

Eurasian Scientific Herald 	Maternal Mortality Forecasting For Bahrain Using The Double Exponential Smoothing Approach
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ABSTRACT	This study uses annual time series data on MMR for Bahrain 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 0.3 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will remain low in the out of sample period. Therefore, we encourage authorities to attend to local causes of maternal deaths.
Keywords:	Exponential smoothing, Forecasting, Maternal Mortality Ratio

Introduction

According to WHO, a maternal death is the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and the site of the pregnancy, from any cause related to or aggravated by pregnancy or its management, but not from accidental or incidental causes (WHO, 2012). The UN Maternal Mortality Estimation Interagency Group (MMEIG) revealed that worldwide, in 2020 around 287 000 maternal deaths were reported. During the same year (2020), the probability of a 15-year-old girl to die from any maternal cause was 1/210. In addition, in 2020,

the global maternal mortality ratio (MMR) was 223 maternal deaths per 100 000 livebirths. The etiology of more than fifty percent of maternal mortality cases are postpartum hemorrhage, severe pre-eclampsia and eclampsia, infections and sepsis during ante partum or postpartum period, and intrapartum complications such obstruction and secondary arrest of labor especially in multiparous women (Say et al. 2014). The objective of this paper is to model and forecast MMR for Bahrain using the double exponential smoothing technique. The findings of this paper will inform national policy and allocation of resources to the healthcare sector.

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
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
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%)
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)
Diguisto et al. (2022)	to compare maternal mortality in eight countries with enhanced	Descriptive multi-country population-based study.	Variations in maternal mortality ratios exist between high income European countries with

	surveillance systems		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
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 Bahrain. 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 Bahrain 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	0.300
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	1.529382
Sum Square Error (SSE)	227.770998
Mean Square Error (MSE)	5.840282
Mean Percentage Error (MPE)	-3.135858
Mean Absolute Percentage Error (MAPE)	11.981859

Residual Analysis for the Applied Model

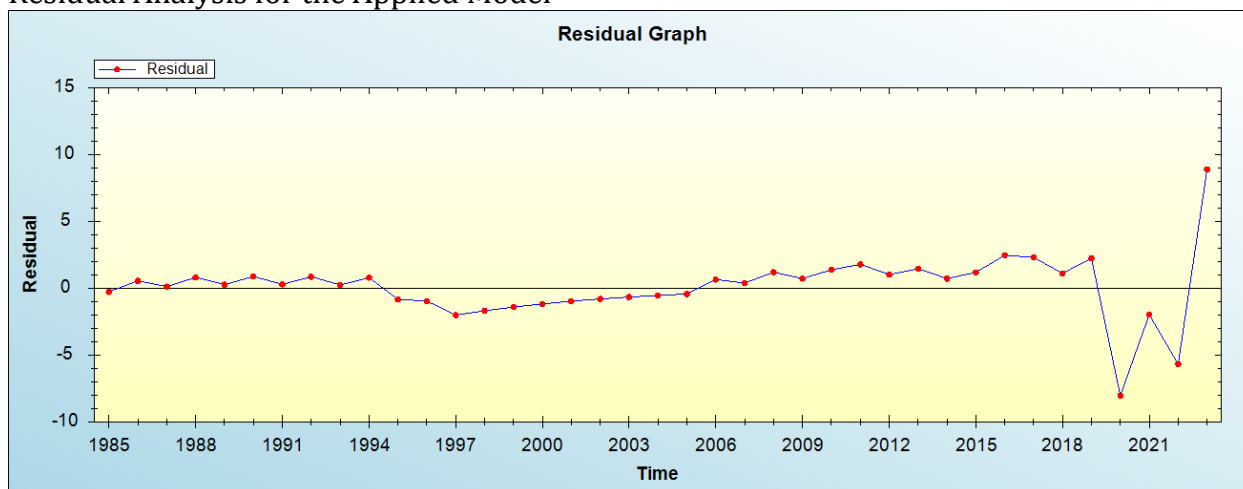


Figure 1: Residual analysis

In-sample Forecast for A

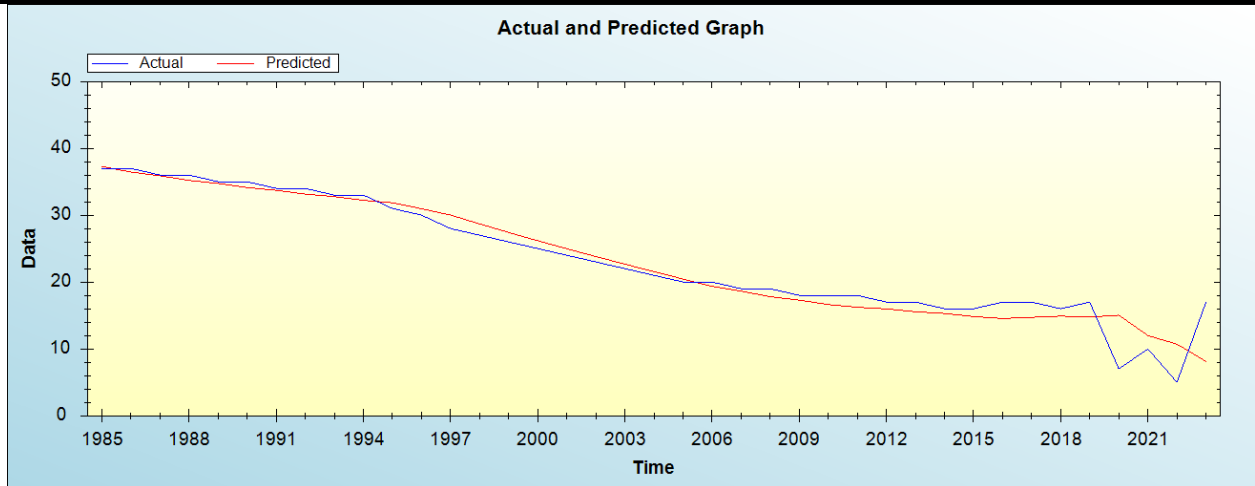


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

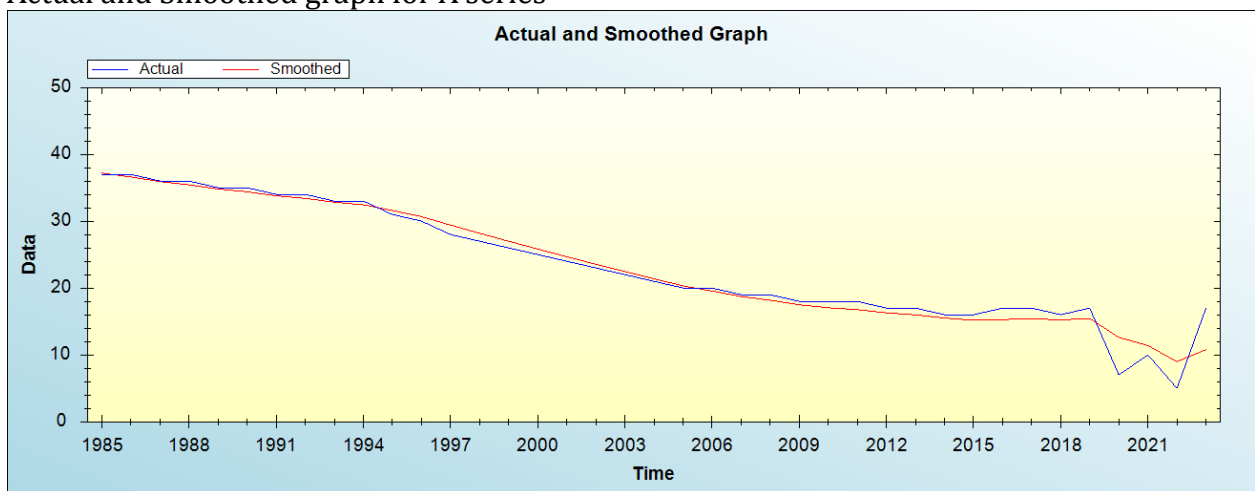


Figure 3: Actual and smoothed graph for A series

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

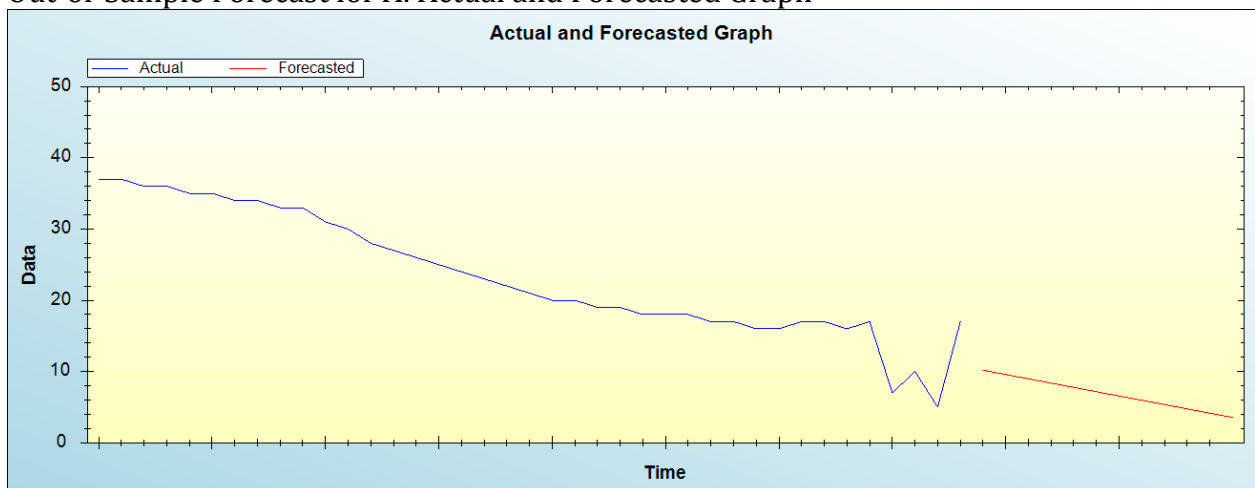


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	10.1814
2025	9.5793
2026	8.9773
2027	8.3752
2028	7.7731
2029	7.1711
2030	6.5690
2031	5.9669
2032	5.3649
2033	4.7628
2034	4.1608
2035	3.5587

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 low in the out of sample period.

Conclusion

This paper applies the double exponential smoothing model to forecast MMR for Bahrain. Study results indicate that annual MMR will remain low in the out of sample period. Therefore, we encourage authorities in Bahrain to attend to local causes of preventable maternal deaths.

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