



Maternal Mortality Projections For Azerbaijan Using The Double Exponential Smoothing Technique

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ABSTRACT

This study uses annual time series data on MMR for Azerbaijan 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 0.6 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will continue to decline and reach levels around 20 deaths per 100 000 live births by 2035. Therefore, we encourage authorities to address local causes of avoidable maternal deaths and improve surveillance of severe maternal morbidity.

Keywords:

Exponential smoothing, Forecasting, Maternal Mortality Ratio

Introduction

Azerbaijan's population was estimated to be 10.067 million in 2020 (AZSTAT, 2021), 50.1% of whom are women. In addition, 92% of the population are ethnic Azerbaijanis, while the remaining 8% belong to ethnic minority groups such as the Lezgi (2%), Russians (1.5%), Armenians (1.5%) and others, including the Talysh, Avar, Tat and Georgians. The majority of the population (95%) are Muslim. Above half (52.8%) of the population live in urban areas, while 47.2% reside in rural areas (Gender Country Profile Azerbaijan, 2021). According to Gender Country Profile Azerbaijan, 2021, Azerbaijan's fertility rate indicator has declined to 1.7 in urban areas and 2.0 in rural areas in 2019. Child mortality as reported dropped, while life expectancy has increased in the country in recent years. The child mortality rate fell to 13 in 2019, down from 30.5 in 2000 (World Bank, 2020). Azerbaijan has the highest

rate of abortions among its regional neighbors, including Turkey and Central Asian countries (UNFPA, 2018). This is mainly as a result of a lack of information on contraceptive methods and the prevalence of sex-selective abortions. The adolescent birth rate is 55.8 births per 1,000 women for girls between 15 and 19 years old. For every 100,000 live births, 26.0 women die from pregnancy-related complications. Overall, 93.9% of adult women have reached at least a secondary level of education, compared to 97.5% of men. Women's participation in the labor market stands at 63.4%, compared to a rate of 69.7% for men (AZSTAT, 2020). The objective of this paper is to model and forecast MMR for Azerbaijan using the double exponential smoothing technique. The study findings are envisioned to inform planning and allocation of resources to the health sector with a view to eradicate all preventable maternal deaths.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
Mackin et al. (2026)	-to understand how levels of MNH care are organized in different country contexts	-scoping review of peer-reviewed literature published after 2009.	-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
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	-A prospective cross-sectional study was carried out at Nelson Mandela Academic Hospital, a rural tertiary hospital in the Eastern Cape Province, over a 6-month period between January 2019 and June 2019. All cases that met the WHO criteria for MNM, together with maternal mortality cases, were identified and included in the study	-The conditions that resulted in the highest fatality rate were potentially preventable, namely eclampsia and puerperal sepsis. Many patients with life-threatening conditions were low-risk patients, and this emphasizes the need for more vigilant surveillance of patients during the antenatal, intrapartum and postpartum periods
Maruf et al. (2025)	-To illustrate the potential impact that continued improvements in maternal and neonatal health can have in terms of lives saved, and progress towards development goals	-modelling approach	-If coverage of evidence-based neonatal and maternal interventions reaches 90% of those in need by 2030, the neonatal mortality rate would drop from 36 to 16 per 1,000 live births, and the maternal mortality ratio from 638 to 237 per 100,000 live births
Glass et al. (2023)	-to examine Afghan health workers' experiences and	-conducted a survey	-The combination of economic collapse, lack of sustained

	perceptions of availability and quality of maternal and child health care		donor support for health care and Taliban interference with human rights has severely compromised access and quality of maternal and child health care
Tawfiq et al. (2023)	-to address this knowledge gap	-Data were used from the Afghanistan Health Survey 2018. Women's knowledge in terms of danger signs or symptoms during pregnancy was assessed.	-findings suggest that pregnant women's healthcare seeking behavior is influenced among others by women's knowledge of danger signs and symptoms during pregnancy, women's education, socioeconomic status and access to media
Pouyanfar et al. (2022)	-to investigate the factors affecting the maternal mortality ratio (MMR) in different regions of Iran	-Systematic Review	-While Iran has made significant progress in reducing maternal mortality, rates varied considerably across provinces, ranging from 15.8 to 384 per 100,000 live births
Bartlett et al. (2017)	-to study maternal mortality risk and causes, care-seeking patterns, and costs within the country	-household survey (RAMOS-II) in the urban area of Kabul city and the rural area of Ragh, Badakshan. Questionnaires were administered to senior female household members and data were collected by a team of female interviewers with secondary school education	-Remarkable maternal and other mortality reductions have occurred in Afghanistan, but the disparity between urban and rural sites is alarming, with all maternal mortality indicators significantly higher in Ragh than in Kabul
Girum and Wasie (2017)	to identify correlates of maternal mortality in	This study was conducted using international data	Maternal mortality ratio is very high in developing

	developing countries	bases of health metrics from 2008 to 2016 using aggregates of health indicator data from WHO, World Bank, UNDP and UNICEF data bases for 82 developing countries. The dependent variable was the maternal mortality ratio, while the independent variable was socio-economic, health care related and morbidity variables. Data was compiled in excel and analyzed using SPSS version 21	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. There was an inverse and significant correlation of the maternal mortality ratio with Antenatal care coverage, skilled birth attendance, access to an improved water source and sanitation, adult literacy rate, the Gross National Income per capita and positive relation with disease incidence, unmet need and others
Najafizada et al. (2017)	-to examine the impact of various social determinants of health on maternal health in Afghanistan, filling an important gap in the existing literature	-This narrative review was conducted using Arksey and O'Malley's framework of (1) defining the question, (2) searching the literature, (3) assessing the studies, (4) synthesizing selected evidence in context, and (5) summarizing potential programmatic implication of the context. We	-social determinants such as maternal education, sociocultural practices, and social infrastructure have a significant impact on maternal health

		searched Medline, CABI global health database, and Google Scholar	
Tamburlini et al. (2011)	-to identify priority issues and promote action in maternity and newborn care	-A standard-based tool was used	Quality of care is essential in order to improve maternal and neonatal outcomes
Bimbashi et al. (2010)	-To survey attitudes and an audit of practice in a large maternity hospital in Albania	-Survey of 35 obstetricians and audit of practice during the third stage of labor was conducted in July 2008 at a tertiary referral hospital in Tirana. The survey questionnaire was self-completed.	-Most obstetricians reported always or usually using active management for the third stage of labor. For timing and choice of the uterotonic drug, reported practice was similar to actual practice

Methodology

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

$$A_t = \mu_t + \rho_t \mathbf{t} + \varepsilon_t$$

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**

$\mathbf{t}$ 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 Azerbaijan 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

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	A
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.600

Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	4.395221
Sum Square Error (SSE)	2417.400308
Mean Square Error (MSE)	61.984623
Mean Percentage Error (MPE)	-1.802274
Mean Absolute Percentage Error (MAPE)	11.694169

Residual Analysis for the Applied Model

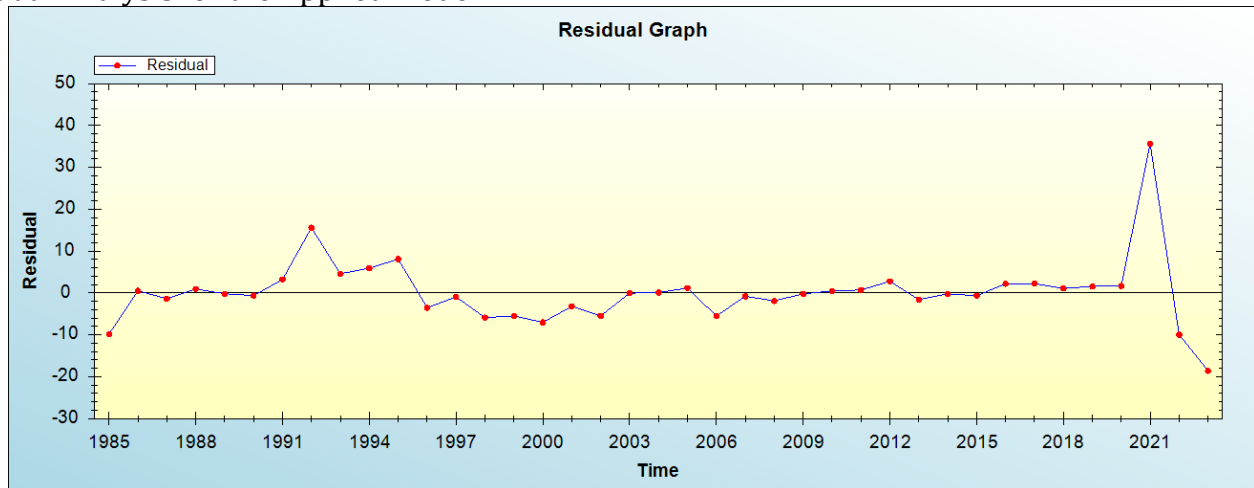


Figure 1: Residual analysis

In-sample Forecast for A

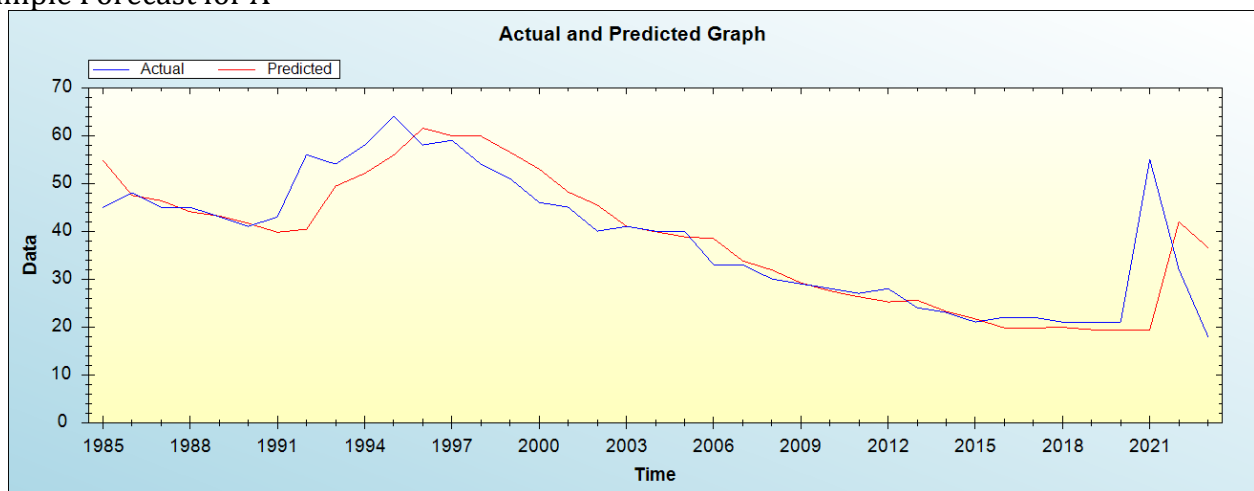


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

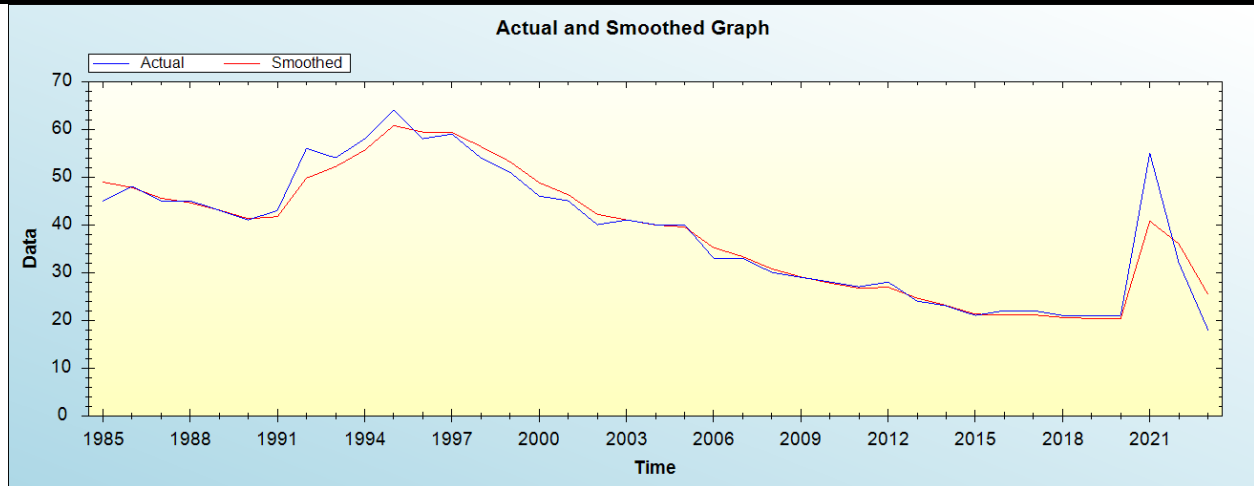


Figure 3: Actual and smoothed graph for A series

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

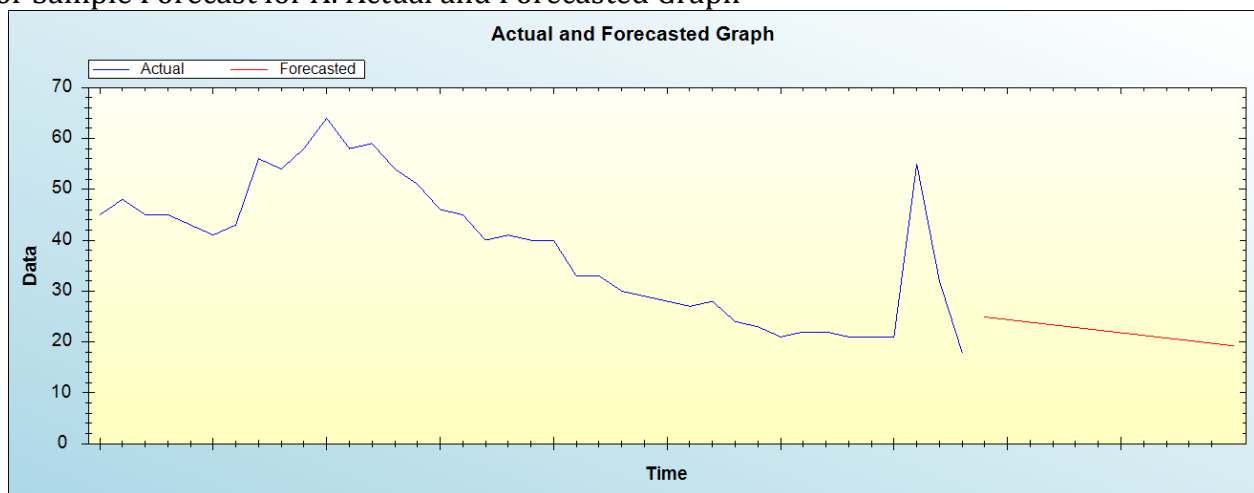


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	24.9137
2025	24.3965
2026	23.8793
2027	23.3620
2028	22.8448
2029	22.3275
2030	21.8103
2031	21.2931
2032	20.7758
2033	20.2586
2034	19.7414
2035	19.2241

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 continue to drop and reach levels around 20 deaths per 100 000 live births by 2035.

Conclusion

This paper highlights the importance of forecasting models in public health. The applied model forecasts indicate that MMR will continue to decline and reach levels around 20 deaths per 100 000 live births by 2035. Therefore, we encourage authorities to address local causes of maternal deaths and also improve on surveillance of severe maternal morbidity across the country.

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