

Estimating Future Values Of Annual Maternal Mortality For Guatemala Using The Double Exponential Smoothing Technique

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Abstract

This study uses annual time series data on MMR for Guatemala 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 from around 91 in 2024 to around 54 deaths per 100 000 live births in 2035. Therefore, we encourage authorities to attend to local causes of maternal mortality and direct some of the resources to quality improvement activities.

Keyword(s): - *Exponential smoothing, Forecasting, Maternal Mortality Ratio*

Introduction

Guatemala has a Human Development Index (HDI) of 0.581 and is considered one of the least developed countries in Latin America and ranked 133rd in the list of 161 countries included by UNDP in the Human Development Report 2013 (Khalid et al. 2013). The main causes of maternal mortality in Latin America and the Caribbean are hypertensive disease (25% of total deaths), postpartum hemorrhage (21%), obstructed labor (13%), abortions (12%) and sepsis/ infections (8%).³ Meanwhile, the main causes of infant mortality in developing countries are pneumonia (19%), diarrhea (18%) and malaria (8%), followed by episodes related to pregnancy and childbirth, such as prematurity (10%), neonatal sepsis (10%) and asphyxia at birth (8%) (Khalid et al; 2006; Bryce et al. 2005). Guatemala has made significant national progress in lowering its maternal mortality ratio (MMR) to 88 maternal deaths per 100,000 live births (WHO, 2015). This national average masks huge regional and ethnic disparities. The MMR for indigenous women (163 per 100,000) is twice that of non-indigenous women (78 per 100,000), and indigenous women account for 71% of the country's maternal deaths compared with 54% of the country's births. In addition, the national percentage of deliveries that occur in facilities is 29% for indigenous women and 70% for non-indigenous women (SEGEPLAN, 2011). The purpose of this study is to model and forecast MMR for Guatemala using the double exponential smoothing technique. The study findings are expected to inform policy, planning and allocation of resources to the maternal and child health program in order to further reduce maternal mortality to levels below 30 deaths per 100 000 live births.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
Marks & Castro (2026)	To examine how MWHs have been implemented across Latin America, analyzing their evolution, the specific needs they address in different countries, and their impact on maternal and neonatal	Systematic review	The evolution of MWHs suggests that they address a spectrum of needs beyond their original purposes, such as providing culturally responsive maternal support and psychosocial and

	health outcomes throughout the region		early childhood support
Cuestas et al. (2026)	To analyze whether the proportion of Indigenous and Afro-Colombian populations at the municipality level (admin level 3) is associated with high levels of maternal mortality rates in Colombia between 2017 and 2020	Ecological study	-Maternal mortality rates increased between 2017 and 2020, and the increase was concentrated in municipalities in remote areas -municipalities with a higher proportion of Indigenous and Afro-Colombian populations have higher probabilities of presenting high rates of maternal mortality, and when these populations are living in rural areas, maternal mortality increases even more
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 dysglycemia and dyslipidemia after GDM and evaluated whether postpartum changes in body mass index (BMI) independently predicted these outcomes	Prospective cohort study	postpartum weight change may help 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	Systematic literature review	This review offers a thorough overview of the current evidence

	evidence to provide a reference for clinicians and future research		linking SLE, SS and APS to pregnancy and assisted reproductive outcomes. It identifies existing gaps and proposes future research directions
Cruz-Barbosa et al. (2025)	To describe the sociodemographic and anatomopathological characteristics associated with autopsy-verified maternal mortality cases at a Level-4 hospital in southwestern Colombia (2000–2023)	Descriptive retrospective study	The analysis of 42 autopsies (2000–2023) showed that 85.7% were early maternal deaths. Indirect causes predominated (57.1%, n = 24) over direct (42.9%, n = 18). Septic shock was the main indirect cause (65.2% of indirect), often from endemic infections. Hypovolemic shock due to PPH was the main direct cause (50% of direct). A high proportion were from subsidized/uninsured schemes (65.7%) and had a migratory history (20%)
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.

Goicochea et al. (2025)	to identify and analyze maternal complications associated with adolescent pregnancy, with a particular focus on the Latin American context	Mixed methods approach	adolescent pregnancy in Latin America and the Caribbean entails significant medical risks and negatively affects the integral development of adolescents, a situation that is aggravated by the lack of access to health services, education and by factors such as poverty
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
Salazar Flórez et al. (2025)	to examine the trends in maternal mortality in Colombia and its social disparities based on the area of residence from 2014 to 2021	Ecological study	Maternal mortality rates have increased in recent years, with a more pronounced rise in remote rural areas than in settlements and municipal centers
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
Castañeda- Orjuela et al. (2023)	to examine changes in maternal mortality and identify correlates and predictors of excess maternal mortality in Colombia during the pandemic	Analysis of data from the national epidemiological surveillance databases of Colombia (Sivigila)	The COVID- 19 pandemic had considerable impact on maternal health, not only by leading to increased deaths, but also by increasing social health inequity
Rodríguez Hernández et al. (2023)	to analyze the inequalities and inequities in Maternal Mortality (MM) for Chocó (Colombia) between 2010–2018	Mixed method study	The Maternal Mortality Ratio was 224/100 000 live births. The Gini coefficient was 0.35, indicating inequality in the distribution of the number of MM with respect to live births
Critto et al. (2022)	To examine the effects of a pandemic influenza virus on cause-specific	-conducted a population-based natural experiment from national vital	Over this 38-year study, the MMR decreased by 58.6% (69.5 to 28.8

	maternal mortality time series, using Argentinian vital statistics	records of maternal deaths between 1980 and 2017 -applied Join-point regression models	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)
Stollak et al. (2016)	to assess the contribution of 2 Casas Maternas in Guatemala to health facility deliveries among partner and non-partner communities, with particular emphasis on equity in access	Mixed methods approach	The Casa Materna approach to strengthening maternity care as developed by Curamericas has potential to increase health facility utilization in isolated mountainous areas inhabited by an indigenous population where access to government services is limited and where maternal mortality is high

Methodology

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

$$G_t = \mu_t + \rho_t t + \varepsilon_t$$

Smoothing equation

$$S_t = \alpha G_t + (1-\alpha) (S_{t-1} + b_{t-1})$$

$$0 < \alpha < 1$$

Trend estimation equation

$$b_t = \beta (S_t - S_{t-1}) + (1 - \beta)b_{t-1}$$

$$0 < \beta < 1$$

Forecasting equation

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

G_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 Guatemala 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	G
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	6.040308
Sum Square Error (SSE)	2978.856663
Mean Square Error (MSE)	76.380940

Mean Percentage Error (MPE)	0.540605
Mean Absolute Percentage Error (MAPE)	3.834987

Residual Analysis for the Applied Model

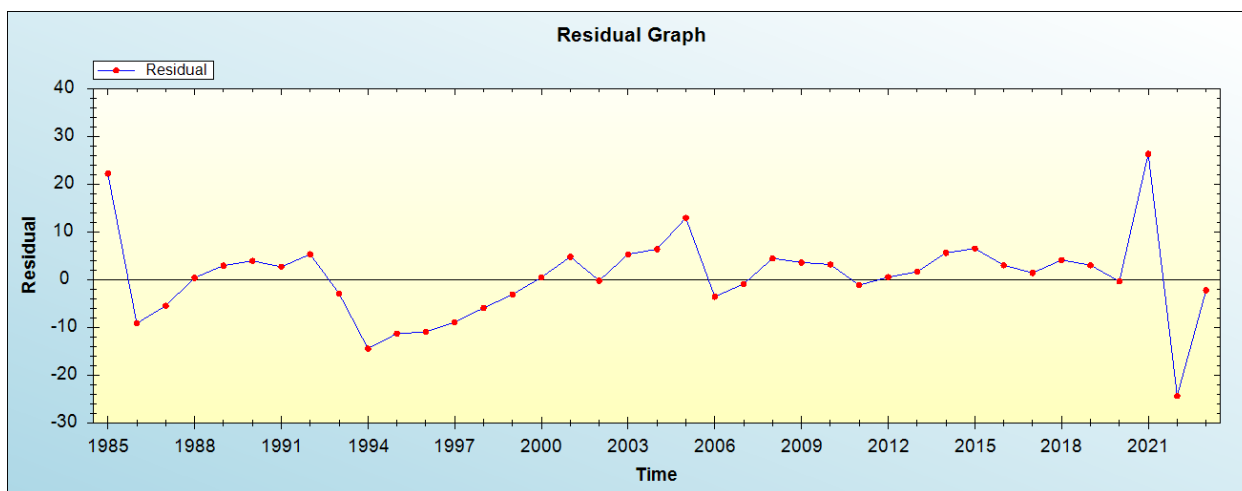


Figure 1: Residual analysis

In-sample Forecast for G

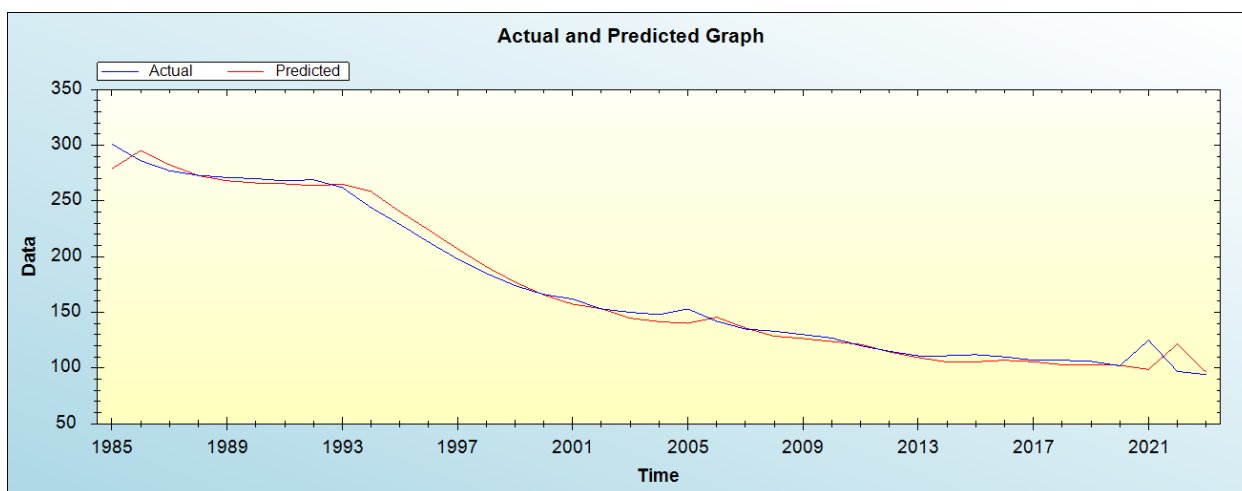


Figure 2: In-sample forecast for the G series

Actual and Smoothed graph for G series

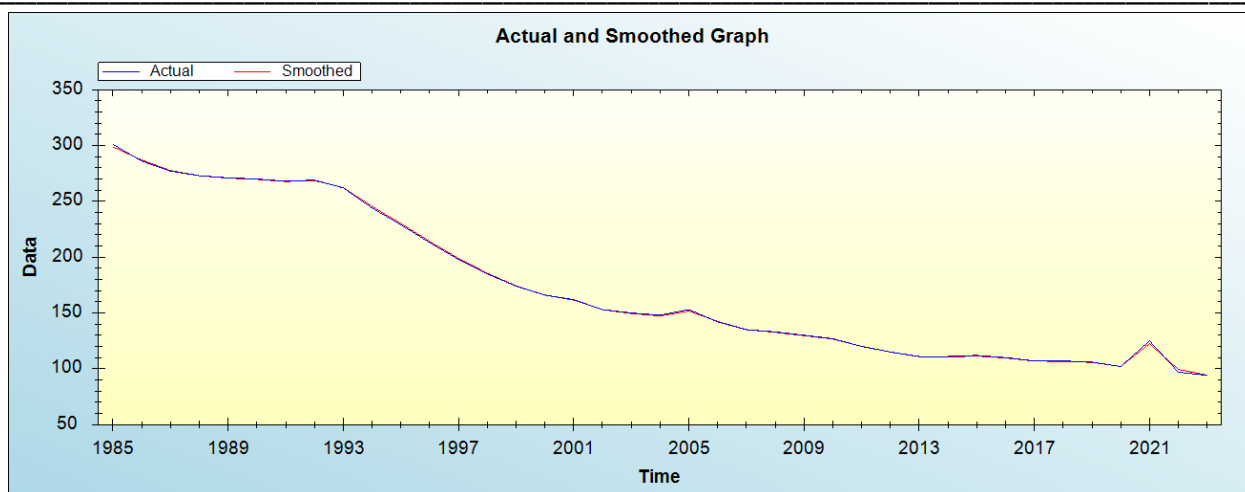


Figure 3: Actual and smoothed graph for A series

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

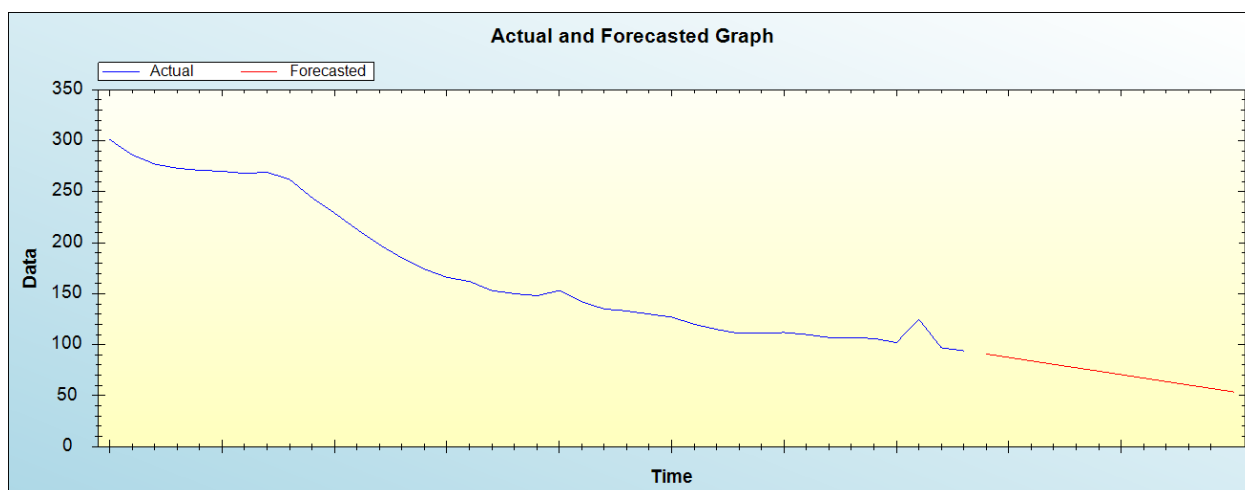


Figure 4: Out-of-sample forecast for G: actual and forecasted graph

Out-of-Sample Forecast for G: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	90.8502
2025	87.4737
2026	84.0973
2027	80.7208

2028	77.3443
2029	73.9679
2030	70.5914
2031	67.2149
2032	63.8385
2033	60.4620
2034	57.0855
2035	53.7091

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 from around 91 in 2024 to around 54 deaths per 100 000 live births in 2035.

Recommendations & Conclusion

Maternal mortality is still a problem in the Americas including Guatemala. The mountainous areas of Guatemala have higher mortality rates when compared to other areas. Government health programs should relentlessly target these areas in order to achieve desired health outcomes at the community level. This paper applied the double exponential smoothing model to forecast MMR for Guatemala and the results indicate that MMR will decline from around 91 in 2024 to around 54 deaths per 100 000 live births in 2035. Hence, we implore health authorities to address local factors associated with maternal deaths and conduct routine quality improvement activities during the antenatal, child birth and postpartum periods.

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