



PREDICTION OF ANNUAL MATERNAL MORTALITY RATE FOR YEMEN USING HOLT'S LINEAR METHOD

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Abstract

This study uses annual time series data on MMR for Yemen 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 drop from around 114 in 2024 to about 66 deaths per 100 000 live births in 2035. Therefore, we encourage authorities to address local causes of maternal deaths and direct some of the resources towards implementation of quality improvement strategies.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio

Introduction

Despite huge investments in the health sector around the world, maternal mortality remains an issue of international concern. Maternal death has negative socio-economic consequences on the society, and on the health and lives of family, especially on the new born babies, particularly under conditions of socioeconomic deprivation (Moazzeni, 2013). In the International statistical classification of diseases and related health problems (ICD), the World Health Organization (WHO) defines maternal death as the demise of a woman while pregnant or within 42 days of termination of pregnancy, regardless of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from unintentional or incidental causes (WHO, 2019). The global estimates for the year 2017 revealed that there were



295,000 maternal deaths; 35% lower than in 2000 when there were an estimated 451,000 maternal deaths. The global MMR in 2017 was estimated at 211 maternal deaths per 100,000 live births, representing a 38% reduction since 2000, when it was estimated at 342 per 100 000 live births. The average annual rate of reduction in global MMR during the 2000–2017 period was 2.9%. This means that the global MMR dropped by 2.9% every year between 2000 and 2017 (WHO, 2019). In 2017, maternal mortality ratio (MMR) for Yemen was 164 deaths/100,000 live births. Yemen MMR fell gradually from 462 deaths per 100,000 live births in 1998 to 164 deaths per 100,000 live births in 2017 (UNICEF, 2017). In Yemen, the maternal mortality rate in 2015 was 385 per 100 000 live births due to complication in pregnancy and childbirth (WHO, 2016). However, most of these deaths were avoidable, if there had been careful planning, adequate preparation and care during pregnancy, childbirth and immediately after birth. It is also crucial to highlight that Yemen has suffered decades of armed conflict which adversely affected the provision of quality health care services. This paper models and projects MMR for Yemen using Holt's linear method. The results this paper will assist in designing policies and allocation of resources to the health sector to help reduce preventable maternal deaths.

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
Alsharif et al. (2023)	to review all cases of maternal mortality during a seven-year period of conflict at Jiblah Referral Hospital, Ibb, Yemen	retrospective, observational study was conducted between 2011 and 2017, including all maternal deaths that occurred at Jiblah Referral Hospital, Ibb, Yemen	maternal deaths occurred among young women, referred cases, with no regular antenatal care visits, low socioeconomic conditions, and who were residents of rural areas. Delays in seeking care and delays in reaching first-level health facilities were the most common causes of maternal death due to unawareness of danger signs, illiteracy, and ignorance
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



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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
Basha et al. (2022)	to understand the state of maternal health in Syria focused on underage pregnancy and caesarean sections using a scoping review and quantitative analysis; the latter draws on data from the Syrian American Medical Society's (SAMS) maternal health facilities in northwest Syria	Mixed methods study	-The quality of available literature was poor with country- level generalizations -quantitative analysis revealed some evidence around the changes to caesarean section rates in northwest Syria
Kükrer et al. (2022)	to examine and compare the rates of cesarean section (CS) and spontaneous vaginal delivery (SVD) in adolescent and adult pregnant women using the Robson ten group classification system (RTGCS)	retrospective cross-sectional study	Adolescent pregnancy is particularly prevalent among young females with poor levels of education and Syrian adolescent girls. Pregnant adolescent women face a greater risk of obstetric and neonatal problems than pregnant adult women of reproductive age
Pinchas-Mizrachi et al. (2022)	To examine the disparities in breast cancer-related mortality rates among women from urban areas compared to rural areas in Israel	This was a retrospective, follow-up study on mortality from breast cancer among 894,608 Israeli women born between the years of 1940 and 1960	A higher incidence of mortality from breast cancer in Israel was found among urban women compared to rural women (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	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



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		Public Health in Lebanon	sulfate for eclampsia, adequate transfer to tertiary care hospitals comprising specialist care, and involvement of skilled medical staff in obstetric emergencies
Bashour et al. (2021)	to highlight the experience of childbirth and delivery care as described by women and doctors at times of severe violence affecting Damascus	based on secondary analysis of qualitative data collected between 2012 and 2014 for a WHO-funded implementation research project introducing clinical audits for maternal near-misses	both women and doctors experienced difficulty reaching the hospital and accessing and providing the services, respectively; second, quality of care was challenged at that time as perceived by both women and doctors; and third, women and doctors expressed their psychological suffering in times of hardship and uncertainty and how this affected them.
Abdulla (2020)	to assess the yearly maternal mortality ratio, to investigate the trend in maternal deaths and analyze some associated factors over the period 2008-2018 at Al-Sadaka Teaching Hospital	This was a descriptive retrospective, hospital-based study carried out at Al-Sadaka Teaching Hospital over an 11-year period from 1st January 2008 to 31st Dec 2018 addressing pregnancy-related deaths.	The leading causes of direct maternal deaths were toxemia of pregnancy (27.3%) followed by obstetric hemorrhage (13.6%) and sepsis and anesthesia complication (8% each). Just more than half of maternal deaths (54.6%) occurred after delivery, and 17% occurred during labor whereas most of the remaining died in second half of pregnancy (21.6%). The majority of the causes was avoidable
Amiri et al. (2020)	to assess the utilization of SRH and MISP after 9 years of the crisis in Syria	Systematic review	this review indicated a number of barriers to access, utilization, and implementation of SRH services, including lack of reliable information on sexual and gender-based violence (SGBV), aggravation of early marriages by crisis setting, gaps in the knowledge and use of family planning services, inadequate STIs and HIV coverage, and some issues around the provision of maternal health services
Hyzam et al. (2020)	to examine the health education and promotion patterns, health-seeking behavior of mothers, and	qualitative approach	-data showed that health education and promotion activities on maternal health were ad hoc and coverage was poor



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	barriers to the use of maternal health services from public health facilities in two rural areas of Yemen		- poor quality of services, as indicated by inadequate numbers of female doctors, lack of medical equipment and medicines, and costs of services were barriers to use maternal health services
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
Terkawi et al. (2019)	to provide an updated account of women's health, including pregnancy, perinatal care, childbirth, and other conditions to identify obstacles and challenges to health-care delivery in Northwestern Syria	prospective data registry study, using a medical electronic records system that builds on the International Classification of Diseases, Tenth Revision (ICD-10) codes	The study found a huge deficiency in ANC and PNC visits, a high adolescent birth rate, and a higher cesarean-to-vaginal delivery ratio than what is recommended by the WHO - also found a severe shortage in the number of obstetrician-gynecologists serving this population
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 Yemen. 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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

Y_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 Yemen 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	Y
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	7.504871
Sum Square Error (SSE)	5556.959744
Mean Square Error (MSE)	142.486147
Mean Percentage Error (MPE)	0.892754
Mean Absolute Percentage Error (MAPE)	3.731147

Residual Analysis for the Applied Model

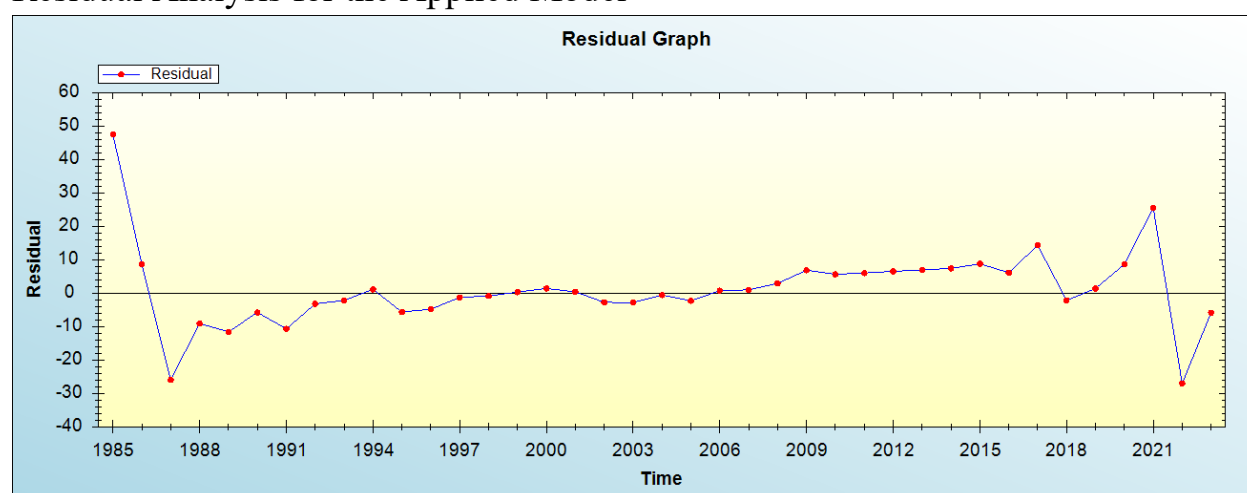


Figure 1: Residual analysis



In-sample Forecast for Y

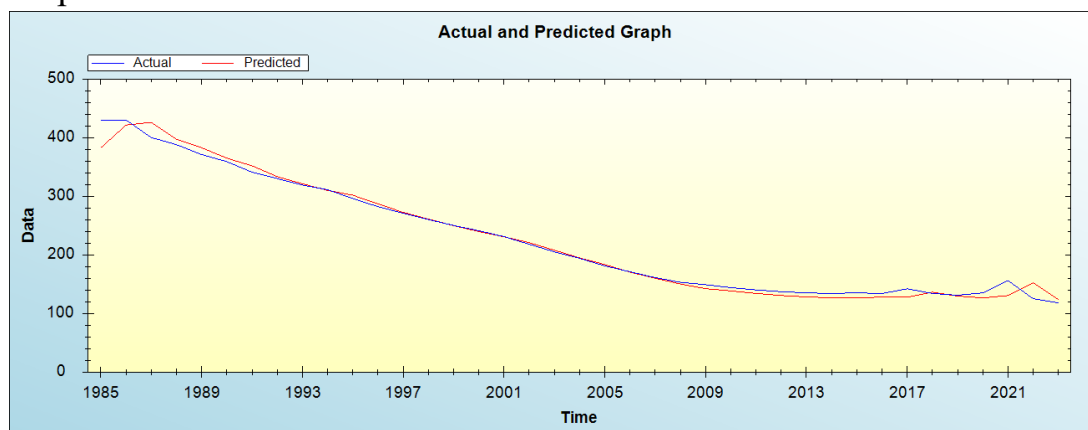


Figure 2: In-sample forecast for the Y series

Actual and Smoothed graph for Y series

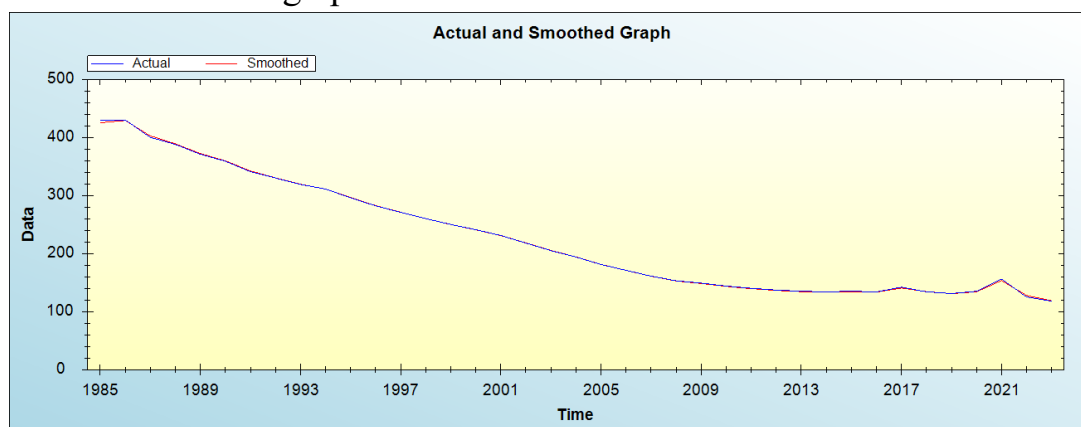


Figure 3: Actual and smoothed graph for Y series

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

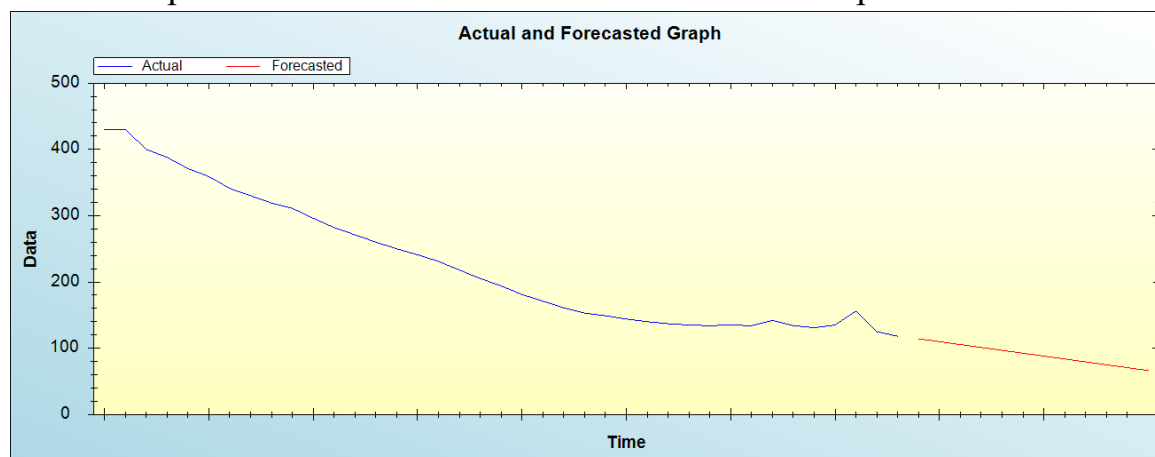


Figure 4: Out-of-sample forecast for Y: actual and forecasted graph



Out-of-Sample Forecast for Y: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	114.2347
2025	109.8812
2026	105.5277
2027	101.1743
2028	96.8208
2029	92.4673
2030	88.1139
2031	83.7604
2032	79.4069
2033	75.0535
2034	70.7000
2035	66.3465

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 drop from around 114 in 2024 to about 66 deaths per 100 000 live births in 2035.

Conclusion

Yemen has suffered decades of armed conflict which adversely affected the provision of quality health care services. Hence, the burden of maternal mortality is high. In this study Holt's linear method was applied to model and forecast MMR and results indicate that MMR will drop from around 114 in 2024 to about 66 deaths per 100 000 live births in 2035. Therefore, we implore health authorities to address all factors associated with maternal mortality and direct some of the resources towards implementation of quality improvement initiatives.



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