



MATERNAL MORTALITY PREDICTION IN BOLIVIA USING THE DOUBLE EXPONENTIAL SMOOTHING APPROACH

Smartson. P. NYONI¹, Thabani NYONI²

¹Independent Researcher & Medical Doctor, Harare, Zimbabwe

²Independent Researcher & Health Economist, Harare, Zimbabwe

Article history:

Received: November 20th 2025

Accepted: 14th February 2026

Abstract:

This study uses annual time series data on MMR for Bolivia 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 decline but still remain high throughout the out of sample period. Therefore, we encourage authorities to ensure availability of medical supplies and staff, and direct some of the resources towards quality improvement activities across the country.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio

INTRODUCTION

Maternal mortality is often regarded as an indicator of the status of women and the adequacy of the overall healthcare system in a country (UN, 2009), and MMR is a core indicator for sexual and reproductive health within the global developmental agenda (Donati et al. 2016). Nearly 800 pregnant women die every day globally, with a predominant burden observed in low- and middle-income countries (WHO, 2023). The main causes include severe hemorrhage, infections, and hypertensive disorders (PAHO, 2023). The majority of these complications are preventable or manageable. Timely identification of both individual and population-level risk factors, including consistent health care throughout pregnancy and access to essential services that promote wellbeing, can make a huge difference

(Kurjak et al. 2023; Alper et al. 2021). Maternal mortality is an important public problem because of its serious societal, community, and familial consequences (UN, 2016). Bolivia achieved a 52% drop in maternal mortality with a decline from 425 maternal deaths per 100,000 live births in 1990 to 206 maternal deaths per 100,000 live births in 2015 (WHO, 2015). Maternal mortality in Bolivia in 2015 stood at 155 maternal deaths per 100,000 live births (WHO, 2015). The objective of this study is to model and forecast MMR for Bolivia using the double exponential smoothing technique. The findings of this paper will assist in policy making, planning and allocation of adequate resources the health sector so that further reduction of preventable maternal deaths is achieved.

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	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
Tsushima et al. (2026)	To determine the long-term incidence of	Prospective cohort study	postpartum weight change may help



	dysglycemia and dyslipidemia after GDM and evaluated whether postpartum changes in body mass index (BMI) independently predicted these outcomes		identify women at higher risk of subsequent metabolic abnormalities, particularly dysglycemia, in this high-risk population, although causal relationships cannot be inferred from this observational study
Yue et al. (2026)	to perform an umbrella review to summarize the current evidence to provide a reference for clinicians and future research	Systematic literature review	This review offers a thorough overview of the current evidence linking SLE, SS and APS to pregnancy and assisted reproductive outcomes. It identifies existing gaps and proposes future research directions
Cresswell et al. (2025)	To obtain updated evidence on causes of maternal death is needed to accelerate progress	Systematic review	Globally, the most common cause of maternal death was hemorrhage (27%; 80% uncertainty interval 22–32), followed by indirect obstetric deaths (23%, 18–30), and hypertensive disorders (16%, 14–19). The proportion of hemorrhage deaths varied substantially by region and was highest in sub-Saharan Africa and Western Asia and Northern Africa.
Quiroz-Acuña et al. (2025)	To assess maternal mortality trends in LAC women from 1997 to 2019, providing key insights to address this issue.	ecological observational time-series study	Despite overall progress, regional differences in maternal mortality persist across Latin America and the Caribbean. These variations highlight the importance of strengthening maternal health systems, improving access to skilled birth attendance, and ensuring quality



			prenatal and postnatal care
Silvana et al. (2025)	To describe the factors influencing the reduction of maternal mortality during the 2022–2024 management period at Tartagal Hospital (HT)	Participatory Action Research (PAR) with a qualitative-quantitative analysis. Twelve meetings and interviews were conducted with the healthcare team, along with 10 validated surveys administered to obstetric inpatients (10/12/24), and an analysis of hospital databases	intercultural, comprehensive, and territory-based management of pregnancy and childbirth led to a reduction in maternal mortality beginning in 2022. Teamwork and intersectoral collaboration optimized available resources, consolidating a sustainable and effective model for maternal health. However, the greatest challenge lies in maintaining and increasing funding to ensure the continuity of this policy
Nigenda and Serván-Mori (2024)	To discuss the relationship between the availability of human resources for health and the maternal mortality ratio for the period 1990–2021 in Latin America	used secondary data from a global source to show patterns in the relationship between these two aspects and identify gaps in the Latin American and Caribbean regions	Although variations in maternal mortality rate cannot be explained solely through the provision of health personnel, it is important to consider that it is critical to find new modalities on how human resources for health could integrate and create synergies with other resources to increase systems capacity to deliver care according to conditions in each country
Silva et al. (2024)	To assess maternal mortality (MM) in Brazilian Black, Pardo, and White women	evaluated the maternal mortality rate (MMR) using data from the Brazilian Ministry of Health public databases from 2017 to 2022. We compared MMR among Black, Pardo, and White women according to the region of the country, age, and cause. For statistical analysis, the	Black women presented higher MMR in all years, in all geographic regions, age groups, and causes. In Brazil, Black skin color is a key MM determinant



		Q2 test prevalence ratio (PR) and confidence interval (CI) were calculated	
Critto et al. (2022)	To examine the effects of a pandemic influenza virus on cause-specific maternal mortality time series, using Argentinian vital statistics	-conducted a population-based natural experiment from national vital records of maternal deaths between 1980 and 2017 -applied Join-point regression models	Over this 38-year study, the MMR decreased by 58.6% (69.5 to 28.8 deaths/100,000 live births), transitioning from direct obstetric causes (67.0 to 21.1/100,000 live births; 68.4% decrease) to indirect causes (2.6 to 7.7/ 100,000 live births; 196.2% increase)

METHODOLOGY

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

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

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**

$\mathbf{t}$ 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 Bolivia 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)	14.077405
Sum Square Error (SSE)	28855.930337
Mean Square Error (MSE)	739.895650
Mean Percentage Error (MPE)	-0.180975
Mean Absolute Percentage Error (MAPE)	5.659485

Residual Analysis for the Applied Model

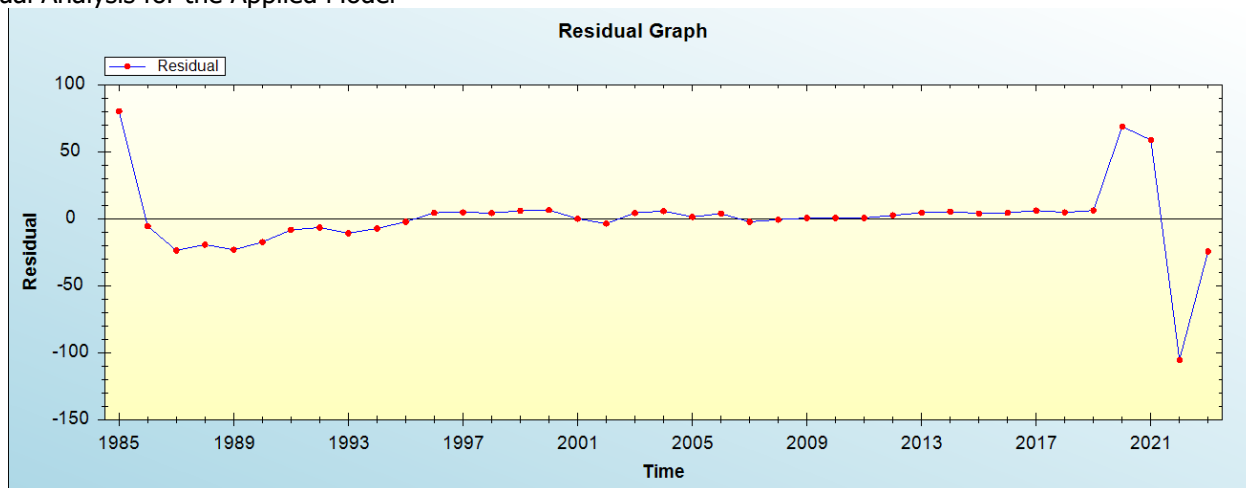


Figure 1: Residual analysis

In-sample Forecast for Z

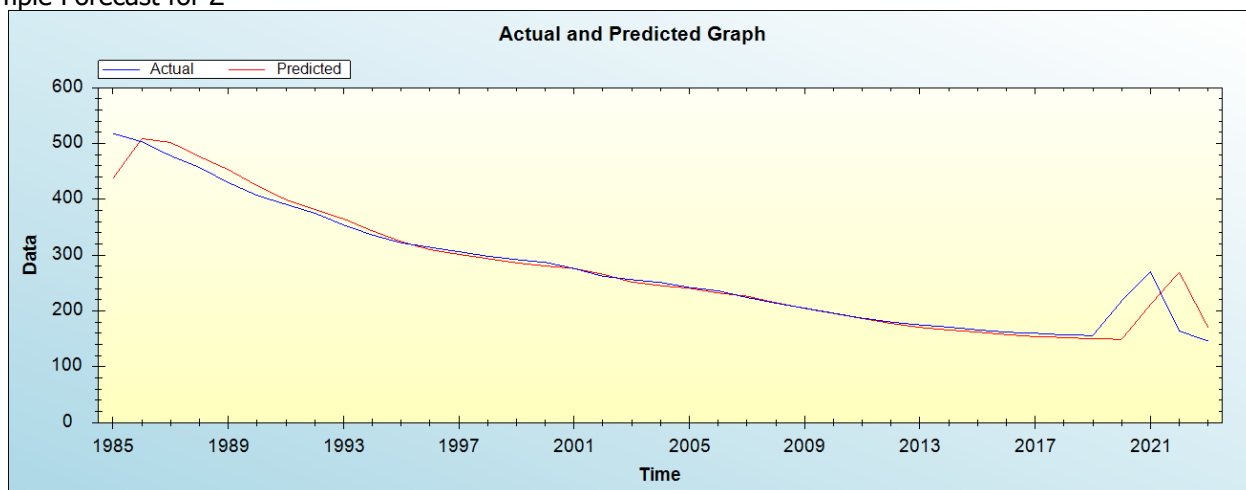


Figure 2: In-sample forecast for the Z series

Actual and Smoothed graph for Z series

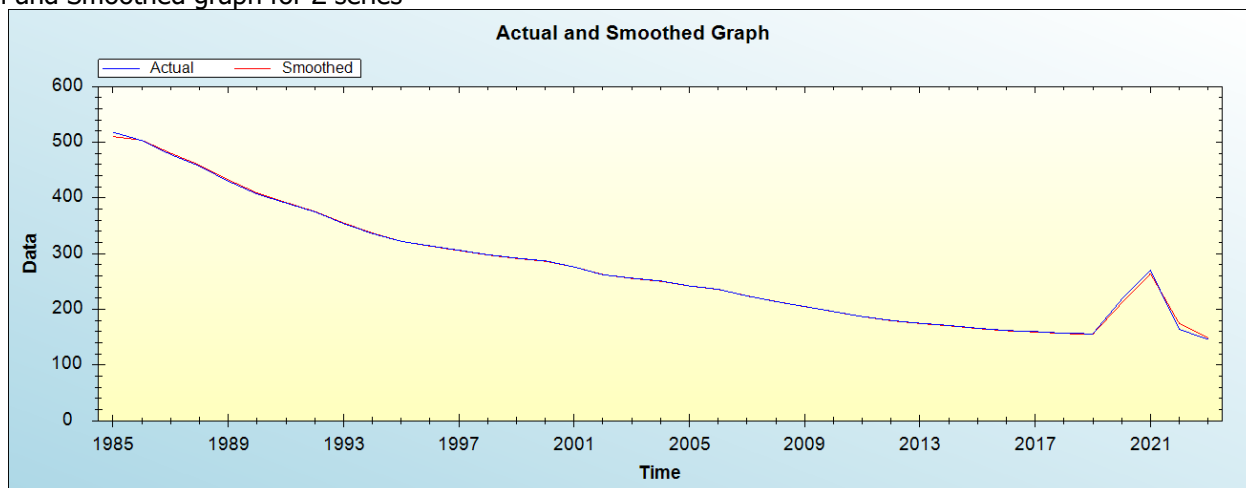


Figure 3: Actual and smoothed graph for Z series

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

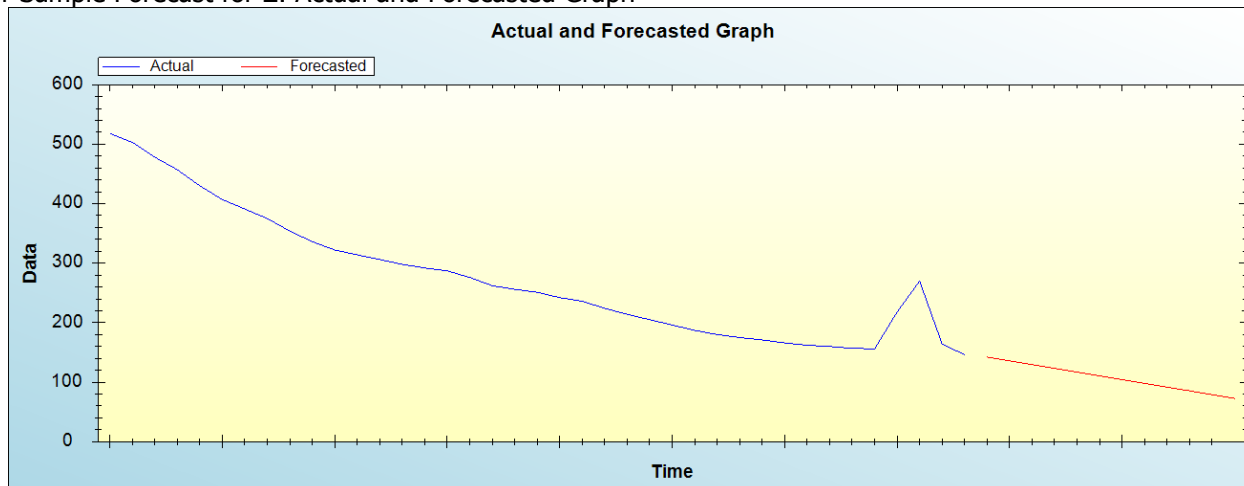


Figure 4: Out-of-sample forecast for Z: actual and forecasted graph

Out-of-Sample Forecast for Z: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	142.1407
2025	135.8365
2026	129.5324
2027	123.2283
2028	116.9241
2029	110.6200
2030	104.3159
2031	98.0118
2032	91.7076
2033	85.4035
2034	79.0994
2035	72.7953

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 decline but still remain high over the out of sample period

RECOMMENDATIONS & CONCLUSION

Maternal mortality rates in Bolivia are relatively high although significant reduction was observed over the previous decades. This paper uses the double exponential smoothing model to project MMR for Bolivia with results indicating that MMR will decline but still remain high throughout the out of sample period. This paper argues that there is need to continuously ensure availability of adequate medical supplies and health care staff at all levels of healthcare across the country and authorities should focus on quality improvement initiatives.

REFERENCES

1. Alper J., Martinez R.M., and McHugh K (2021), National Academies Press (US), National Academies of Sciences, Engineering, and Medicine (US), National Academies of Sciences, Engineering, and Medicine (US) (Eds). Advancing maternal health equity and reducing maternal morbidity and mortality: proceedings of a workshop. Washington, DC: National Academies Press, 2021
2. Donati S., Maraschini A., and Buoncristiano M (2016). Methods to estimate maternal mortality: a global perspective. J Epidemiol Community Health. 2016; 70:217–8.
3. Kurjak A., Stanojević M., and Dudenhausen J (2023). Why maternal mortality in the world remains tragedy in low-income countries and shame for high-income ones: will sustainable development goals (SDG) help? Journal of



Perinatal Medicine 2023; 51(2): 170-181. DOI link, PMid:35636412

4. Pan American Health Organization (2023). Maternal health. Available: web link (Accessed 2 October 2023).
5. United Nations (2009). 'All people benefit' when maternal health care is improved: UN Secretary-General's message marking the fifteenth anniversary of population and development conference (ICPD). <https://www.un.org/press/en/2009/sgsm12539.doc.htm>.
6. United Nations (2016). Sustainable Development Goals. Available: web link (Accessed 1 September 2022)
7. WHO (2015). EPMM Working Group, Strategies toward ending preventable maternal mortality (EPMM).
8. World Health Organization (2015). Trends in maternal mortality: 1990–2015: estimates by WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division. Geneva: WHO; 2015. p. 2015.
9. World Health Organization (2023). Trends in maternal mortality 2000 to 2020: estimates by WHO, UNICEF, UNFPA, World Bank Group and UNDESA/Population Division. Geneva: World Health Organization, 2023