

Detection Of Future Trends Of Maternal Mortality In Costa Rica Using The Double Exponential Smoothing Approach

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 Costa Rica 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 0.3 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will hover around 29 deaths per 100 000 live births throughout the out of sample period. Therefore, we encourage authorities to address local causes of maternal deaths and pay attention to quality improvement in all health facilities.

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

Introduction

Maternal mortality ratio is defined by the World Health Organization (WHO) as the number of female deaths per 100,000 live births happening during pregnancy or within 42 days of termination, irrespective of the cause (Alipour et al; 2023; WHO, 2012). Low-middle income countries bear the largest burden of maternal mortality in the world (Rodríguez-Robles et al. 2023; Ruas et al. 2020). According to WHO data, in 2017, around 295,000 maternal deaths were reported worldwide, with an overall maternal mortality ratio (MMR) of 211 per 100,000 live births (WHO, 2019). Moreover, above 300,000 women die yearly as a result of complications linked to pregnancy and childbirth (Huang et al. 2025). During the period 1990-2015, maternal deaths declined by 43%, from 532,000 to 303,000, with the MMR decreasing from 385 to 216 per 100,000 live births (Kurjak et al. 2023; Alkema et al. 2016). Maternal mortality continues to be a huge burden in Latin America and the Caribbean (LAC) as significant health disparities persist due to unequal access to medical resource (Nigenda & Serván-Mori, 2024; Sáenz et al. 2024). It is important to highlight that that maternal mortality is largely preventable through strategic interventions, including high-quality preconception, prenatal, intrapartum, and postpartum care (Souza et al. 2024; Lawrence et al. 2022; Kinney et al. 2021).

The objective of this paper is to model and forecast MMR for Costa Rica using the double exponential smoothing model. The study findings will inform policy and resource allocation in order to reduce further maternal mortality across the country.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
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	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

	Colombia between 2017 and 2020		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 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
Cruz-Barbosa et al. (2025)	To describe the sociodemographic and anatomopathological characteristics associated with	Descriptive retrospective study	The analysis of 42 autopsies (2000–2023) showed that 85.7% were early maternal deaths. Indirect causes

	autopsy-verified maternal mortality cases at a Level-4 hospital in southwestern Colombia (2000–2023)		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 approach methods	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	used secondary data from a global source to show patterns in the relationship between	Although variations in maternal mortality rate cannot be explained solely

	health and the maternal mortality ratio for the period 1990–2021 in Latin America	these two aspects and identify gaps in the Latin American and Caribbean regions	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 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)
Sing et al. (2022)	to inform on potential options for measuring maternal mortality	Applied a case study approach to compare methodologies and estimates of	For Bangladesh, PRMR from the 2011 census falls closely in line with the 2010

		pregnancy-related mortality ratio (PRMR)/maternal mortality ratio (MMR) obtained from four different data sources from similar time periods in Bangladesh, Mozambique, and Bolivia—national population census; post-census mortality survey; household sample survey; and sample vital registration system (SVRS)	household survey and SVRS estimates, while SVRS' MMR estimates are closer to the PRMR estimates obtained from the household survey. Mozambique's PRMR from household survey method is comparable and shows an upward trend between 1994 and 2011, whereas the post-census mortality survey estimated a higher MMR for 2007. Bolivia's DHS and post-census mortality survey also estimated comparable MMR during 1998–2003
Marin et al. (2021)	To describe the epidemiology of NCDs and maternal and child health needs in Venezuelan migrants in major South American host countries	Scoping review	the rate of chronic disease among Venezuelan migrants to range from 9–14% within countries who reported this data. Significant rates of psychiatric conditions such as depression and post-traumatic stress disorder were reported. Other conditions described were ophthalmologic diseases, diabetes, chronic pain, asthma, cough, dyslipidemia and hypertension among others

Methodology

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

C_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 Costa Rica 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	C
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.300
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	1.674206
Sum Square Error (SSE)	460.821249
Mean Square Error (MSE)	11.815929
Mean Percentage Error (MPE)	0.336708
Mean Absolute Percentage Error (MAPE)	5.108099

Residual Analysis for the Applied Model

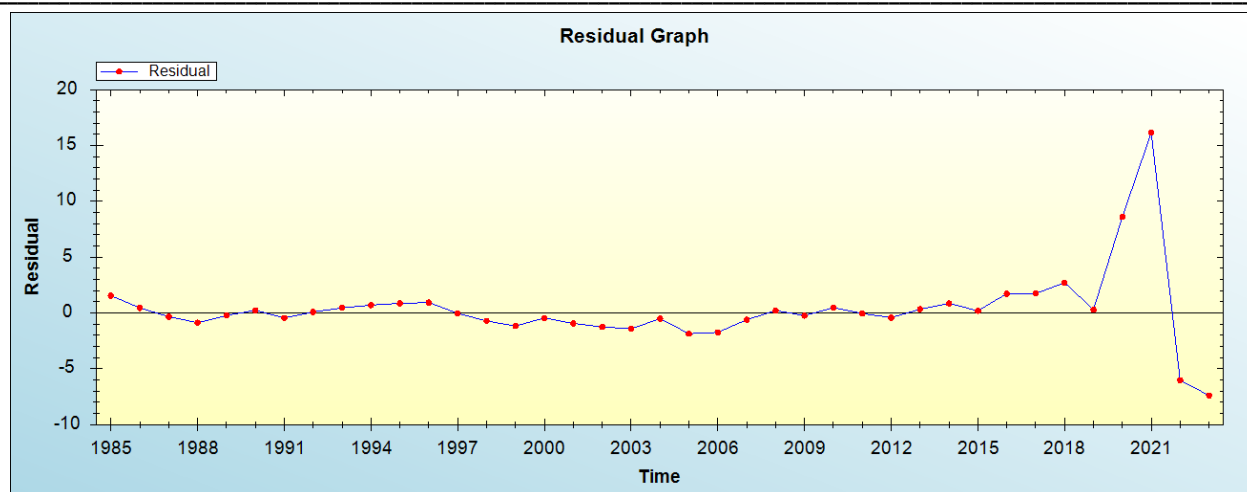


Figure 1: Residual analysis

In-sample Forecast for C

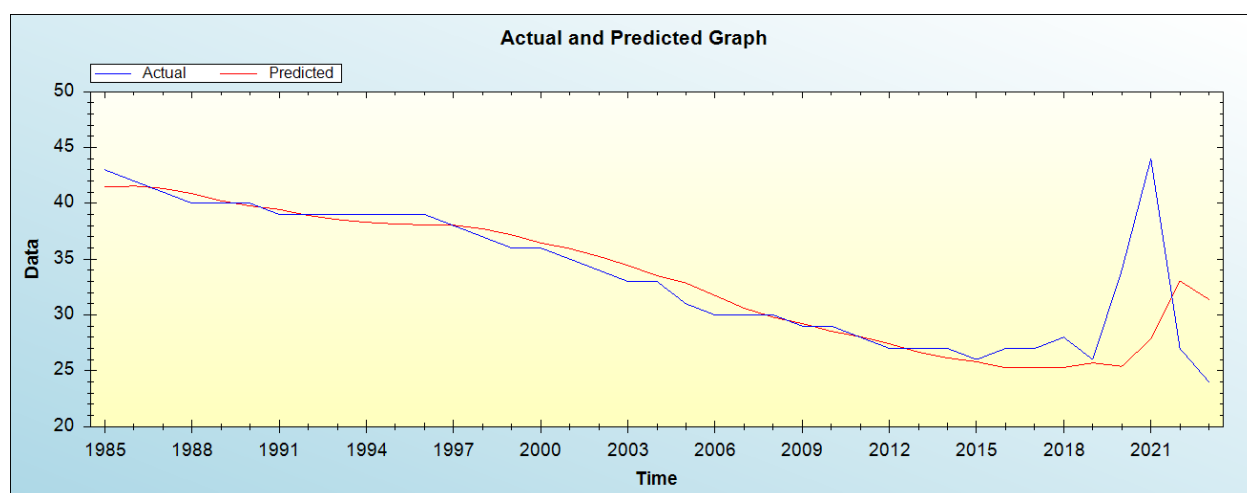


Figure 2: In-sample forecast for the C series

Actual and Smoothed graph for C series

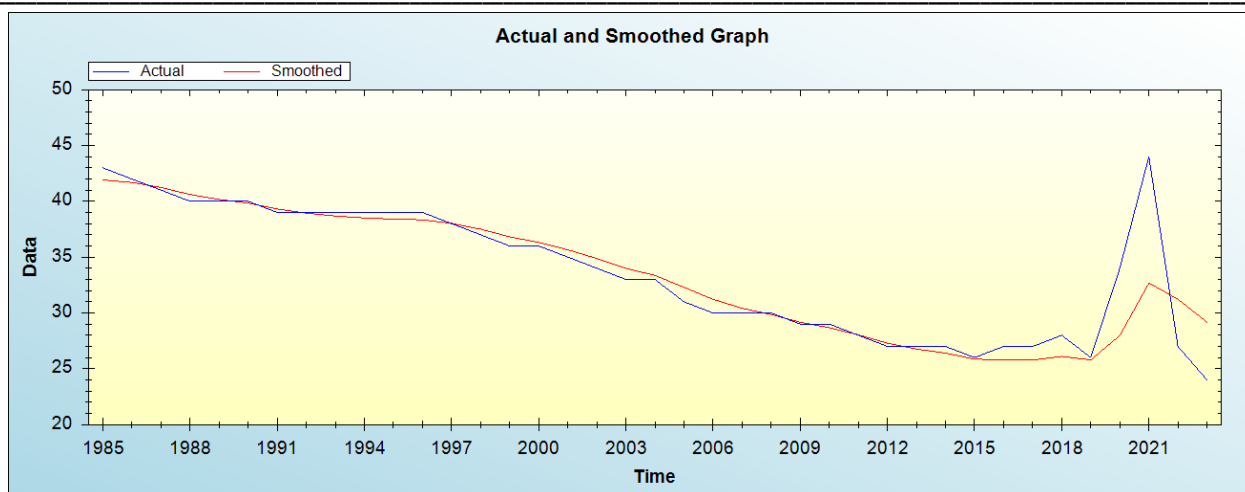


Figure 3: Actual and smoothed graph for C series

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

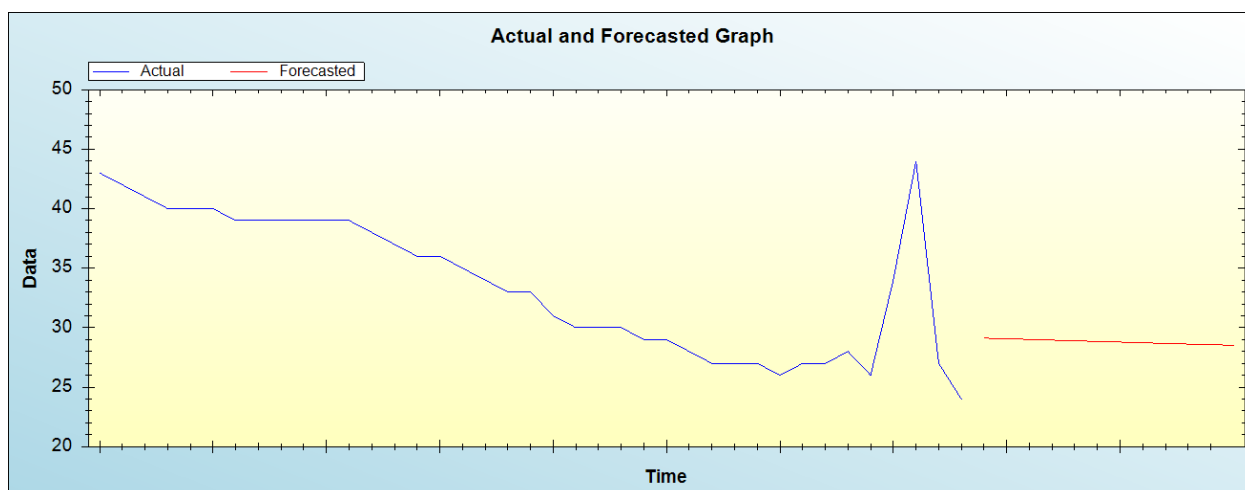


Figure 4: Out-of-sample forecast for C: actual and forecasted graph

Out-of-Sample Forecast for C: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	29.1198
2025	29.0649
2026	29.0100
2027	28.9551

2028	28.9003
2029	28.8454
2030	28.7905
2031	28.7356
2032	28.6808
2033	28.6259
2034	28.5710
2035	28.5161

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 hover around 29 deaths per 100 000 live births over the out of sample period.

Recommendations & Conclusion

This paper uses the double exponential smoothing model to forecast MMR for Costa Rica and study findings indicate that MMR will hover around 29 deaths per 100 000 live births throughout the out of sample period. Therefore, we encourage health authorities to address local causes of maternal deaths and also pay attention to quality improvement initiatives.

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