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ANALYSIS OF FUTURE TRENDS OF ANNUAL MATERNAL MORTALITY RATE FOR ST VINCENT AND THE GRENADINES USING HOLT'S LINEAR APPROACH

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Abstract
This study uses annual time series data on MMR for St Vincent and the Grenadines 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 slightly increase from around 65 in 2024 to about 67 deaths per 100 000 live births in 2035. Therefore, we encourage authorities to address major drivers of maternal mortality across the country.

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

Introduction

St. Vincent and the Grenadines had population estimate of 110,418 inhabitants as 2022, with a fairly even sex distribution (Statistical Office, 2022). Approximately 90 percent of the total population live on mainland St. Vincent, and the remainder distributed between the Northern and Southern Grenadines. St Vincent and the Grenadines is classified as an upper-middle income economy by the World Bank. According to the World Bank the country's economy is based on services, mainly related to tourism. In 2021, the estimated gross domestic product (GDP) per capita was $US 8,666.40, with an overall upward trend over the past decade. St. Vincent and the Grenadines ranked 89 out of 191 countries and territories worldwide. In 2015, the national unemployment rate was 22.5 percent, with a higher percentage of unemployed women (St Vincent & the Grenadines, 2015). According to poverty level indicators in 2008, approximately one-third of the population in Saint Vincent and the Grenadines was classified as poor, with an additional 3 percent categorized as indigent (Budget speech,2022). The consistent upward trend in mortality rate per 1,000 people for St. Vincent and the Grenadines from 2014 to 2021 has been largely due to increasing mortality from noncommunicable diseases (NCDs), that now account for more than 75 percent of all deaths. The predominant underlying causes of mortality from NCDs are ischemic and other forms of heart disease, diabetes, hypertension, and malignant neoplasm (World Bank, 2022). Although maternal mortality is generally low, NCDs are the main causes of maternal deaths. The objective of this paper is to model and forecast MMR for St Vincent and the Grenadines using a double exponential smoothing technique. The study results are expected to facilitate planning and allocation of resources to the health sector so that preventable maternal deaths are eradicated.

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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	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

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	outcomes throughout the region		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) indepen dently 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-

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			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

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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	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

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	data for three Latin American countries		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 St Vincent and the Grenadines. 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

$V_t=\mu_t + \rho_t \mathbf{t} + \varepsilon_t$

Smoothing equation

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

$0<\alpha<1$

Trend estimation equation

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

$0<\beta<1$

Forecasting equation

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

V_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

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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 St Vincent and the Grenadines 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	V
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.300
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	6.326947
Sum Square Error (SSE)	4248.673882
Mean Square Error (MSE)	108.940356
Mean Percentage Error (MPE)	-0.453505
Mean Absolute Percentage Error (MAPE)	9.114447

Residual Analysis for the Applied Model

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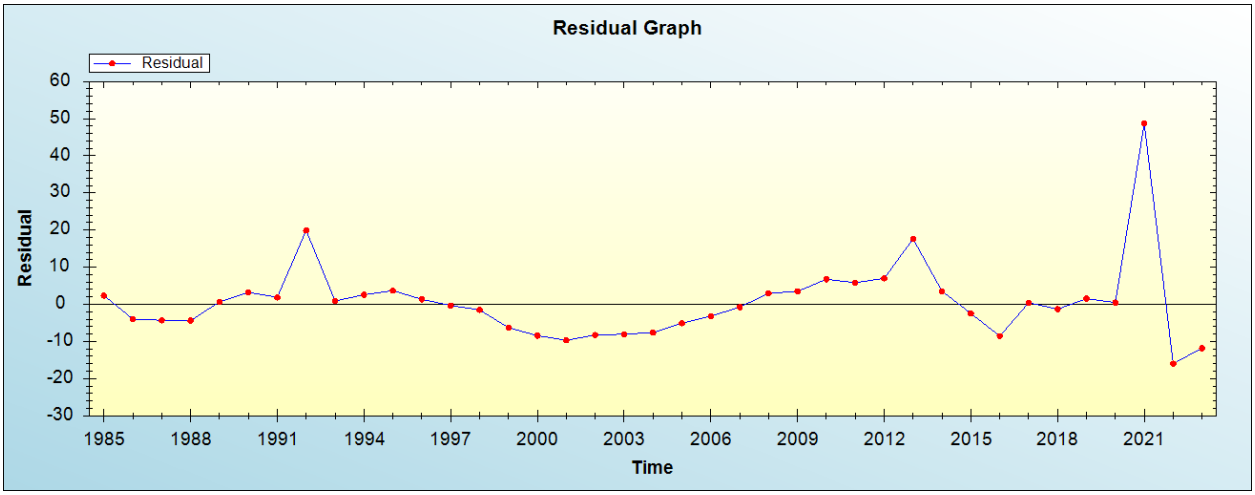


Figure 1: Residual analysis

In-sample Forecast for V

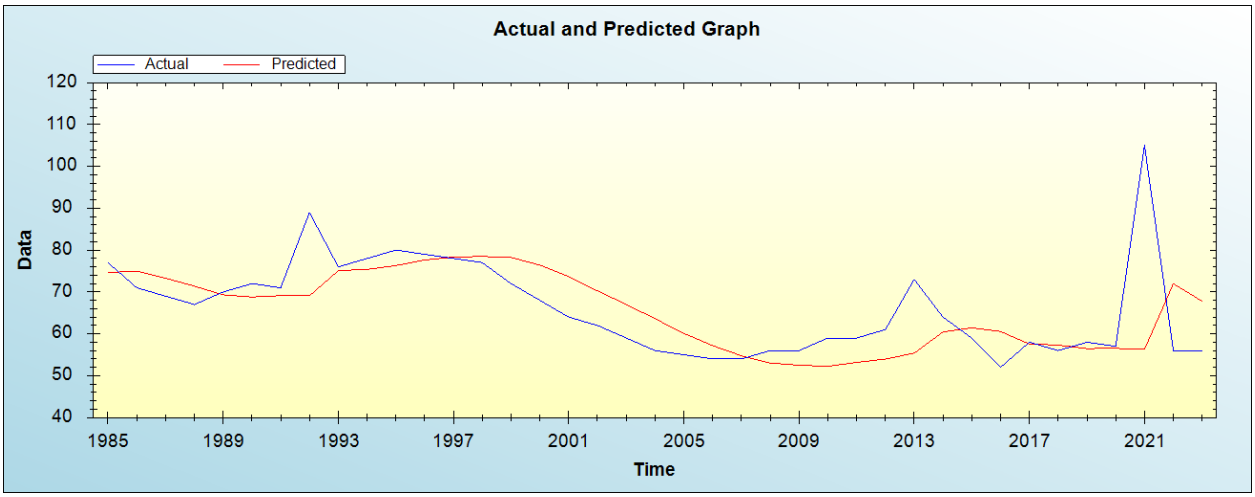


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for V series

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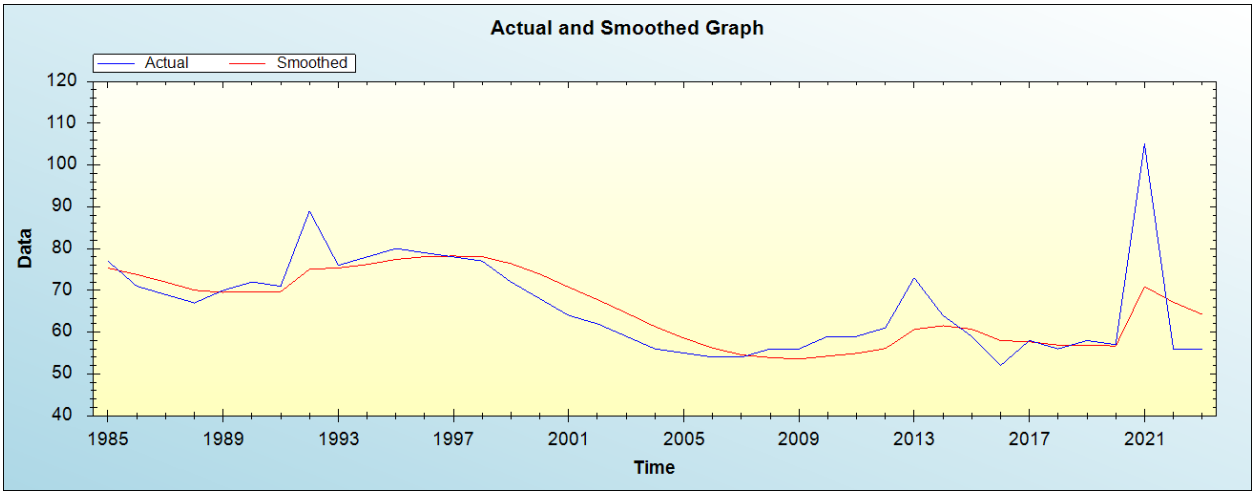


Figure 3: Actual and smoothed graph for V series

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

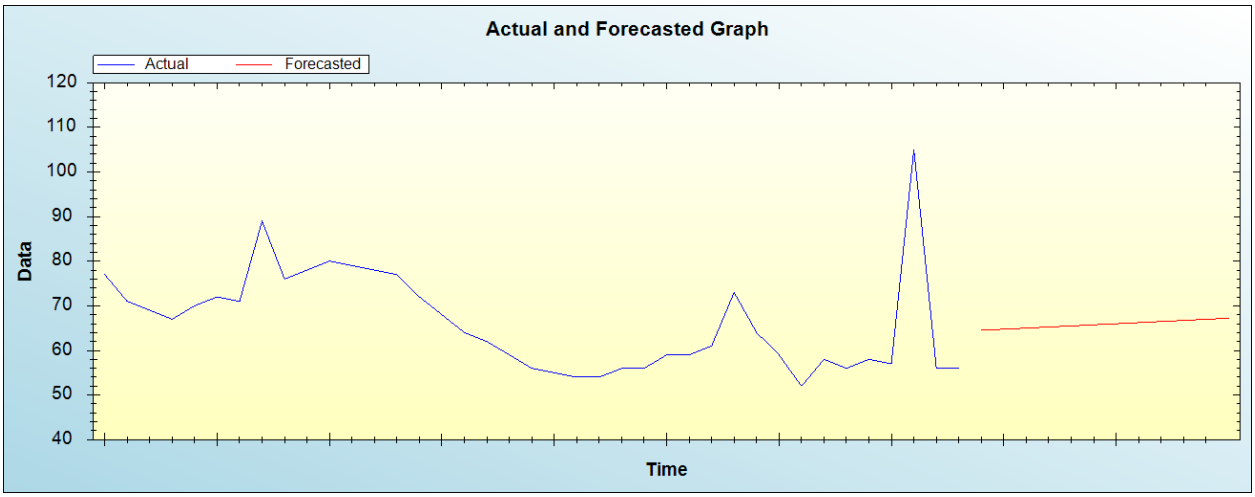


Figure 4: Out-of-sample forecast for V: actual and forecasted graph

Out-of-Sample Forecast for V: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	64.5017
2025	64.7490
2026	64.9964
2027	65.2438

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2028	65.4912
2029	65.7386
2030	65.9859
2031	66.2333
2032	66.4807
2033	66.7281
2034	66.9755
2035	67.2228

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 slightly increase from around 65 in 2024 to about 67 deaths per 100 000 live births by 2035.

Conclusion

This study demonstrates the use of the Holt's linear method to forecast MMR for St Vincent and the Grenadines and findings indicate that MMR will slightly increase from around 65 in 2024 to about 67 deaths in 2035. Hence, health authorities are encouraged to relentlessly attend to local factors associated with maternal mortality.

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