



FORECASTING ANNUAL MATERNAL MORTALITY RATE FOR PARAGUAY USING THE DOUBLE EXPONENTIAL SMOOTHING METHOD

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Abstract

This study uses annual time series data on MMR for Paraguay 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 continue to drop and reach levels below 10 deaths per 100 000 live births by 2035. Therefore, we encourage authorities to relentlessly address local causes of maternal mortality.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

Maternal mortality ratio (MMR) is a measure of the risk of death linked to 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 decline of 2.9% per year (WHO, 2023; WBG, 2023; WHO, 2020). In the Americas region, the average maternal mortality ratio was 67 per 100,000 live births in 2017, but with wide disparities between countries, from less than 10 per 100,000 in Canada and the United States, to 476 per 100,000 in Haiti (OMS, 2023; OPS & OMS, 2019). Paraguay, over the period 2008-2018, has managed to reduce MMR from a ratio of 117 to 71 per 100,000 live births (Mora-Escobar et al. 2020). However, this progress has not been equitable, with higher mortality being recorded in some regions of the country. The aim of this study is to model and forecast MMR for Paraguay using the double exponential smoothing technique. The study results are expected to guide policy and allocation of resources with a view to lower further preventable maternal deaths across the country.

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,	Systematic review	The evolution of MWHs suggests that they address a spectrum of needs beyond their original purposes, such



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	analyzing their evolution, the specific needs they address in different countries, and their impact on maternal and neonatal health outcomes throughout the region		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.
Espínola-Canata et al. (2025)	-To examine the characteristics of MM in Paraguay between 2014 and 2021 - to describe the sociodemographic and clinical characteristics	-a retrospective cross-sectional descriptive study was conducted using data from death certificates of the General Directorate of Strategic Health Information (DIGIES) of	there were 740 maternal deaths, with an average ratio of 83.91 per 100,000 live births. 2021 had the highest ratio (159.98). The majority occurred in young (58.65 %) and adult women (66.31 %),



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	of maternal mortality in Paraguay during the period 2014-2021	the Ministry of Public Health and Social Welfare - analyzed 740 cases of maternal deaths registered in the 18 Health Regions of the country, considering sociodemographic variables and variables related to causes of death	with predominant causes being diseases of Respiratory System 18.11 %, toxemia 15.81 %, and hemorrhaged 12.03 %
Federico et al. (2025)	To describe the clinical characteristics and outcomes of obstetric patients admitted to the multi-purpose intensive care units of two public hospitals in Paraguay during the period 2018-2023	An observational, descriptive, retrospective study was conducted in two public referral hospitals in Paraguay between January 2018 and December 2023	Obstetric patients represent a low percentage of intensive care admissions in the hospitals studied. They were characterized as a young population, predominantly postpartum women, whose main causes of admission were hypertensive disease of pregnancy and postpartum hemorrhage. The observed mortality was low compared to similar studies in the region
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,



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			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)
Ester et al. (2020)	To analyze the situation of Maternal Deaths in Paraguay and the scope of 2008 to 2018 period	Observational, descriptive, transverse and retrospective study	abortion (20.1%), hemorrhagic complications (19.8%) hypertensive disorders (18.7%), sepsis (4.6%), AIDS (1.1%), obstetric tetanus (0.3%), other perinatal complications (35.4%); and the main causes of direct MD in 2018 continue to be main causes of maternal mortality
Villalba & Sa'nchez (2020)	To describe tendencies and factors involved in the MMR in Paraguay, South America	retrospective cross-sectional study	The study showed significant decreased tendency of MMR, although remaining high compared to high income countries
Hill et al. (2009)	To assess the feasibility of measuring maternal	Applied established demographic techniques	The PRMRs for Honduras (2001), Nicaragua (2005) and Paraguay (2002) were



	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		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
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Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Paraguay. 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 Paraguay 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	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	9.929792
Sum Square Error (SSE)	11842.630699
Mean Square Error (MSE)	303.657197
Mean Percentage Error (MPE)	-0.657694
Mean Absolute Percentage Error (MAPE)	9.400618



Residual Analysis for the Applied Model

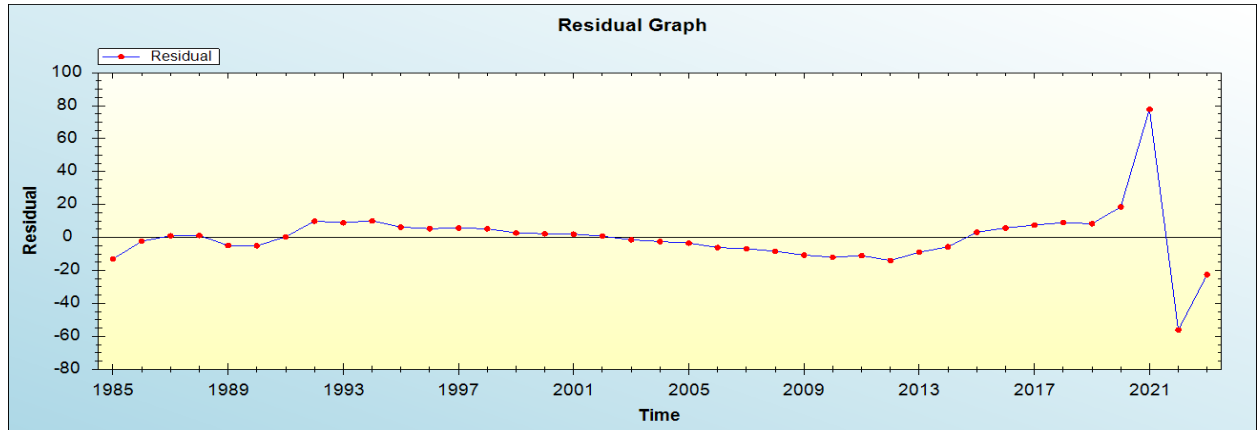


Figure 1: Residual analysis

In-sample Forecast for A

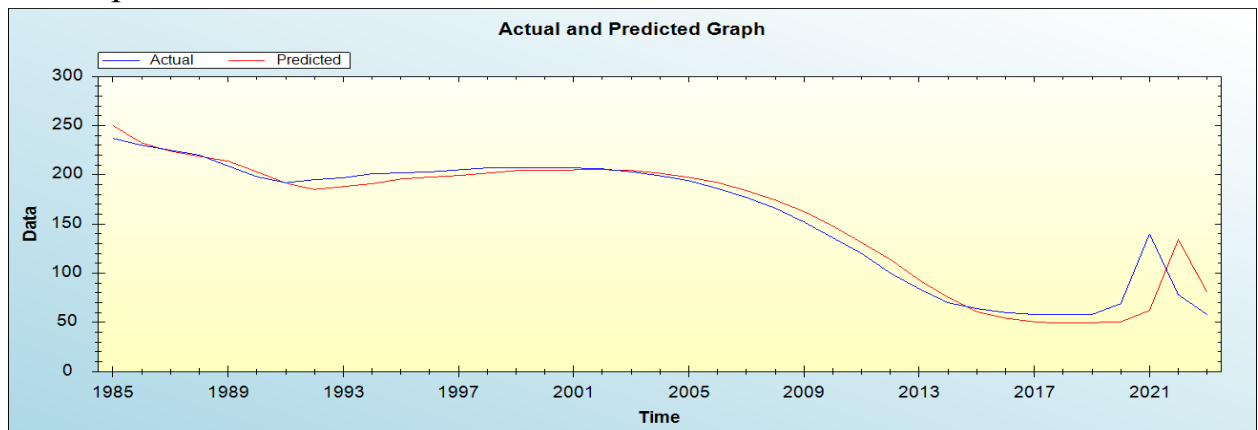


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

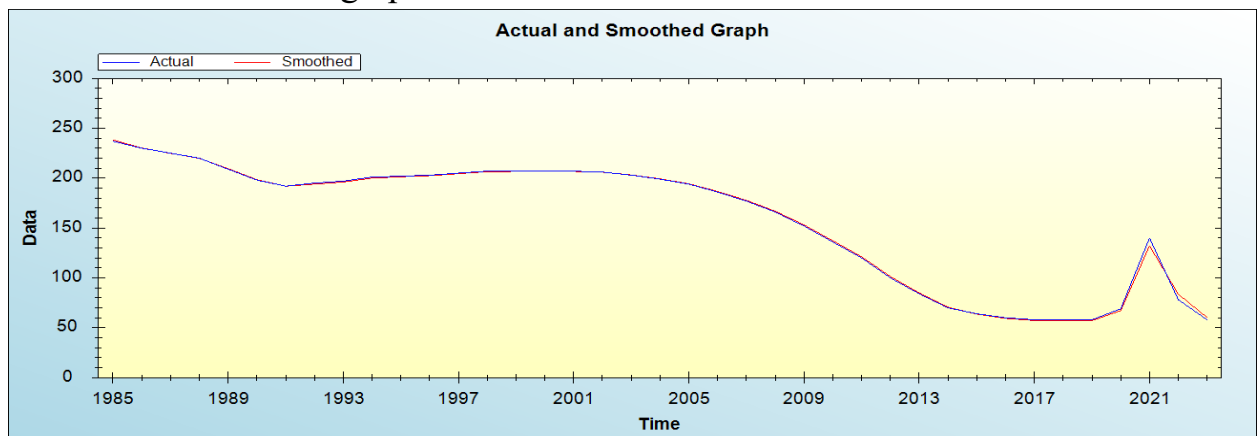


Figure 3: Actual and smoothed graph for A series

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

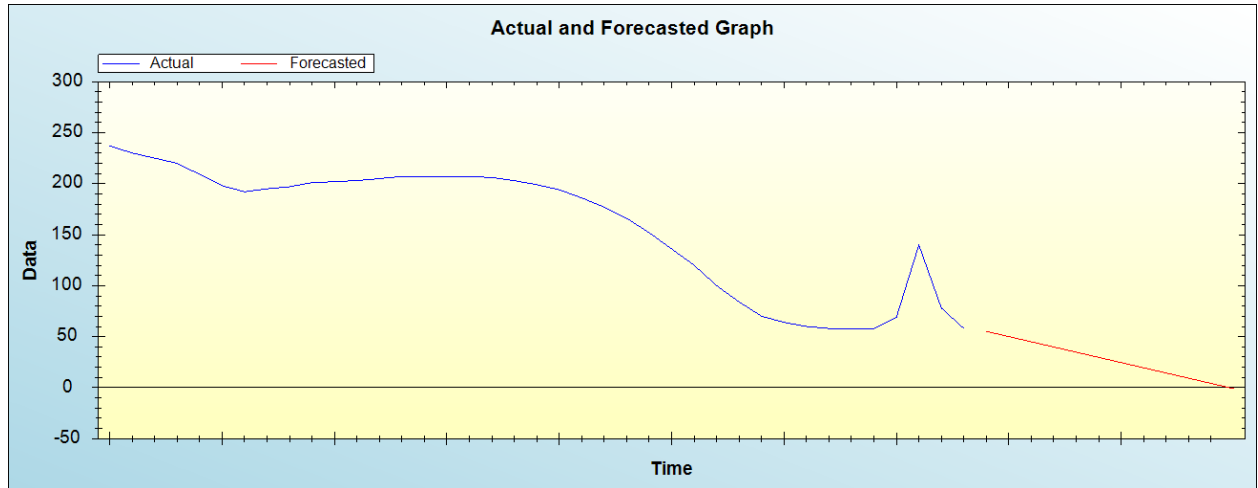


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	55.1567
2025	50.0582
2026	44.9597
2027	39.8613
2028	34.7628
2029	29.6643
2030	24.5658
2031	19.4674
2032	14.3689
2033	9.2704
2034	4.1720
2035	-0.9265

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 to reach levels below 10 deaths per 100 000 live births by 2035.



Recommendations & Conclusion

Maternal mortality is relatively high in Paraguay as a result of existing challenges along the continuum of care. This paper models and forecasts MMR for Paraguay and results indicate that MMR will continue to drop to reach levels below 10 deaths per 100 000 live births by 2035. Hence, we encourage health authorities to address local drivers of maternal deaths and continue routine quality improvement activities.

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