



CALCULATING ANNUAL MATERNAL MORTALITY RATE FOR OMAN USING THE DOUBLE EXPONENTIAL SMOOTHING MODEL

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Abstract

This study uses annual time series data on MMR for Oman 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 0.2 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will slightly increase from around 24.6 in 2024 to about 31 deaths per 100 000 live births by 2035. Therefore, we encourage authorities relentlessly address local causes of maternal deaths and direct some of the resources to quality improvement initiatives.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio

Introduction

The maternal mortality ratio (MMR) is a measure of the risk of death associated with each pregnancy, was estimated to be 400 per 100 000 live births globally in 2000. In certain regions, women encounter this risk several times during their lives and the cumulative lifetime risk of maternal death can be as high as 1 in 16, compared with 1 in 2800 in developed countries (WHO, 2006). Nearly 800 women die each day from preventable causes related to pregnancy or childbirth (WHO, 2023). Hemorrhage, hypertensive disorders, and sepsis are responsible for over 50% of maternal deaths worldwide (Khan et al. 2006). In Sub-Saharan Africa, 65% of maternal deaths from hemorrhage occur following delivery (Campbell et al. 2006; Li et al, 1996). Maternal mortality affects low-middle



countries more than the developed countries. According to the WHO, at the global level, the maternal mortality ratio in 2020 was estimated at 233 per 100,000 live births (WHO, 2020). However, during the recent years, a significant decline of maternal mortality ratio at the global level was noted, with a reduction of 34.3% between 2000 and 2020, an average rate of reduction of 2.9% per year (WHO, 2023; WBG, 2023; WHO, 2020). The aim of this paper is to model and forecast MMR for Oman using the double exponential smoothing model. The study findings will assist in designing appropriate policies and implementation of timeous corrective measures to further reduce avoidable maternal deaths.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Ara et al. (2025)	to summarize the frequencies of sociodemographic characteristics, parity distribution, antenatal care patterns, and causes of death among maternal mortality	Conducted a retrospective study which analyzed maternal mortality at Rangpur Medical College Hospital, Bangladesh, in 2024, reviewing 4,741 birth records with 83 maternal deaths.	-Among 83 maternal deaths, majority of deaths occurred among women aged 16–25 (41%) and those from low socioeconomic backgrounds (72.2%). -Parity distribution showed 49.39% had 1–2 children, while 73.4% received no antenatal care (ANC), highlighting gaps in healthcare access. - Eclampsia (37.35%) and obstetric hemorrhage (26.50%) were the predominant cause of maternal deaths.
Feng et al. (2025)	-to analyze trends (1990–2021) and projected (to 2050) MMR in Southeast Asia using the Global Burden of Disease (GBD) 2021 database and addressing gaps in regional granularity	-Data GBD 2021, covering MMR and age-standardized MMR (ASMR) for 1990–2021, stratified by country, age group, and cause -Trend assessment was conducted using the estimated annual percentage change (EAPC), while 30-year projections were generated via an autoregressive integrated moving average (ARIMA) model	The ASMR in Southeast Asia fell by 59%, dropping from 255.88 in 1990 to 104.56 per 100,000 live births by 2021. This decline was primarily driven by reduced rates of maternal hemorrhage and hypertensive disorders. Progress slowed during the 1997 Asian financial crisis yet picked up pace after 2000



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Singh & Swain (2025)	to explore the factors influencing CDMR and its effect on maternal and fetal outcomes	Prospective cohort study	The prevalence of CDMR was 21.35%, which was relatively higher than the World Health Organization's recommended guidelines
Phan et al. (2024)	To examine the association between health insurance coverage and antenatal care (ANC) visits during pregnancy	The study 19 utilized data from the 2021-22 Cambodia Demographic and Health Surveys (CDHS). A total of 20 3,162 weighted women who gave birth within two years were included in the analysis. Multiple logistic regression analysis assessed the association between health insurance coverage and pregnant women who attended at least four antenatal care visits during pregnancy	Having health insurance coverage was significantly associated with four or more 31 ANC visits
Hossain et al. (2023)	To report the current level and major causes of maternal deaths in Bangladesh, focusing on care-seeking practices, timing, and place of deaths	-analyzed data from the 2016 Bangladesh Maternal Mortality and Health Care Survey (BMMS), conducted with nationally representative sample of 298 284 households -adapted the World Health Organization's 2014 verbal autopsy (VA) questionnaire. Trained physicians reviewed the responses and assigned the cause of death based on the International Classification of Diseases (ICD-10)	Nineteen per cent of the maternal deaths occurred at home, another 19% in-transit, almost half (49%) in a public facility, and 13% in a private hospital. Hemorrhage contributed to 31% and eclampsia to 23% of the maternal deaths. Twenty-one per cent of the maternal deaths occurred due to indirect causes
Jabeen et al. (2023)	To examine the current levels, trends, time of death, and care-seeking practices for hemorrhage-related maternal deaths in Bangladesh	-conducted a secondary analysis with data from the nationally representative 2001, 2010, and 2016 Bangladesh Maternal Mortality Surveys (BMMS) -The cause of death information was collected through verbal autopsy (VA) interviews using a country-adapted version of the standard World Health Organization VA questionnaire	Postpartum hemorrhage remains the primary cause of maternal mortality in Bangladesh



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Win et al. (2023)	to summarize all possible factors influencing maternal mortality in CLMV countries	Systematic review	Poor family income, illiteracy, low education levels, living in poor households, and agricultural and unskilled manual job types of mothers contributed to insufficient antenatal care
Singh et al. (2022)	to inform on potential options for measuring maternal mortality	Applied a case study approach to compare methodologies and estimates of pregnancy-related mortality ratio (PRMR)/maternal mortality ratio (MMR) obtained from four different data sources from similar time periods in Bangladesh, Mozambique, and Bolivia—national population census; post-census mortality survey; household sample survey; and sample vital registration system (SVRS)	For Bangladesh, PRMR from the 2011 census falls closely in line with the 2010 household survey and SVRS estimates, while SVRS' MMR estimates are closer to the PRMR estimates obtained from the household survey. Mozambique's PRMR from household survey method is comparable and shows an upward trend between 1994 and 2011, whereas the post-census mortality survey estimated a higher MMR for 2007. Bolivia's DHS and post-census mortality survey also estimated comparable MMR during 1998–2003
Chham et al. (2021)	to explore the coverage level of the Optimal CoC by (1) measuring the continuity of optimal antenatal care (ANC), skilled birth attendance (SBA) and optimal post-natal care (PNC), (2) identifying the determinants of drop ping out from one service to another and (3) of not achieving the complete CoC	The study employed data from the Cambodia Demographic Health Survey 2014. We restricted our analysis to married women who had a live birth in the five years preceding the survey (n = 5678). Bi-variate and multivariate logistic regression were performed using STATA version 14	Household wealth was found to be the most influential factor, yet the study discovered also other barriers to optimal maternal health care which need to be addressed
Akhter, & Alam. (2019)	-to present the trends of maternal and neonatal mortality - to explain the maternal and neonatal mortality rate by background characteristics and the causes of maternal and neonatal deaths in Bangladesh on the basis of South Asian perspective	The main source of data collection and analysis was the secondary sources, from different journals and project reports published between the years 2001 to May 2018	In Bangladesh, 35% maternal deaths occurred as indirect causes and 9% causes of deaths are still remaining unidentified. hemorrhage (31%) and pre-eclampsia-eclampsia (20%) are found two vital causes of maternal deaths with two more causes which are due to obstructed labor (7%), and termination of pregnancy (1%)
Akhter et al. (2018)	to present, analyze and interrelate recent data to find barriers to achieving set MDG 5 targets by 2015	literature review has been done as a main method of data collection from Elsevier, Lancet, WHO,	approximately 80% of maternal deaths could be averted if women had access to essential maternity and basic health care services



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		UNICEF, BBMS, NIPORT published from 2001 to May 2018	
Begum et al. (2017)	To identify indications and determinants of C-sections	Retrospective study	During 2013, facility delivery rate was 84% and population-based C-section rate was 35% of all deliveries in icddr,b service area. Of all C-sections, only 1.4% was conducted for Absolute Maternal Indications (AMIs). Major indications of C-sections included: repeat C-section (24%), foetal distress (21%), prolonged labour (16%), oligohydramnios (14%) and post maturity (13%)
Girum and Wasie (2017)	-to identify correlates of maternal mortality in developing countries	Literature review	-Maternal mortality ratio is very high in developing countries and enormously varies among countries -A significant relationship between the maternal mortality ratio and socio-economic, health care and morbidity indicator variables was observed
Wang and Hong (2015)	To understand where the gaps are in seeking care along the pathway and what factors contribute to the gaps.	Used data from the 2010 Cambodia Demographic and Health Survey, we examine the levels of service use along the continuum of care. Three sequential regression models are fitted to identify factor(s) that affect women from getting skilled birth attendance (SBA) after receiving antenatal care (ANC), and from getting postnatal care (PNC) after having both ANC and SBA	Cambodia has made remarkable progress in extending the reach of maternal health care in most areas of the country

Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Oman. 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

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

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 Oman 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	0.200
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	5.411734
Sum Square Error (SSE)	4709.006935
Mean Square Error (MSE)	120.743768
Mean Percentage Error (MPE)	-2.652554
Mean Absolute Percentage Error (MAPE)	20.762512

Residual Analysis for the Applied Model

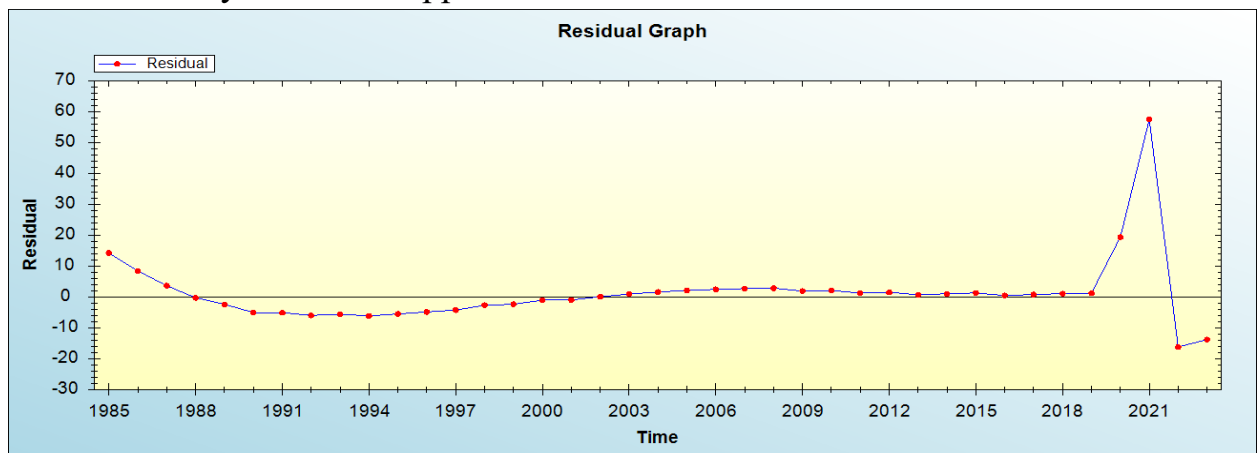


Figure 1: Residual analysis

In-sample Forecast for Z

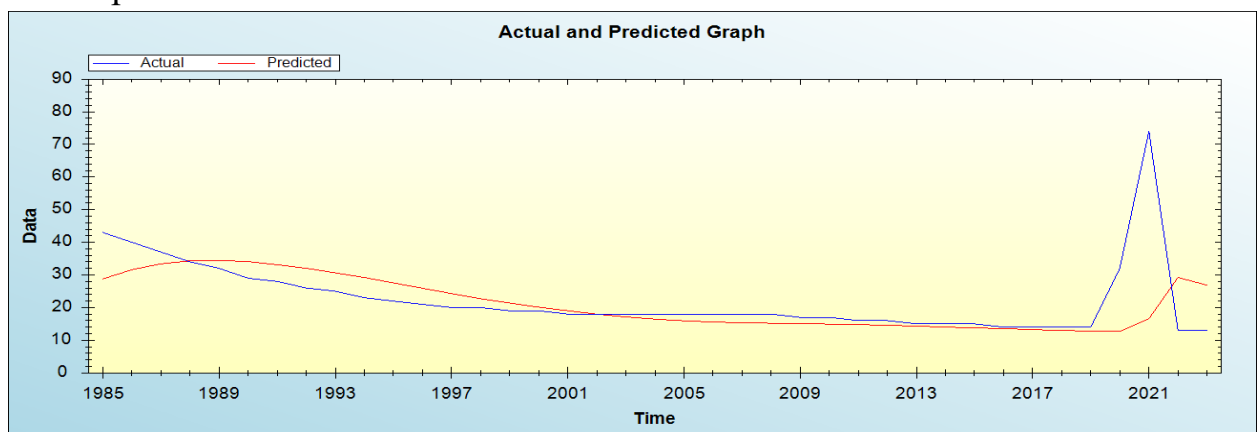


Figure 2: In-sample forecast for the Z series



Actual and Smoothed graph for Z series

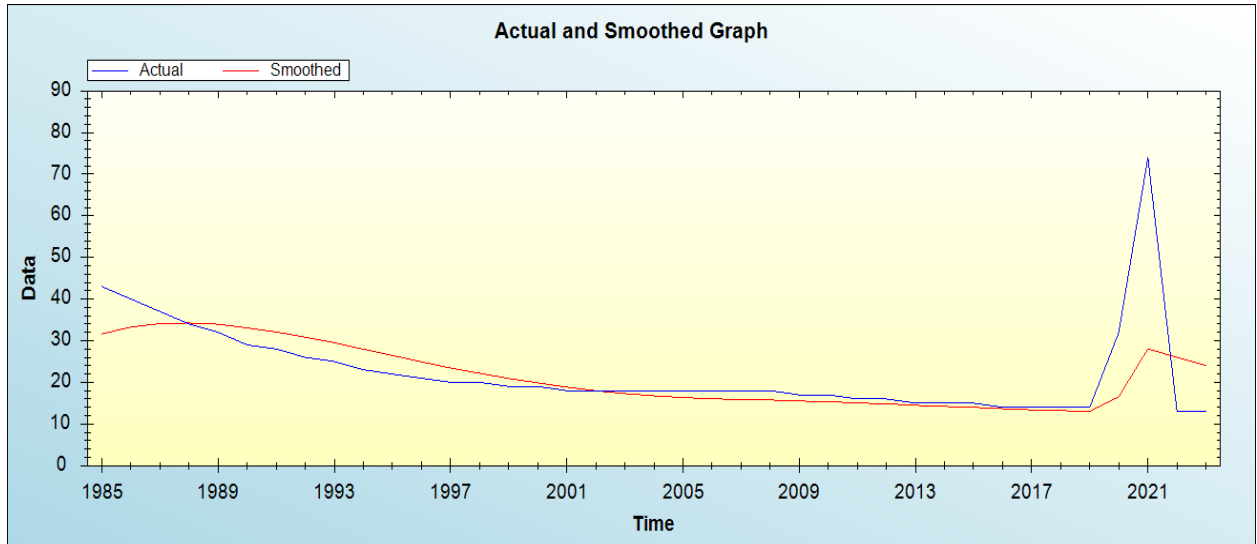


Figure 3: Actual and smoothed graph for Z series

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

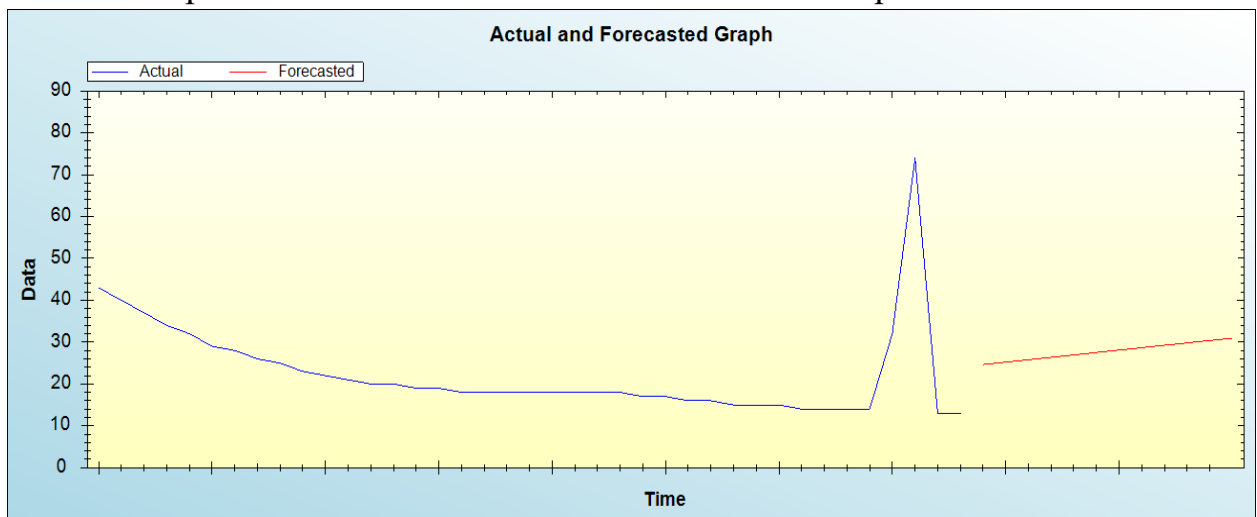


Figure 4: Out-of-sample forecast for Z: actual and forecasted graph



Out-of-Sample Forecast for Z: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	24.6497
2025	25.2240
2026	25.7984
2027	26.3727
2028	26.9470
2029	27.5213
2030	28.0957
2031	28.6700
2032	29.2443
2033	29.8186
2034	30.3930
2035	30.9673

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 slightly increase from around 24.6 in 2024 to about 31 deaths per 100 000 live births by 2035.

Conclusion

Low-middle income countries bear the largest burden of maternal mortality as result of existing gaps in the continuum of care. These countries are affected by shortage of skilled birth attendants, inadequate infrastructure, limited medical supplies and staff incompetencies of varying degree. In this study we applied the double exponential smoothing technique to model and forecast MMR for Oman and results indicate that MMR will slightly increase from around 24.6 in 2024 to about 31 deaths per 100 000 live births by 2035. Therefore, we implore health authorities to address local causes of preventable maternal deaths and direct some of the resources towards implementation of quality improvement strategies.



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