



TRACKING FUTURE TRENDS OF ANNUAL MATERNAL MORTALITY RATE FOR SAUDI ARABIA USING HOLT'S LINEAR METHOD

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Abstract

This study uses annual time series data on MMR for Saudi Arabia 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 remain very low over the out of sample period. Therefore, we encourage authorities to address local causes of maternal mortality.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

Maternal mortality ratio in Saudi Arabia remains relatively high at approximately 17 per 100 000 live births (Rouzi et al. 2023). Factors associated with maternal mortality include older multiparous women, those with low income, and those with no education (Al-Meshari et al. 1996). Antenatal care services have been shown to improve maternal health outcomes in this country and elsewhere as this ensures early detection and management of pregnancy complications (WHO, 2021; EBCOG, 2015). Furthermore, recent evidence indicates that antenatal care has favorable outcomes for both mother and fetus regardless of the presence of factors such as increasing age, parity, and comorbidities that make the pregnancy 'higher-risk' (Harrison et al. 1988). The association between un-booked pregnancy and poorer obstetric outcomes has been demonstrated in several



countries (Aamir et al. 2012; Tucker et al. 2009; Owalabi et al. 2008). This paper models and forecasts MMR for Saudi Arabia using Holt's linear method. The study findings are expected to trigger an appropriate national response so that all preventable maternal deaths are eradicated in this country.

Literature Review

Author (s)	Objective(s)	Methodology	Main finding(s)
Mackin et al. (2026)	to understand how levels of MNH care are organized in different country contexts	Scoping review	Three or four levels of MNH facility care were most commonly reported. Linking maternal and newborn facility care to community connections is an important consideration to ensure equitable access to routine and emergency care
Al-Taïar et al. (2025)	to assess the prevalence of anemia in pregnant women and its associated factors in the Kuwait Birth Cohort study	Prospective cohort study	-The prevalence of anemia was 28.16% (95% CI:25.53–30.91%), with 8.75% of women experiencing moderate anemia and 19.40% mild anemia. No cases of severe anemia were observed -Multivariable analysis identified current iron supplement use, (Adjusted Odds Ratio [AOR] 0.52, 95%CI:0.28–0.99; p = 0.049), vitamin D status (sufficient vs. insufficient/deficient), (AOR 0.63, 95%CI:0.43–0.92; p = 0.018), iron levels (p < 0.001), and ferritin levels (p < 0.001) as factors significantly associated with anemia
Cresswell et al. (2025)	To obtain updated evidence on causes of maternal death to accelerate SDG progress	conducted a multi-strategy systematic review to identify causes of maternal deaths occurring in 2009–20	Hemorrhage remains the leading cause of death, despite the existence of effective clinical interventions, emphasizing the need for improved access to quality health care
Hamdan et al. (2025)	To describe postpartum Hemorrhage Burden,	Scoping review	the review identified critical gaps in blood loss estimation methods, with visual estimation being unreliable and leading to



	Management and Challenges in Malaysia		underdiagnosis, while patient intrinsic factors such as uterine atony, retained placenta, and placenta accreta spectrum disorders contribute to treatment complexity.
Kama et al. (2025)	to establish the period prevalence of MNM and mortality index, and to compare near-miss cases with maternal mortality and to identify their risk factors and causes	Cross-sectional study	The leading causes of MNM were eclampsia (47.8%), abruptio placentae (19.7%) and postpartum hemorrhage (8.3%), and the leading causes of maternal death were eclampsia (29.2%), puerperal sepsis (25%) and postpartum hemorrhage (12.5%)
Qattan & Kattan (2025)	to evaluate the regional distribution of obstetricians and gynecologists (OB/GYN) across Saudi Arabia and its impact on maternal and neonatal health outcomes	cross-sectional secondary data analysis	This nationwide analysis highlights significant disparities in the distribution of OB/GYN specialists across Saudi Arabia. Urban regions are underserved relative to their population size, while rural regions often lack adequate infrastructure to support existing specialists
Bhalotra & Clarke (2024)	to investigate the association of women's education with maternal and child mortality	Panel regression	moving an additional 1 percentage point of women into primary education reduces rates of maternal death by 4.6%, and reduces the rate of infant deaths by 1.9%
Duka et al. (2024)	to quantify the inequalities in the distribution of nurses in Albania, analyzing the nurse-to-population ratio and its impact on the quality of healthcare	Descriptive analytic study	The average nurse-to-population ratio in Albania is 28 nurses per 10,000 inhabitants, with significant variations between regions. Tirana has the highest ratio (60 nurses per 10,000 inhabitants), while Kukës and Dibër have the lowest values (10 per 10,000 inhabitants)
Al Qasem et al. (2023)	To determine the incidence, risk factors, and maternal outcomes of "major degree" placenta previa) PP	retrospective study	Major degree of PP/PAS is associated with high maternal morbidity but rare mortality



	(/placenta accreta spectrum) PAS (in Abha Maternity and Children's Hospital, Abha, Saudi Arabia. Secondly, to compare our findings to those of previous studies on PP/PAS in Saudi Arabia		
Chin et al. (2023)	to understand the demography, case characteristics and causes of maternal mortality in Sabah from 2015 through 2020	Retrospective study	Majority of deceased women, 56.7%, never attended antenatal visits prior to their death in the latest pregnancy. Overall, 63.88% deaths were due to direct obstetric causes, postpartum hemorrhage was the leading direct cause of death (24.53%), and most of the maternal deaths (65.5%) were preventable
Rouzi et al. (2023)	To investigate whether booking status for antenatal care impacted outcomes for pregnant women and identify outcomes that predicted booking status in Saudi Arabia	All Saudi women admitted to the labor or delivery units between January 2011 and December 2019 were included. Outcomes were compared between booked and un-booked women, and logistic regression was used to identify outcomes that predicted booking status, adjusted for age	The rate of perinatal and maternal mortality in this cohort was relatively low and equivalent between booked and un booked mothers, contrary to our expectations. More analysis of the socioeconomic data may explain this striking result
Diguisto et al. (2022)	to compare maternal mortality in eight countries with enhanced surveillance systems	Descriptive multi-country population-based study.	Variations in maternal mortality ratios exist between high income European countries with enhanced surveillance systems. In-depth analyses of differences in the quality of care and health system performance at national levels are needed to reduce maternal mortality further by learning from best practices and each other



Pouyanfar et al. (2022)	to investigate the factors affecting the maternal mortality ratio (MMR) in different regions of Iran	Systematic review	The leading causes of maternal death were hemorrhage (43.7%), preeclampsia/eclampsia (24.5%), other hypertensive disorders (24%), and embolism (22.8%)
Gabrani et al. (2020)	to identify key factors influencing the utilization of governmental and private primary healthcare services in Albania	cross- sectional health facility survey using a 4- point Likert scale questionnaire to rank the importance of factors driving services utilization.	The use of primary healthcare is strongly influenced by geographical and financial access for public facility users and availability of equipment for private users. This study found that aspects of acceptability and adequacy of services are equally valued
Norhayati et al. (2016)	to study severe maternal morbidity and maternal near miss among women in two tertiary hospitals in Kota Bharu, Kelantan, Malaysia	A cross-sectional study with record review was conducted in 2014. Severe maternal morbidity and maternal near miss were classified using the new World Health Organization criteria. Health indicators for obstetric care were calculated and descriptive analyses were performed using SPSS version 22.0	The maternal near miss mortality ratio was 23.5 and the mortality index was 4.1 %. The process indicators for essential interventions were almost 100.0 %. Hemorrhagic disorders were the most common event for severe maternal morbidity (68.6 %) and maternal near miss (80.9 %) and management-based criteria accounted for 85.1 %
Tamburlini et al. (2011)	to identify issues in maternal and neonatal care and promote action	-A standard based tool was utilized	Neonatal care scored better than obstetric care

Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Saudi Arabia. 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 Saudi Arabia 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)	0.891482
Sum Square Error (SSE)	89.692723
Mean Square Error (MSE)	2.299813
Mean Percentage Error (MPE)	0.973927
Mean Absolute Percentage Error (MAPE)	6.069766

Residual Analysis for the Applied Model

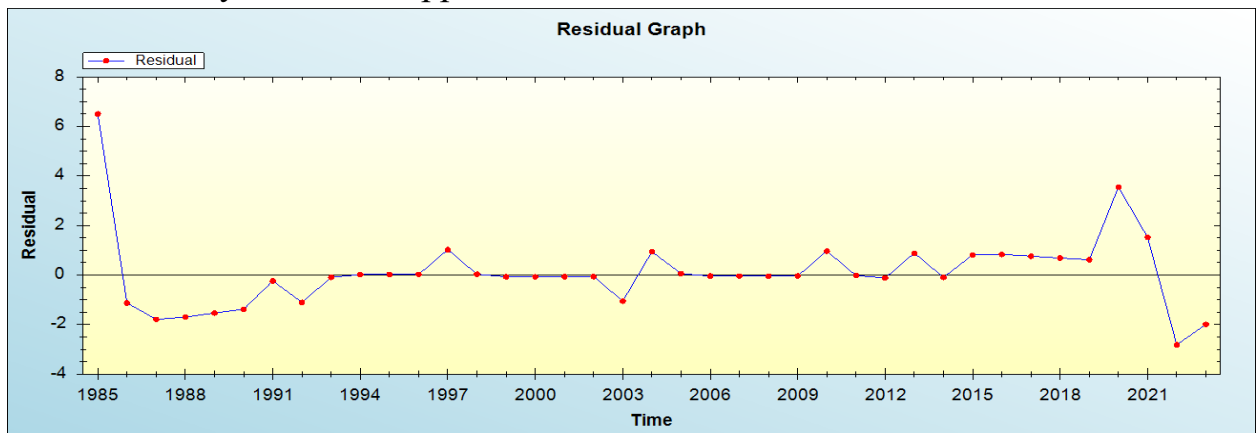


Figure 1: Residual analysis

In-sample Forecast for A

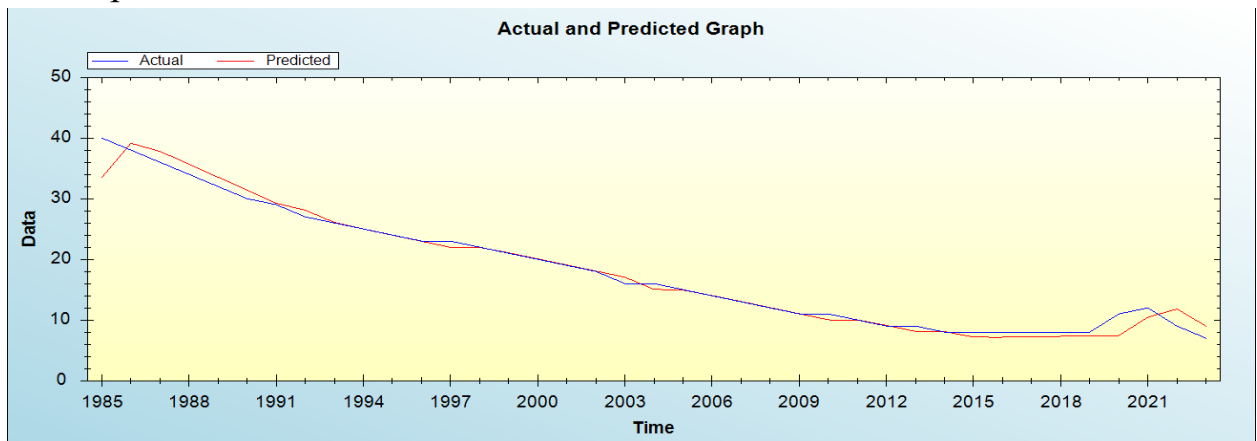


Figure 2: In-sample forecast for the A series



Actual and Smoothed graph for A series

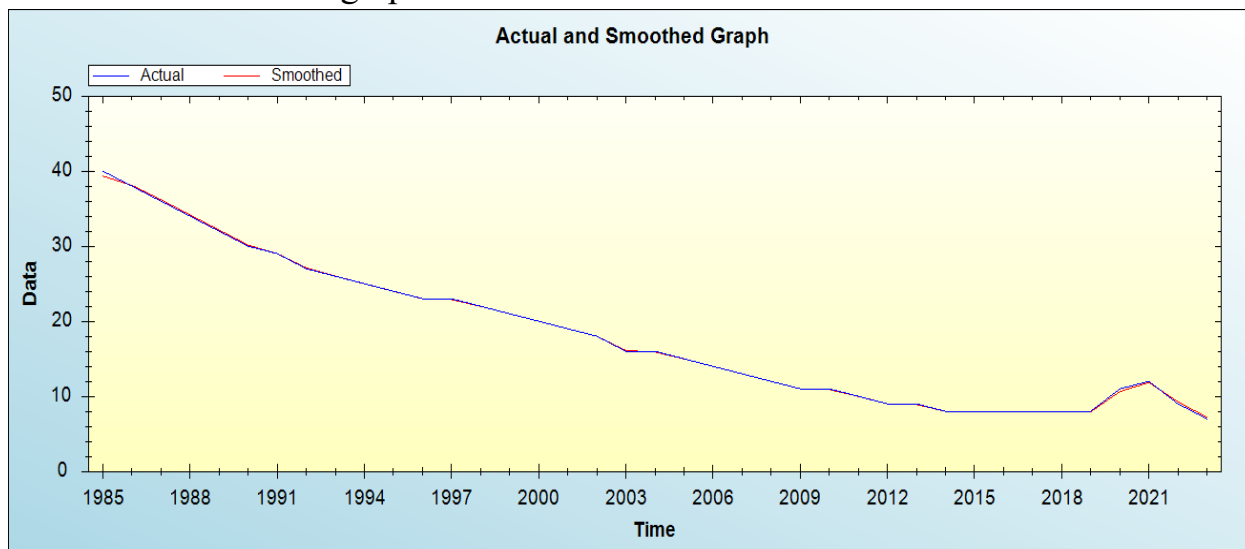


Figure 3: Actual and smoothed graph for A series

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

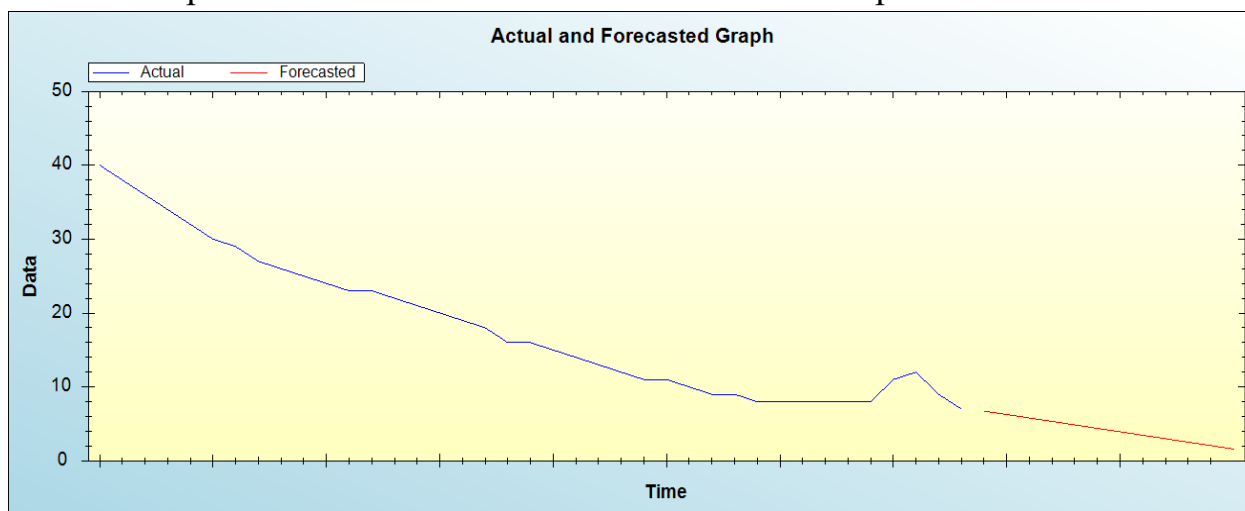


Figure 4: Out-of-sample forecast for A: actual and forecasted graph



Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	6.7327
2025	6.2660
2026	5.7994
2027	5.3327
2028	4.8660
2029	4.3993
2030	3.9326
2031	3.4659
2032	2.9992
2033	2.5325
2034	2.0659
2035	1.5992

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 remain very low in the out of sample period.

Conclusion

In this paper we utilized the Holt's linear technique to model and forecast MMR for Saudi Arabia and results suggest that MMR will remain very low in the forecast period. Hence, health authorities are encouraged to attend to local causes of maternal mortality.

References

1. Aamir F., Fasih A., Mahesh A., and Charles E (2012). A comparative review of maternal morbidity and perinatal outcome in booked and un-booked mothers. Pak J Surg 28(4):280–4.
2. Al-Meshari A., Chattopadhyay S.K., Younes B., and Hassonah M (1996). Trends in maternal mortality in Saudi Arabia. Int J Gynecol Obstet 1996;52(1):25–32. Doi: 10.1016/0020 7292(95)02556-1.



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3. EBCOG Scientific Committee (2015). The Public Health Importance of Antenatal Care. Facts, Views Vis ObGyn 2015;7(1):5.
 4. Harrison K.A (1988). Maternal mortality--a sharper focus on a major issue of our time. Trop J Obs Gynaecol 1(1):9–13.
 5. Owalabi T., Fatusi A., Kuti O., Adeyemi A., Fatureti S., and Obiajuwa P (2008). Maternal complications and perinatal outcomes in booked and unbooked Nigerian mothers. Orig Artic Singapore Med J 2008;49(7):526.
 6. Rouzi A., Sahly N., Kafy A.M., Alamoudi R.A., Abualsaud R.M., Alsheri W.A (2023). Mortality outcomes between pregnant women booked for antenatal care and unbooked pregnant women. Ann Saudi Med 2023; 43(6): 357-363. DOI: 10.5144/0256 4947.2023.357.
 7. Tucker A., Ogutu D., Yoong W., Nauta M., and Fakokunde A (2009). The unbooked mother: a cohort study of maternal and foetal outcomes in a North London Hospital. Arch Gynecol Obstet 2009 281(4):613–6. Doi: 10.1007/S00404-009-1152-7.
 8. World Health Organization (2021). WHO recommendations on antenatal care for a positive pregnancy experience. <https://apps.who.int/iris/bitstream/handle/10665/250796/97892415?sequence=1>. Accessed December, 2021.