

ESTIMATION OF FUTURE VALUES OF ANNUAL MATERNAL MORTALITY RATE FOR HAITI USING THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

Smartson. P. NYONI ¹

Thabani NYONI ²

¹Independent Researcher & Medical Doctor, Harare, Zimbabwe

²Independent Researcher & Health Economist, Harare, Zimbabwe

ABSTRACT

This study uses annual time series data on MMR Haiti 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 0.4 respectively based on minimum MSE. The results of the study indicate that MMR will continue to drop but still remain very high throughout the out of sample period. Therefore, we encourage authorities to address local drivers of maternal mortality and direct resources to quality improvement initiatives.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

INTRODUCTION

The success of the maternal and child program in any country is dependent on the availability of resources. Haiti continues to report high maternal mortality rates (MMR) partly due to limited availability of advanced health services during pregnancy-related emergencies (Sheffel et al. 2019; Zanonato et al. 2006). Haiti has one of the highest annual maternal mortality rates (Anderson et al. 2008). In 2017, Haiti's maternal mortality ratio was 480 deaths per 100,000 live births (UNFPA, 2020; World Data Atlas, 2017; UNFPA, 2017) with only 42% of births attended by skilled health providers (UNFPA, 2017). In the same year, the WHO indicated that maternal mortality rates were much lower for other Caribbean countries like Trinidad and Tobago, Jamaica, and the Dominican Republic (67 deaths, 80 deaths and 95 deaths per 100,000 live births, respectively) (WHO, 2019). Some of the major barriers to good quality healthcare in Haiti are lack of financial resources and poor governance. The objective of this paper is to model and forecast MMR for Haiti using the double exponential smoothing technique. The results of this study are envisioned to stimulate an appropriate national response so as to further reduce avoidable maternal deaths.

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 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 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
Bayas (2025)	to develop and evaluate a model to improve access to maternal and child health services to reduce maternal mortality in a public hospital in Ecuador	Quantitative approach	the proposed model demonstrated a significant and positive effect on access to maternal and child health services, as evidenced by differences between pretest and posttest scores in the experimental group
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	used secondary data from a global source to show patterns in the relationship	Although variations in maternal mortality rate cannot be explained solely through the provision of health personnel, it is important to consider that it

	ratio for the period 1990–2021 in Latin America	between these two aspects and identify gaps in the Latin American and Caribbean regions	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)
Schuurmans et al. (2021)	-To determine the prevalence of maternal death, stillbirth and low birthweight in women with (pre-) eclampsia and complicated pregnancies or deliveries in Centre de Références des Urgences Obstétricales, an obstetric emergency hospital in Port-au-Prince, Haiti	-conducted a retrospective cohort study of pregnant women admitted to Centre de Référence des Urgences Obstétricales between 2013 and 2018 using hospital records. Risk factors investigated were age group, type of pregnancy (singleton, multiple), type of delivery and use of antenatal care services	Of all admissions, 10 991 (34.9%) were women with (pre-)eclampsia. Caesarean section significantly increased the risk of maternal death in the women with a complicated pregnancy and women with (pre-)eclampsia, but reduced the risk of stillbirth in such women
Bridwell et al. (2019)	to determine reported prevalence of hypertensive disorders in pregnancy (HDP) and maternal and neonatal outcomes associated with	Conducted a retrospective review of 8822 singleton deliveries	A high prevalence of HDP was found among a cohort of Haitian mothers. HDP was associated with higher rates of adverse maternal and neonatal

	these disorders among women delivering at selected hospitals across Haiti	between January 2012 and December 2014 was conducted at four hospitals in separate Departments across Haiti	outcomes in HAS, which is comparable to studies of HDP conducted in high-income countries
--	---	---	---

METHODOLOGY

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

H_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 Haiti 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	H
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.800
Beta (β) for trend	0.400
Forecast performance measures	
Mean Absolute Error (MAE)	22.065682
Sum Square Error (SSE)	44892.342920
Mean Square Error (MSE)	1151.085716
Mean Percentage Error (MPE)	0.245453
Mean Absolute Percentage Error (MAPE)	4.250025

Residual Analysis for the Applied Model

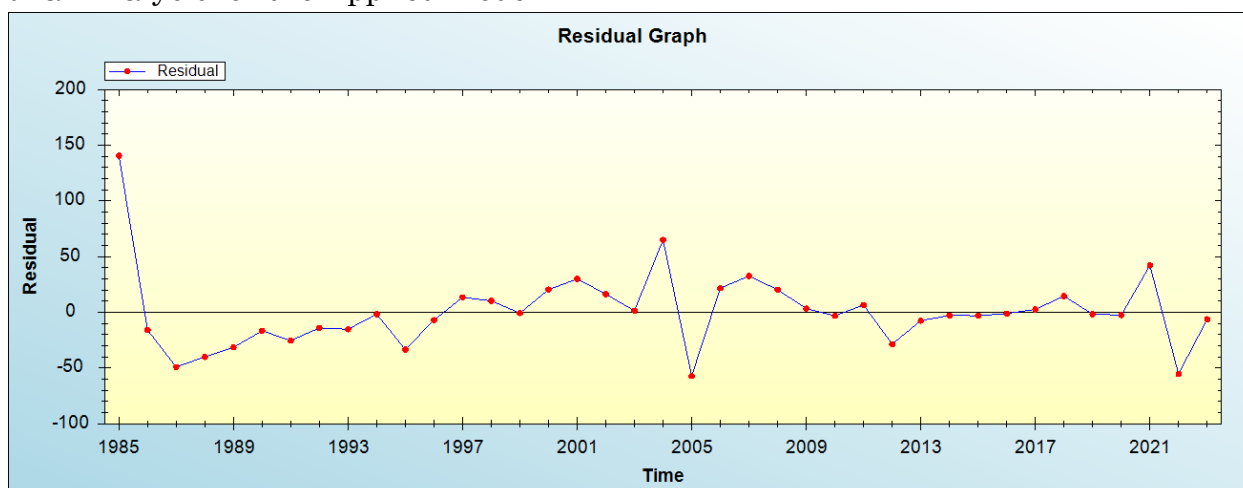


Figure 1: Residual analysis

In-sample Forecast for H

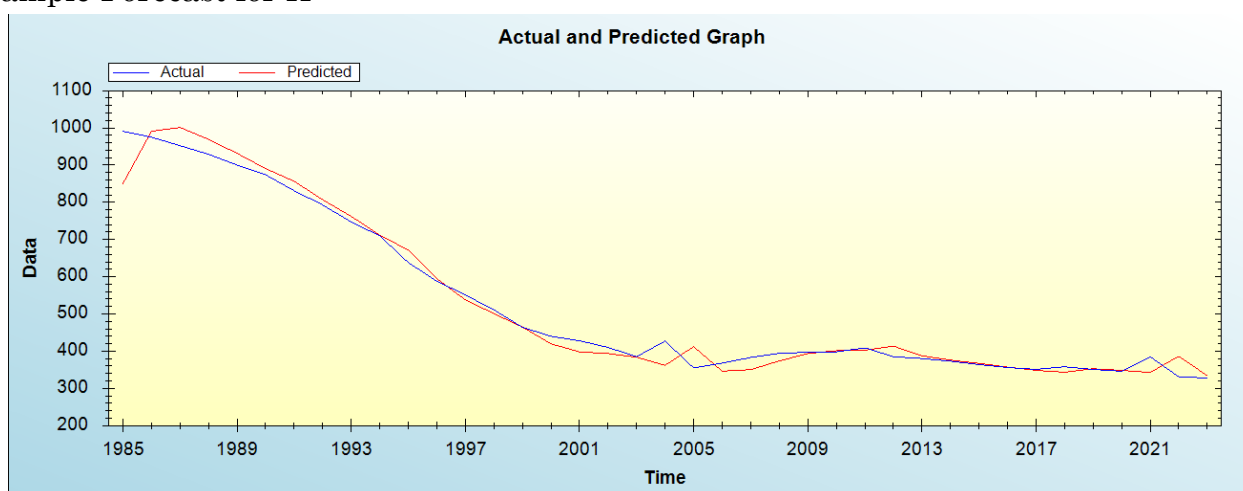


Figure 2: In-sample forecast for the H series

Actual and Smoothed graph for H series

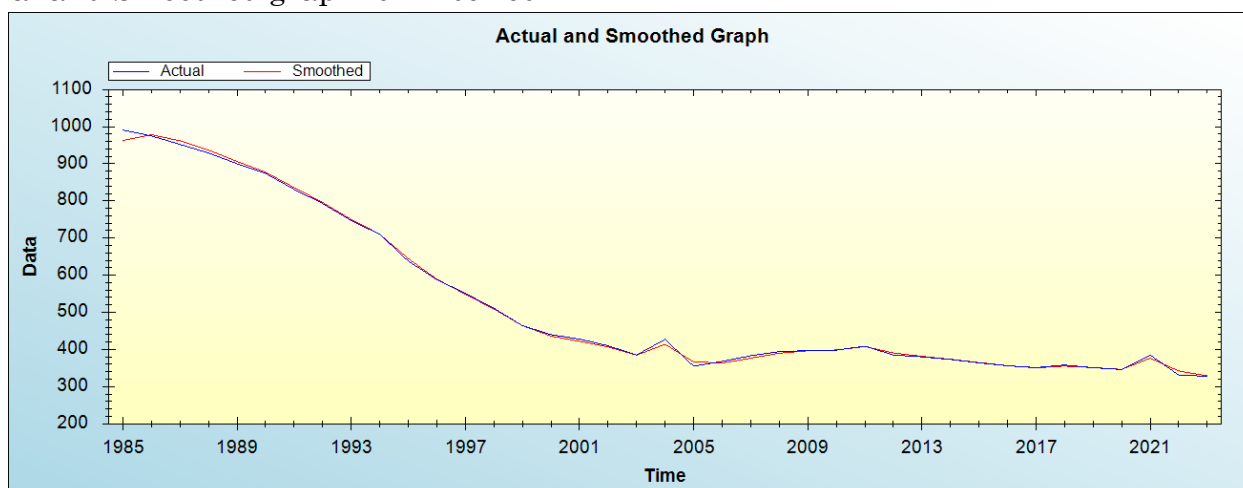


Figure 3: Actual and smoothed graph for H series

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

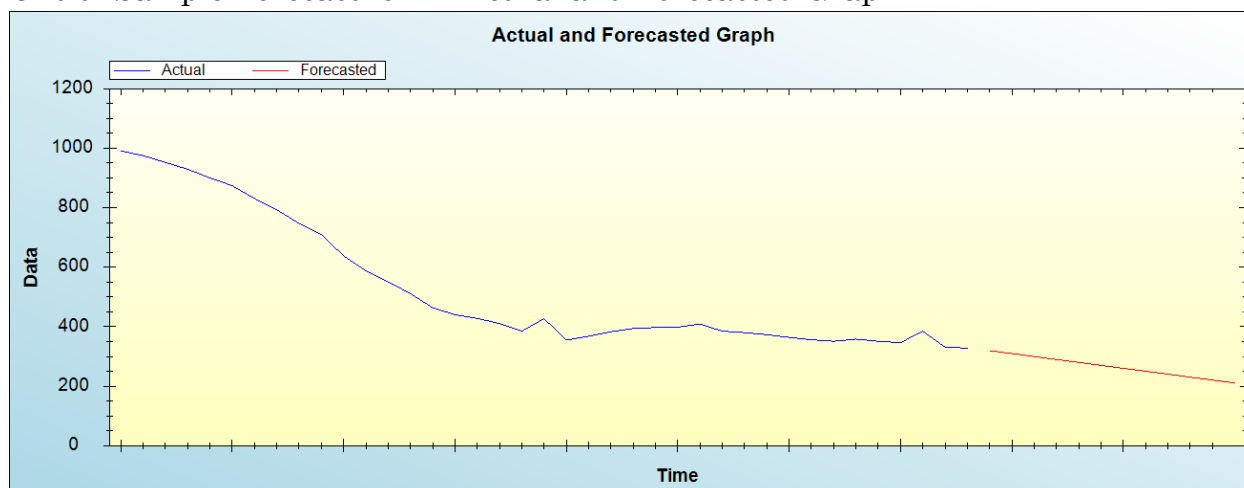


Figure 4: Out-of-sample forecast for H: actual and forecasted graph

Out-of-Sample Forecast for H: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	319.3540
2025	309.4742
2026	299.5945
2027	289.7147
2028	279.8350
2029	269.9552
2030	260.0755
2031	250.1957
2032	240.3160
2033	230.4362
2034	220.5565
2035	210.6767

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 decline but still remain very high over the out of sample period.

RECOMMENDATIONS & CONCLUSION

Haiti has the highest MMR in the Americas and this reflects huge gaps in the continuum of care. Political instability is among the factors that affect accessibility and availability of health care services. This paper projected MMR for Haiti using the double exponential smoothing model and results indicate that MMR will continue to drop but still remain very high in the forecast period. Hence, there is need for health authorities to address major drivers of preventable maternal mortality including conducting quality improvement activities.

REFERENCES

1. Anderson F.W., Naik S I., Feresu S.A., Gebrian B., Karki M., and Harlow S.D (2008). Perceptions of pregnancy complications in Haiti. *Int. J. Gynaecol. Obstet.* 2008, 100, 116–123.
2. Sheffel A., Zeger S., Heidkamp R., and Munos M.K (2019). Development of summary indices of antenatal care service quality in Haiti, Malawi and Tanzania. *BMJ Open.* 2019, 9, e032558.
3. UNFPA (2017). World Population Dashboard: Haiti. United Nations Population Fund. Available online: <https://www.unfpa.org/data/world-population/HT>
4. United Nations Population Fund (2020). Amid Pandemic Disruptions, Haiti's Midwives Urge Pregnant Women to Continue Antenatal Care. Available online: <https://www.unfpa.org/news/amid-pandemic-disruptions-haitis-midwives-urge-pregnant-women-continue-antenatal-care>
5. World Data Atlas (2017). Haiti—Maternal Mortality Ratio. Available online: <https://knoema.com/atlas/Haiti/Maternal-mortality-ratio>
6. World Health Organization (2019). WHO, United Nations Children's Fund; United Nations Population Fund; World Bank Group; Division UNP. Trends in Maternal Mortality (2000 to 2017): Estimates by WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division. 2019. Available online: <https://apps.who.int/iris/bitstream/handle/10665/327596/WHO-RHR-19.23-eng.pdf>
7. Zanconato G., Msolomba R., Guarenti L., and Franchi M (2006). Antenatal care in developing countries: The need for a tailored model. *Semin. Fetal Neonatal Med.* 2006, 11, 15–20.