

ESTIMATING FUTURE VALUES OF ANNUAL MATERNAL MORTALITY RATE FOR LATIN AMERICA AND THE CARIBBEAN USING HOLT'S LINEAR METHOD

Smartson. P. NYONI¹

Thabani NYONI²

¹Independent Researcher & Medical Doctor, Harare, Zimbabwe

²Independent Researcher & Health Economist, Harare, Zimbabwe

ABSTRACT

This study uses annual time series data on MMR for Latin America and the Caribbean 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 0.8 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will decline from around 73 in 2024 to about 57 deaths per 100 000 live births in 2035. Therefore, we encourage health authorities in this region to adopt the suggested 5-fold policy prescription.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio

INTRODUCTION

Maternal mortality is defined as the demise of a woman while pregnant or within 6 weeks of the termination of her pregnancy, regardless of the duration and site of the pregnancy, due to any cause related to or worsened by the pregnancy itself or related care, but not due to accidental or incidental causes (WHO, 2021). During the period 1990-2015, maternal mortality ratio in the Americas declined by 49% (PAHO, 2017). According to WHO data MMR dropped to 58 maternal deaths per 100,000 live births in 2017 (WHO, 2000). However, disparities continue to exist in maternal mortality across countries in the Americas, ranging from 10 maternal deaths per 100,000 live births in Canada to as high as 480 per 100,000 in Haiti in 2017 (WHO, 2000). These disparities are due to socio-economic factors both between geographic areas and population groups. Across and within countries alike, maternal deaths are disproportionately concentrated in women and territories that are poorer, less educated, or that have less access to sanitation and, more proximally, less access to timely and quality health care services (Enríquez-Nava et al. 2020; Tullo et al. 2020; Casalino-Rojo et al. 2018; PAHO, 2017; Sanhueza et al. 2017). The objective of this paper is to model and forecast MMR for Latin America and the Caribbean using Holt's linear method. The findings of this study will inform policy making, planning and allocation of resources to the maternal and child health program in the region in order to eliminate all avoidable maternal deaths.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Key finding(s)
Becerra et al. (2026)	to identify and analyze maternal complications associated with adolescent pregnancy, with a particular focus on the Latin American context	qualitative and descriptive 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
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
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 health outcomes throughout the region	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 early childhood support
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 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
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)
Hill et al. (2009)	To assess the feasibility of measuring maternal mortality in countries lacking accurate birth and death registration through national population censuses by a detailed evaluation of such data for three Latin American countries	Applied established demographic techniques	The PRMRs for Honduras (2001), Nicaragua (2005) and Paraguay (2002) were 168, 95 and 178 per 100 000 live births, respectively. Surprisingly, evaluation of the data for Nicaragua and Paraguay showed overreporting of adult deaths, so a downward adjustment of 20% to 30% was required

METHODOLOGY

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Latin America and the Caribbean. 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

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

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 Latin America and the Caribbean 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	0.800
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	6.958139
Sum Square Error (SSE)	6517.495348
Mean Square Error (MSE)	167.115265
Mean Percentage Error (MPE)	-0.043267
Mean Absolute Percentage Error (MAPE)	6.597705

Residual Analysis for the Applied Model

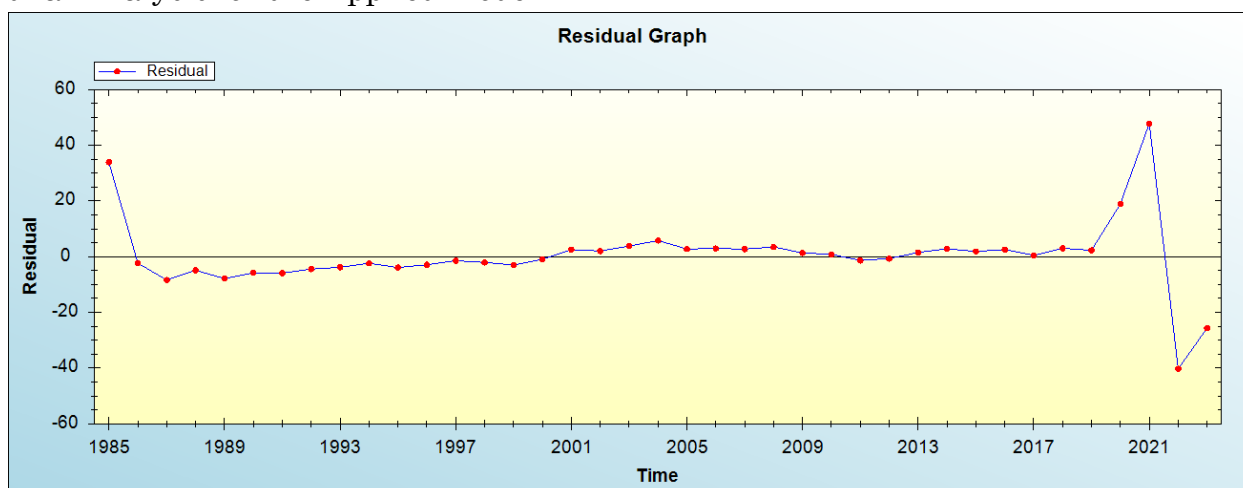


Figure 1: Residual analysis

In-sample Forecast for A

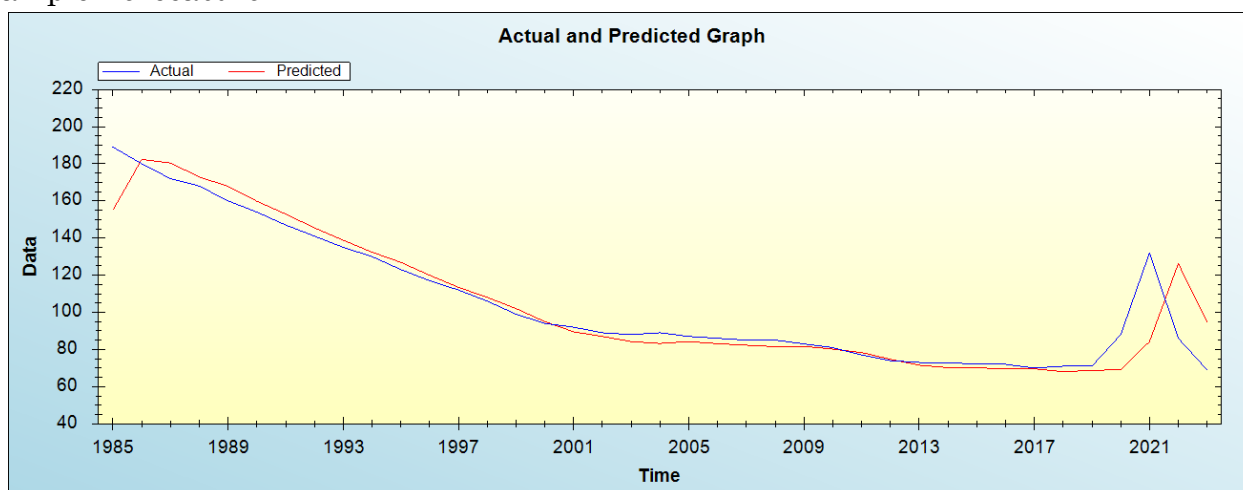


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

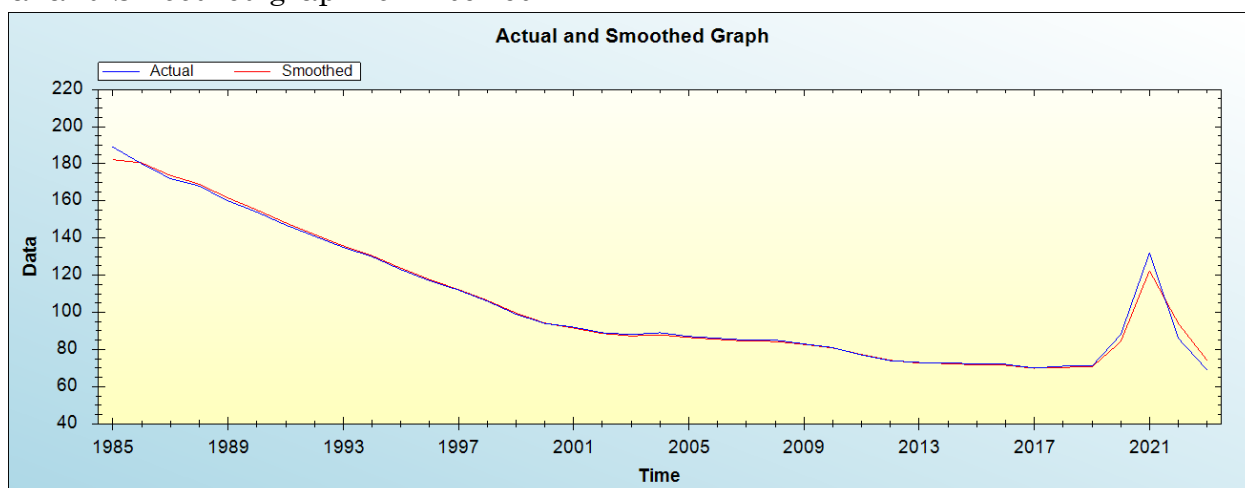


Figure 3: Actual and smoothed graph for A series

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

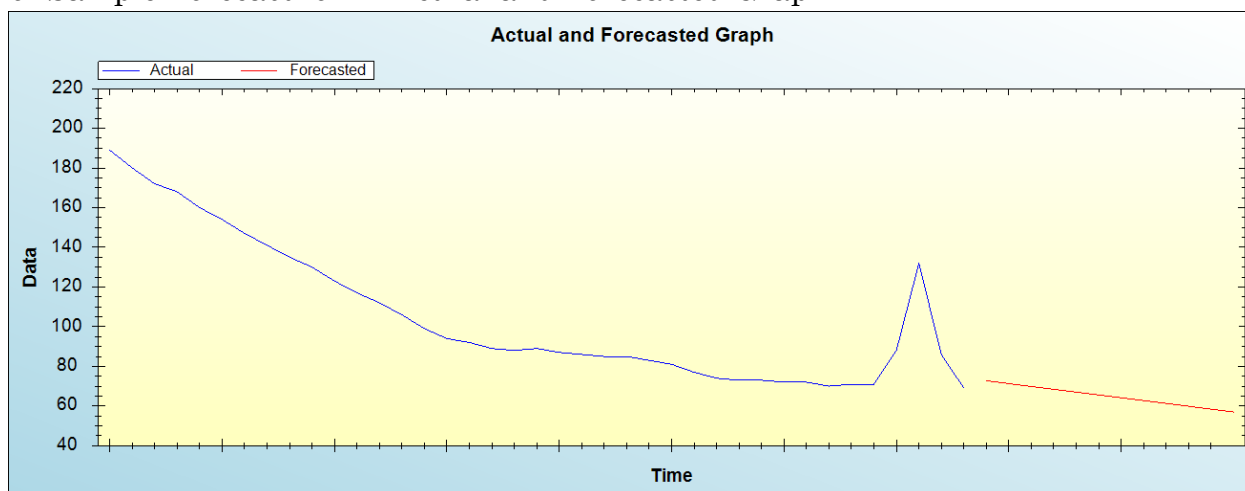


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	72.7099
2025	71.2823
2026	69.8547
2027	68.4271
2028	66.9995
2029	65.5719
2030	64.1442
2031	62.7166
2032	61.2890
2033	59.8614
2034	58.4338
2035	57.0062

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 73 in 2024 to about 57 deaths per 100 000 live births in 2035.

RECOMMENDATIONS & CONCLUSION

Maternal mortality remains a public health issue in the Americas with countries such as Haiti still reporting very high maternal mortality rates. Regional effort is required to eliminate maternal mortality in this part of the world. This paper uses Holt's linear method to forecast MMR for Latin America and the Caribbean and study findings indicate that MMR will decline from around 73 in 2024 to about 57 deaths per 100 000 live births in 2035. Therefore, we encourage regional authorities to adopt the following policy prescription: (1) curb teenage pregnancy by enforcing laws that prohibit early child marriage, promote female education and comprehensive sexual and reproductive health education in schools (2) Improve coverage of maternal and child health services across the region (3) carryout routine quality improvement activities (4) ensuring availability of adequate commodities and medical staff in all medical facilities and (5) to improve on surveillance of severe maternal morbidities and address root causes.

REFERENCES

1. Casalino-Rojo E., Ochoa-Almenabar E., Mujica O.J., and Munayco C.V (2018). Desigualdades sociogeográficas en la mortalidad materna en Perú: 2001–2015 [Sociogeographic inequalities in maternal mortality in Peru: 2001–2015]. *Rev Peru Med Exp Salud Publica*. 35(2):351–3.
2. Enríquez-Nava M.F., Esquivel-Velásquez A.D., PatónSanjines M., Pooley Ayarza B.C., Alarcón R., Hernández Muñoz R (2020). Comportamiento y desigualdades sociales en indicadores priorizados del Objetivo de Desarollo Sostenible 3 en Bolivia [Behavior and social inequalities in prioritized indicators of Sustainable Development Goal 3 in Bolivia]. *Pan Am J Public Health*. 2020;44: e1018.
3. PAHO (2017). Regional progress towards achieving the health-related Millennium Development Goals. Washington DC.
4. Pan American Health Organization (2017). Health in the Americas +, 2017 Edition. Summary: Regional outlook and country profiles.
5. Sanhueza A., Roldán J.C, Ríos P., Acuña M.C., and Espinosa I (2017). Social inequalities in maternal mortality among the provinces of Ecuador. *Pan Am J Public Health*. 2017;41: e97.
6. Tullo E., Lerea M.J., González R., Galeano J., Insfrán M.D., and Muñoz M (2020). Desigualdades sanitarias y sociales en la salud materna y del niño en Paraguay [Health and social inequalities in maternal and child health in Paraguay]. *Pan Am J Public Health*. 2020;44: e107.
7. WHO (2000). Trends in Maternal Mortality. to 2017: estimates by WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division. Geneva, p. 2019.
8. WHO (2021). International Classification of Diseases, Eleventh Revision (ICD-11), World Health Organization (WHO) 2019/2021. [https:// icd. who. int/ browsell](https://icd.who.int/browsell).