparity, whereas postpartum BMI change

			was not independently associated after multivariable adjustment
Yue et al. (2026)	to perform an umbrella review to summarize the current evidence to provide a reference for clinicians and future research	Systematic review	Positive aPLs significantly increased the risk of miscarriage rate in assisted reproductive technology (ART) and were also associated with total fetal loss, PE, intrauterine growth retardation and placental abruption
Nunn et al. (2025)	To explore whether changes in key characteristics among Victorian Aboriginal and/or Torres Strait Islander women contributed to reduced perinatal death rates	Retrospective population-based cohort study of all births in Victoria from 2000–2019	Changes in key maternal characteristics may have contributed to improved perinatal death rates among babies of Victorian Aboriginal and/or Torres Strait Islander women
Kaddoura et al. (2024)	to assess the feasibility of establishing a prospective cohort of mothers and their full-term and preterm babies in Lebanon, examining the association between social determinants, preterm birth, and developmental outcomes amidst the nation's multifaceted crises	Prospective cohort study	Early analysis reveals significant stress and reduced quality of life among mothers, particularly those with preterm infants, against a backdrop of declining birth rates and health care worker exodus. Conducting research in crisis settings like Lebanon presents unique methodological and ethical challenges but remains crucial for understanding and improving health outcomes in vulnerable populations
Dimassi et al. (2023)	to review the maternal health outcomes of disadvantaged Lebanese and refugee pregnant women seeking ANC services at primary healthcare centers (PHCs) in Lebanon	A retrospective chart review was conducted at twenty PHCs in Lebanon, including Ministry of Public Health (MOPH) and United Nations Relief and Works Agency for Palestine refugees (UNRWA) facilities	Syrians had reduced odds of C-sections, and Beqaa, Mount Lebanon, and South Lebanon regions had reduced odds of abortion. Suboptimal ANC visits and history of C-section increased the odds of C-section and abortion in the current pregnancy. As for preterm onset, the study showed an increased likelihood for it to occur when being Palestinian, having current C-section delivery, experiencing previous preterm onset, and enduring complications at the time of delivery
McCall et al. (2023)	to assess whether the characteristics, management and outcomes of women varied between Syrian and Palestinian refugees, migrant women of other nationalities and Lebanese women giving birth at a public tertiary centre in Beirut, Lebanon	This was a secondary data analysis of routinely collected data from the public Rafik Hariri University Hospital (RHUH) between January 2011 and July 2018	Syrian refugees in Lebanon had similar obstetric outcomes compared to the host population, except for very preterm birth. However, Palestinian women and migrant women of other nationalities appeared to have worse pregnancy complications than the Lebanese women
Pinchas-Mizrachi et al. (2022)	To examine the disparities in breast cancer-related mortality rates among women from urban areas	This was a retrospective, follow-up study on mortality from	A higher incidence of mortality from breast cancer in Israel was found among urban women compared to rural women

	compared to rural areas in Israel	breast cancer among 894,608 Israeli women born between the years of 1940 and 1960	(1047.8/100,000 compared to 837/100,000, respectively)
Rebeiz et al. (2022)	To identify the lessons learned from women who died during pregnancy or childbirth in Lebanon between 2018 and 2020	case series and synthesis of maternal deaths between 2018 and 2020 that were reported by healthcare facilities to the Ministry of Public Health in Lebanon	A total of 49 women died before, during, or after childbirth, with hemorrhage being the most frequent cause (n = 16). The possible factors that would have prevented maternal deaths included a prompt recognition of clinical severity, availability of blood for transfusion and magnesium sulfate for eclampsia, adequate transfer to tertiary care hospitals comprising specialist care, and involvement of skilled medical staff in obstetric emergencies
Rottenstreich et al. (2020)	To determine the prevalence of obstetric ICU admissions in one medical center in Israel and to characterize this population	In this retrospective study the files of women coded for pregnancy, birth, or the perinatal period and admission to the ICU were pulled for data extraction (2005–2013)	Most pregnancies (71.2%) were uneventful prior to admission. ICU admissions were divided equally between direct (usually hemorrhage) and indirect (usually cardiac disease) obstetric causes
Morong et al. (2017)	This study was a retrospective cohort study of cases of in-hospital maternal deaths in the Ochsner Health System (Louisiana, United States) and the Queensland Health System (Australia) from 1995 to 2013	-to determine if American and Australian women have a similar rate of preventable maternal death and if the deaths were attributable to the same factors	Women from Louisiana, United States and Queensland, Australia have similar rates of preventable maternal death. No statistically significant factors explained trends in Australian maternal death; American maternal mortality was significantly associated with point of entry into prenatal care, likely influenced by insurance status
Nahidi & Hajifoghaha (2017)	To provide the current situation and trend of MMR in the Eastern Mediterranean region between 1990 and 2015	Systematic review	Based on the collected data, 36 out of 66 studies met the required criteria and were chosen for analysis. All countries of this region showed a downward trend between 1990 and 2015, and this change varied from 16.30% in Yemen to 76.56% in Lebanon. The maternal mortality reduction was 69.88% in Iran in the same time

METHODOLOGY

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Lebanon. 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 Lebanon 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	0.600
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	4.850984
Sum Square Error (SSE)	2951.758135
Mean Square Error (MSE)	75.686106
Mean Percentage Error (MPE)	-1.764083
Mean Absolute Percentage Error (MAPE)	18.035279

Residual Analysis for the Applied Model

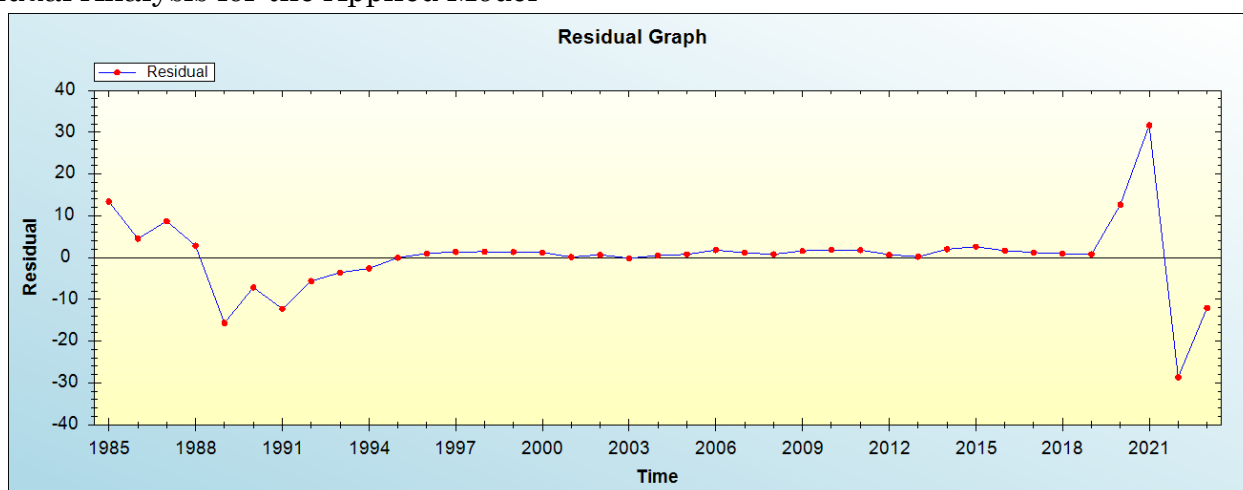


Figure 1: Residual analysis

In-sample Forecast for A

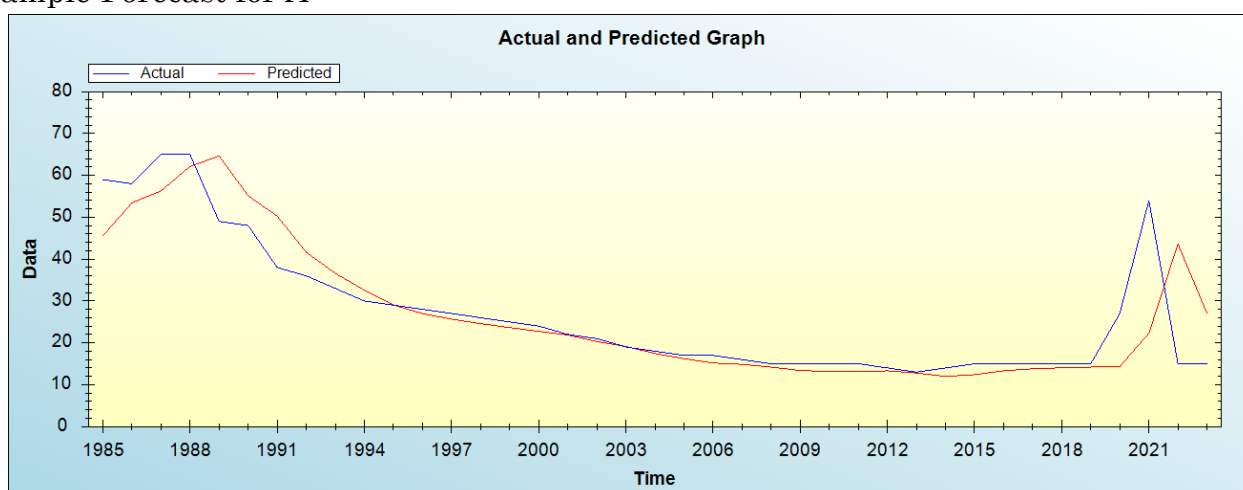


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

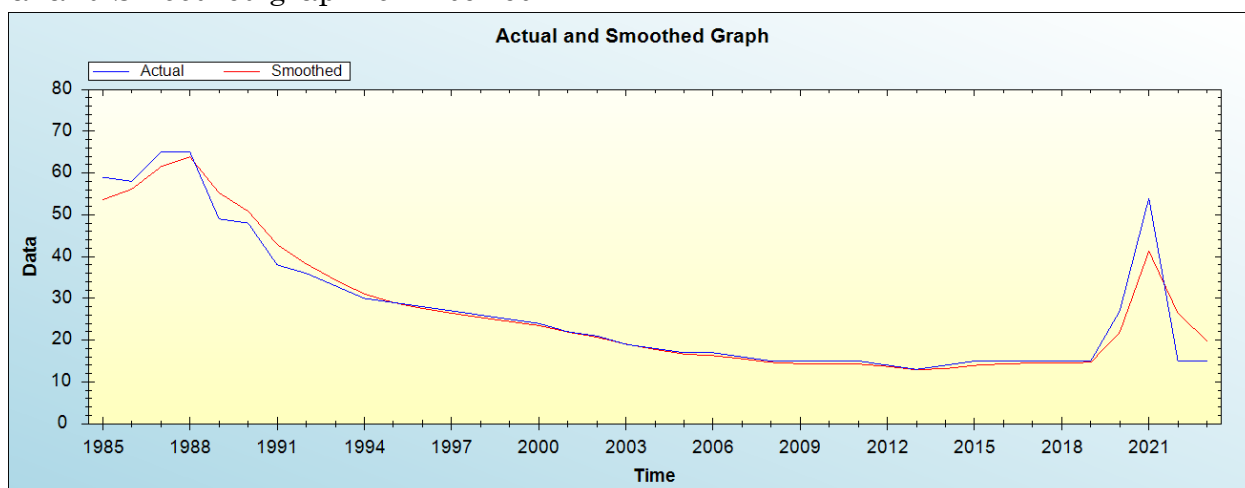


Figure 3: Actual and smoothed graph for A series

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

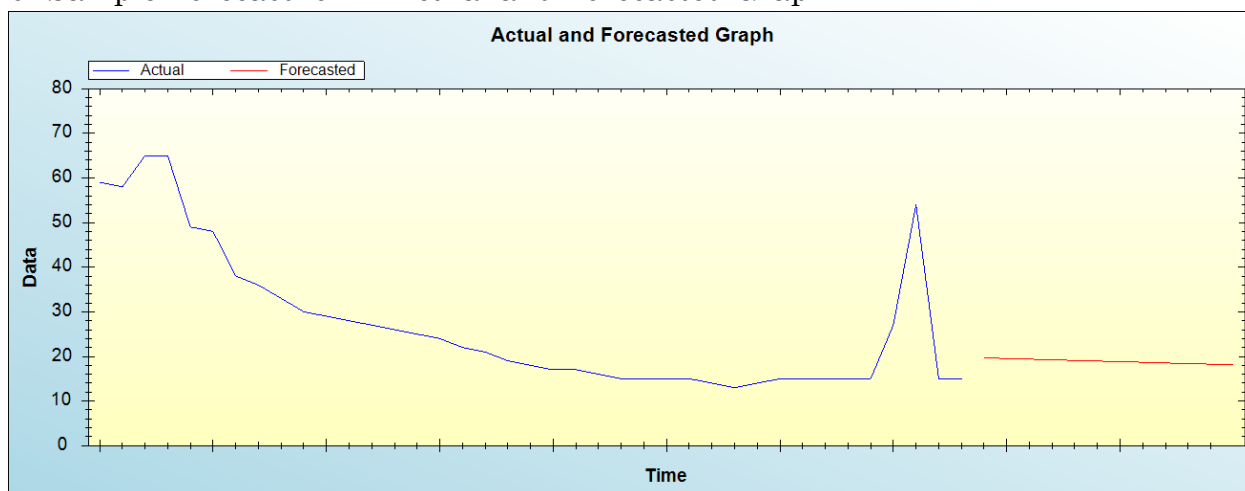


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	19.6704
2025	19.5284
2026	19.3865
2027	19.2445
2028	19.1025
2029	18.9606
2030	18.8186
2031	18.6767
2032	18.5347
2033	18.3928
2034	18.2508
2035	18.1089

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 generally hover around 19 deaths per 100 000 live births over the out of sample period.

RECOMMENDATIONS AND CONCLUSION

This paper applies the double exponential smoothing method to forecast MMR for Lebanon and results indicate that MMR is expected to hover around 19 deaths per 100 000 live births throughout the out of sample period. Hence, we implore health authorities to address local drivers of preventable maternal mortality and to continue reporting severe maternal morbidities.

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