



MATERNAL MORTALITY RATE APPROXIMATION FOR SYRIA USING THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

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Abstract

This study uses annual time series data on MMR for Syria 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 20 in 2024 to about 15 deaths per 100 000 live births in 2035. Therefore, we encourage authorities to attend to local causes of preventable maternal deaths across the country.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

Provision of maternal healthcare services is always a huge challenge especially in regions affected by armed conflict because of limited access to healthcare services, disruption of supply chains and damage to infrastructure. In the case of Syria; before 2011 96% of Syrian women delivered with the help of a skilled birth attendant, and 88% had at least one antenatal care visit (Syria Central Bureau of Statistics, 2011). The maternal mortality ratio (MMR) stood at 52/100,000 live births in 2009 (Syria Central Bureau of Statistics, 2011). Before the war that began in 2011, Syrian women encountered numerous problems such as failure to take preferences of women at childbirth into account (Bashour & Abdulsalam, 2005), and excessive levels of medical interventions, such as unnecessary cesarean sections (Khawaja et al. 2004). Several maternal health problems emerged or were aggravated during the war period. During the years of war, Syria



observed an upward trend of maternal mortality. In 2015, MMR estimate was 68/100,000 live births being the only available figure from the WHO/UNICEF (Syria Country Profile 2017). The main cause of maternal death in Syria is hemorrhage accounting for 65% of maternal deaths (Bashour et al. 2009). Approximately 91% of maternal deaths are avoidable if high-quality maternity services are provided. The objective of this paper is to model and forecast MMR for Syria using the double exponential smoothing technique. The results of this paper will assist in planning and allocation of adequate resources to the maternal and child health program so that preventable maternal deaths are further reduced.

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



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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



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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 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



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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.
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
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 Syria. 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

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

Smoothing equation

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



$$0 < \alpha < 1$$

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 Syria 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	Z
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	2.217294
Sum Square Error (SSE)	451.676078
Mean Square Error (MSE)	11.581438
Mean Percentage Error (MPE)	0.023123
Mean Absolute Percentage Error (MAPE)	7.395766

Residual Analysis for the Applied Model

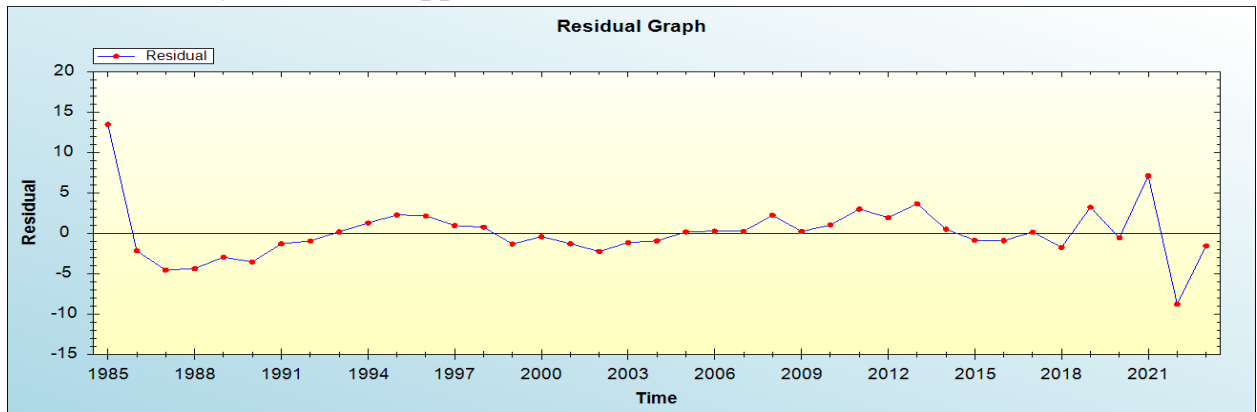


Figure 1: Residual analysis

In-sample Forecast for Z

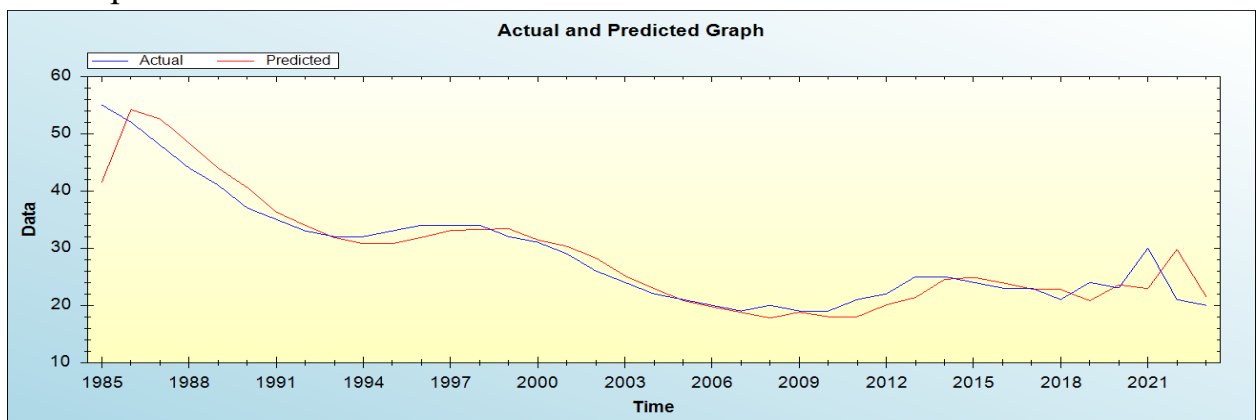


Figure 2: In-sample forecast for the Z series



Actual and Smoothed graph for Z series

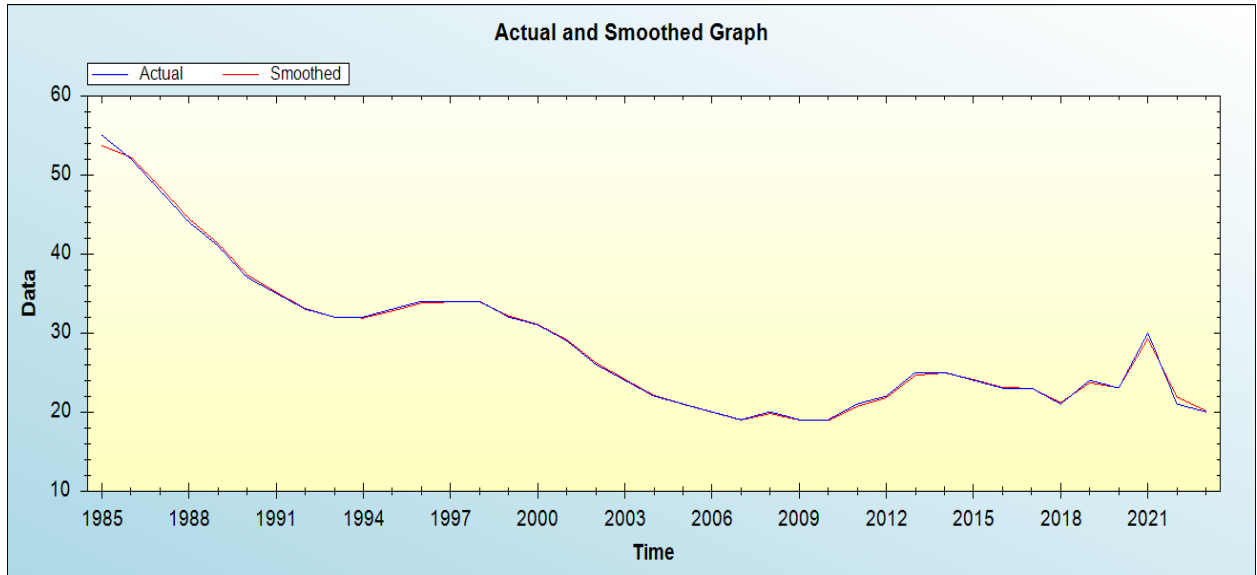


Figure 3: Actual and smoothed graph for Z series

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

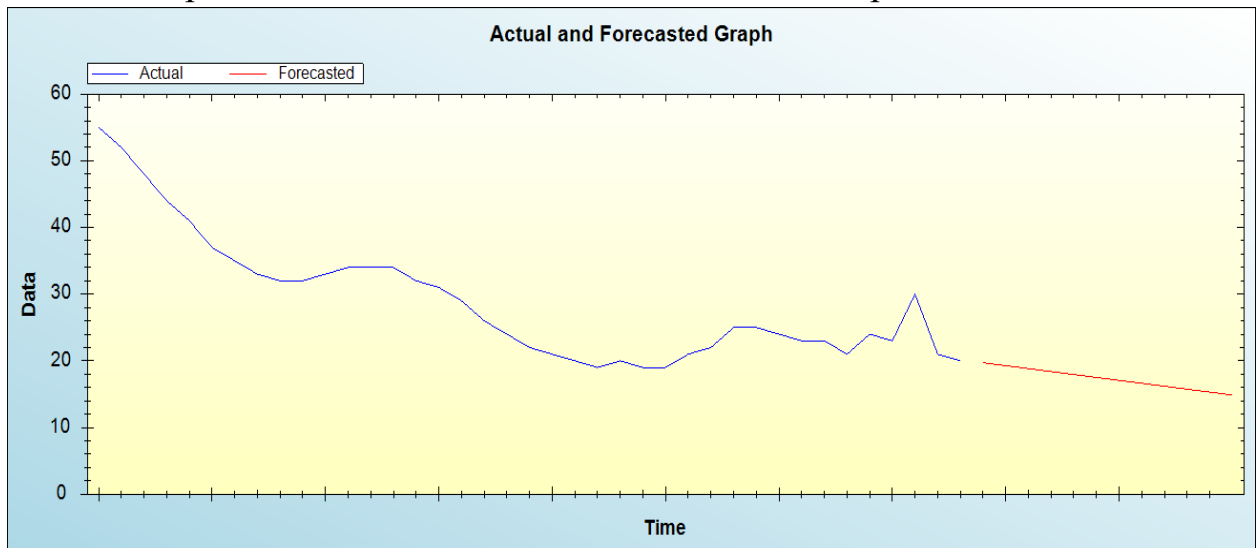


Figure 4: Out-of-sample forecast for Z: actual and forecasted graph



Out-of-Sample Forecast for Z: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	19.7168
2025	19.2757
2026	18.8346
2027	18.3936
2028	17.9525
2029	17.5114
2030	17.0703
2031	16.6292
2032	16.1881
2033	15.7470
2034	15.3059
2035	14.8648

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 20 in 2024 to about 15 deaths per 100 000 live births in 2035.

Conclusion

Maternal mortality is still a public health issue of concern in Syria. The main cause of maternal deaths is antepartum and post-partum hemorrhage in 65% of the cases. In this paper, we applied the double exponential smoothing technique to model and forecast MMR and results indicate that MMR will drop from around 20 in 2024 to about 15 deaths per 100 000 live births in 2035. Therefore, we encourage health authorities to attend to local causes of maternal mortality and also direct some of the resources towards the implementation of quality improvement programs.



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