

Maternal Mortality Projection For Egypt Using The Double Exponential Smoothing Model

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Abstract

This study uses annual time series data on MMR for Egypt 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 decline and remain very low over the out of sample period. Therefore, we encourage authorities in Egypt to address local causes of avoidable maternal mortality and improve surveillance of severe maternal morbidity.

Keyword(s): - Exponential smoothing, Forecasting, Maternal Mortality Ratio

Introduction

Maternal mortality is defined by the tenth revision of the International Classification of Diseases (ICD 10) as the demise of a woman caused by complications related to pregnancy or medical interventions during or shortly after pregnancy, typically within 42 days of delivery. This excludes deaths due to accidental or incidental reasons. Maternal mortality is an important indicator of a country or region's overall health status, indicating the effectiveness, accessibility, and quality of its healthcare system (WHO, 2023). SDG 3.1 aims to bring down the global maternal mortality ratio (MMR) to less than 70 maternal deaths per 100,000 live births by 2030 (WHO, 2023; Das et al. 2021). The major drivers of maternal deaths can be obstetric and non-obstetric causes. (WHO, 2023). Direct maternal deaths are due to obstetric complications during pregnancy, labor, or the postpartum period, as well as from interventions, omissions, or incorrect treatment. These include conditions such as obstetric bleeding, hypertensive disorders, complications related to anesthesia, and undesirable outcomes of cesarean section (Garland J. & Little, 2018). On the other hand, indirect maternal deaths are associated with underlying health conditions or illnesses that develop during pregnancy but are not directly triggered by pregnancy-related medical procedures. These conditions are made worse by the physiological changes that take place during pregnancy and may include chronic illnesses such as cardiovascular or renal diseases (WHO, 2023). According to the Egyptian government, in Egypt, the MMR dropped significantly from 174 deaths per 100,000 live births in 1990 to 52 per 100,000 in 2013. By 2017, the MMR had further decreased to 37 per 100,000, and it reached 17 per 100,000 live births in 2020. The purpose of this paper is to model and forecast MMR for Egypt using the double exponential smoothing model. The results of this paper will guide policy and allocation of resources to the Maternal and Child Health program. The ultimate goal is to further reduce preventable maternal deaths across the country.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
Compaoré et al. (2025)	to determine the frequencies and causes of severe maternal outcomes (SMO: MNM + MD) in regional and district hospitals in	Between 1st February 2008 and 31st October 2010, we conducted an SMO incidence study in 36 hospitals in the three countries	At the time of our study the burden of severe maternal outcomes was high in Benin, Burkina Faso and Niger. -most women had a near miss

	Benin, Burkina Faso and Niger		complication on admission to a participating hospital, indicating the need to facilitate access to obstetric care for women with high-risk pregnancies and complications
Gebili et al. (2025)	to identify the characteristics and predictors of coronavirus disease (COVID-19) related maternal deaths in 2020 and 2021, and to assess maternal mortality ratio (MMR) from 2018 to 2021 in Egypt	A record-based cross-sectional analytical study was conducted in four randomly selected governorates: Kafr El-Sheikh, El-Behira, (Lower Egypt) and Assiut, and Fayoum (Upper Egypt)	-Direct causes, including postpartum hemorrhage, preeclampsia, and embolism, accounted for 47.5% of deaths. As one of indirect causes of deaths, COVID-19 was diagnosed in 25.3%, it was the sole cause in 75.0% of them -The overall MMR increased between 2018 and 2021 with significant increases observed in Fayoum (from 39.25 to 71.65; $p < 0.001$) and Kafr El-Sheikh (from 36.44 to 56.6; $p = 0.032$) -residing in lower Egypt and hospital referral refusals were predictors of COVID19 related maternal mortality
Birabwa et al. (2024)	To describe the trends in IMMR between 2016 and 2021, and the causes and characteristics of maternal deaths in Kampala, Uganda	retrospective study utilized routine data from all facilities in Kampala that provided childbirth services from 2016 to 2021. -conducted descriptive analysis and assessed time trends in IMMR	IMMR in Kampala increased from 2019-2021. Health infrastructure changes and maternal health initiatives potentially accounted for the observed trend by affecting data quality. Referral and facility readiness were underlying reasons for maternal deaths

Musarandega et al. (2021)	to identify the leading causes of maternal deaths using the international classification of disease – 10th revision, for maternal mortality (ICD-MM)	Systematic literature review	Obstetric hemorrhage, hypertensive disorders in pregnancy, non-obstetric complications, and pregnancy-related infections are the leading causes of maternal deaths in SSA
Anya & Enaruna (2020)	to identify current and emerging causes of MM and to examine the recent trend in the etiology of MM University of Benin Teaching Hospital	-The case records of patients who suffered MM in the University of Benin Teaching Hospital, Benin City, Nigeria from 1st January, 2011 to 31st December, 2018 were retrospectively studied -Data on sociodemographic characteristics, clinical diagnosis, and primary cause of maternal death were extracted and analyzed	-A progressive decline in MMR was observed in the initial 5 years, with 58% reduction between 2012 (1.48%) and 2015 (0.61%). A further rise in MMR occurred in the last 3 years, climbing 53% from 2016 (0.81%) to 2018 (1.72%) -Maternal mortality occurred in 235 women during the study period, giving a MMR of 1.1% (1,114/100,000 live births). MMR among booked women of 161/100,000 live births was 6 times lower than MMR for referred women of 953/100,000 live births. Almost half (48%) of the MM occurred within 24 hours of admission to hospital, and 74.5% were postpartum. A teenager had 3-fold risk of mortality, age older than 35 years increased risk of dying 2-fold, and grand-multiparity conferred a 3-fold risk of mortality. Those in

			the lower socioeconomic class were 7 times more likely to suffer mortality The results of multivariable logistic regression models showed disparities in maternal health care service utilization, including antenatal care, facility-based delivery, postnatal care and contraceptive use across selected maternal factors. The current BHDS showed age, region, religion was significantly associated with maternal health care services
Yaya et al. (2018)	To comparatively explore the utilization level of maternal health care, and examine disparities in the determinants of major maternal health outcomes	used data from two rounds of Benin Demographic and Health Survey (BDHS) to examine the utilization and disparities in factors of maternal health care indicators using logistic regression models	The results of multivariable logistic regression models showed disparities in maternal health care service utilization, including antenatal care, facility-based delivery, postnatal care and contraceptive use across selected maternal factors. The current BHDS showed age, region, religion was significantly associated with maternal health care services
Mahmouda & Omar (2018)	to assess the awareness and perceptions of women about maternal mortality issues in rural areas in both		There are no statistical significance differences between both groups in rural communities regarding the levels of

	Assiut and Fayoum Governorates		awareness about maternal mortality
Bashour et al. (2015)	report findings from the formative stage of a World Health Organization (WHO) funded implementation research study that was undertaken to collect primary data at the facility level on the prevalence, characteristics, and management of maternal near-miss cases in four major public referral hospitals- one each in Egypt, Lebanon, Palestine and Syria	conducted a cross-sectional study of maternal near-miss cases in the four contexts beginning in 2011, where we collected data on severe maternal morbidity in the four study hospitals, using the WHO form (Individual Form HRP A65661)	Overall, hemorrhage-related complications were the most frequent conditions among maternal near-miss cases across the four study hospitals. In all hospitals, coagulation dysfunctions (76.1 %) were the most prevalent dysfunction among maternal near-miss cases, followed by cardiovascular dysfunctions. The coverage of key evidence-based interventions among women experiencing a near-miss was either universal or very high in the study hospitals

Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Egypt. 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 Egypt 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	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	3.979919
Sum Square Error (SSE)	1812.451522
Mean Square Error (MSE)	46.473116
Mean Percentage Error (MPE)	0.482438
Mean Absolute Percentage Error (MAPE)	8.783294

Residual Analysis for the Applied Model

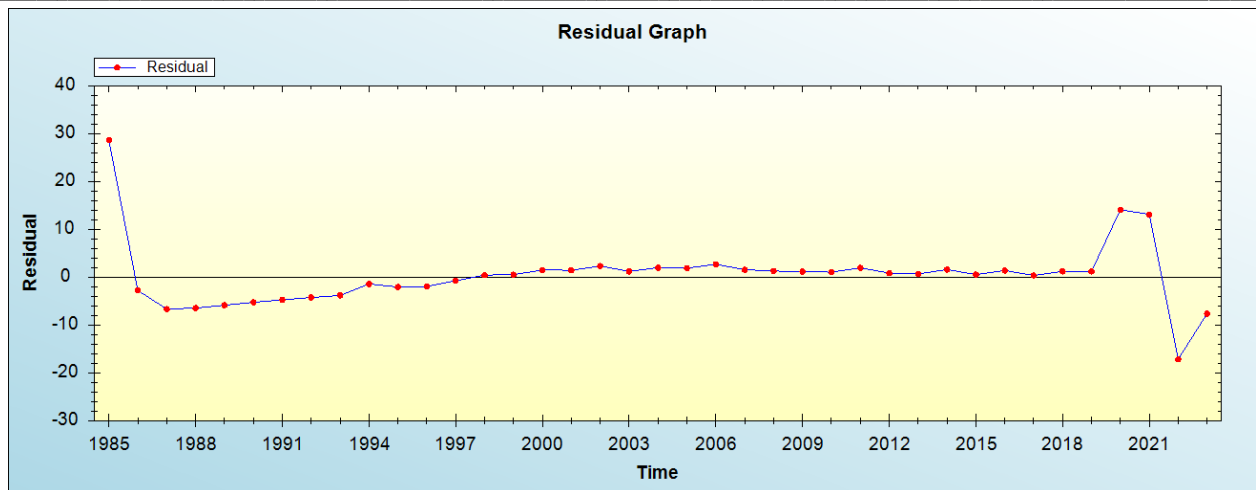


Figure 1: Residual analysis

In-sample Forecast for A

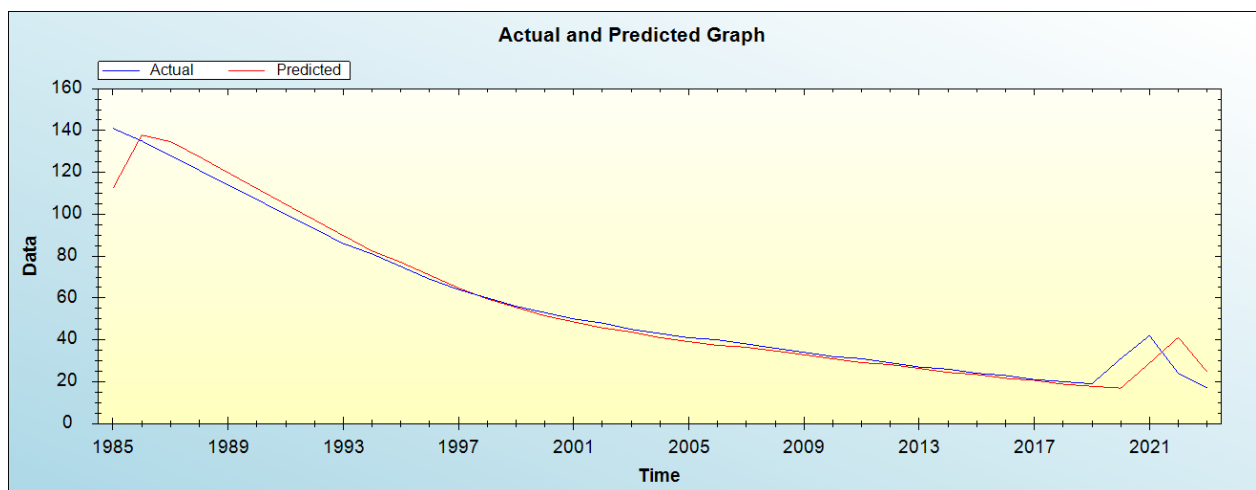


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

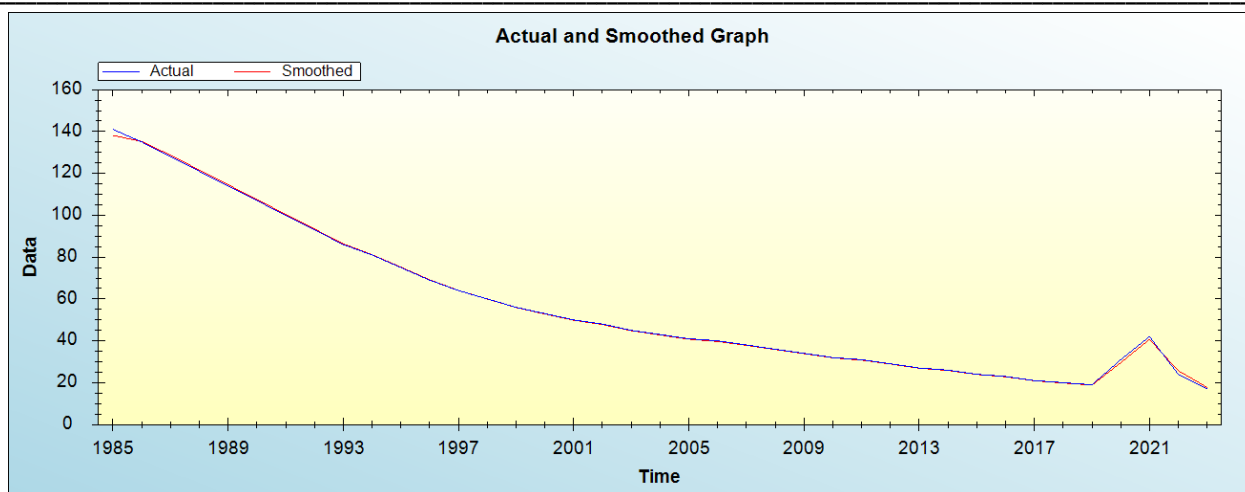


Figure 3: Actual and smoothed graph for A series

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

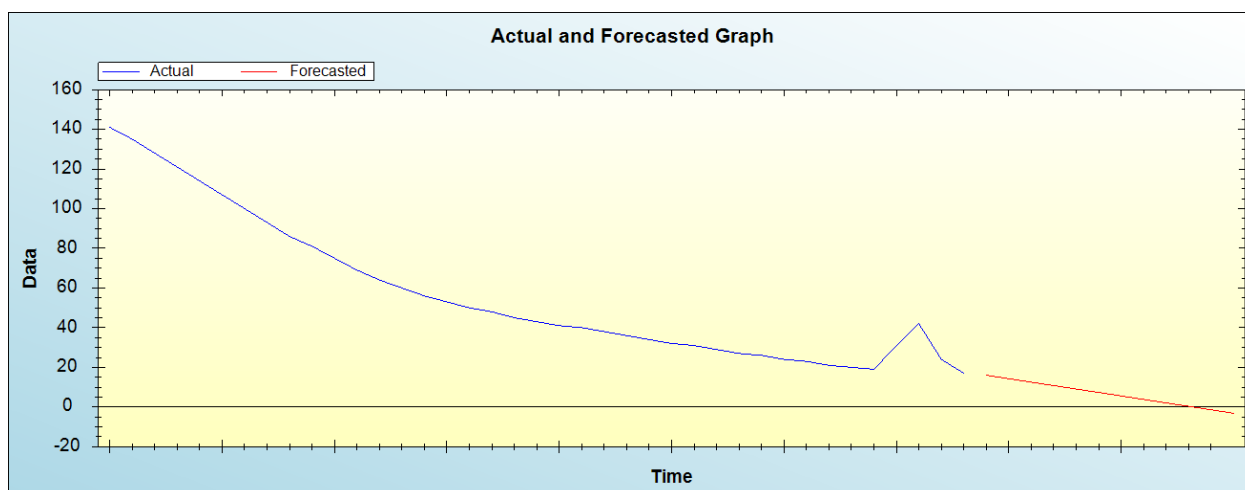


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	16.0236
2025	14.2807
2026	12.5378
2027	10.7949

2028	9.0520
2029	7.3091
2030	5.5662
2031	3.8233
2032	2.0804
2033	0.3375
2034	-1.4054
2035	-3.1483

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 and remain very low over the out of sample period.

Recommendations & conclusion

The Egyptian government has managed to drastically reduce maternal mortality to levels below 30 deaths per 100 000 live births. This indicates significant improvements in the quality of health care offered during the antenatal, child birth and postnatal periods. This study utilized the double exponential smoothing method to model and forecast MMR for Egypt and results indicate that MMR will decline and remain very low over the out of sample period. Hence, we encourage Egyptian authorities to address local causes of maternal deaths and improve surveillance of severe maternal morbidity.

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