

Forecasting Maternal Mortality For Gabon Using The Double Exponential Smoothing Model

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 Gabon 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 0.8 respectively based on minimum MSE. The results of the study indicate that MMR will likely increase and remain very high throughout the out of sample period. Therefore, we encourage authorities to adopt the suggested 5-fold policy prescription.

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

Introduction

Maternal mortality dropped by 34% between 2000 and 2020, but this progress was not enough to meet the Millennium Development Goal 5 (WHO, 2023). With the current global maternal mortality ratio (MMR) at 223 per 100 000 live births, most developing countries are still not on track to meet the 2030 Sustainable Development Goal (SDG) target of less than 70 by 2030 (Urban birth collective, 2025). Across the world, levels of maternal mortality vary from less than 6 per 100 000 live births to more than 1000 per 100 000 live births. This huge difference indicates existing socio-economic inequalities across regions of the world (Graham et al. 2016). The majority of maternal and perinatal deaths result from complications happening within a short time period between the onset of labor and the first days after birth. Timeous management of such complications requires skilled birth attendants and other health sector resources (WHO, 2021; WHO, 2009).

The objective of this paper is to model and forecast MMR for Gabon using the double exponential smoothing model. The findings of this paper are expected to inform national policy and allocation of resources to the maternal and child health program.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
Estelle et al. (2026)	To describe trends, causes, and factors associated with maternal mortality	retrospective descriptive study	Maternal mortality was increasing at the Yamoussoukro Regional Hospital. The direct causes of death were predominant, with obstetric hemorrhage as the main cause. Poor prenatal care and the lack of blood products were associated with the deaths

Harsono et al. (2024)	to identify structural barriers to maternal care during the early adaptation of the mobile Medical Information Service via Telephone (mMIST) program in Cameroon	conducted in-depth interviews and focus groups with 56 key stakeholders including previously and currently pregnant women, primary healthcare providers, administrators, and representatives of the Ministry of Health, recruited by purposive sampling. Thematic coding and analysis via modified grounded theory approach were conducted using NVivo12 software	Dynamic inter-relations among structural level factors create barriers to maternity care in Cameroon
Birabwa et al. (2024)	To describe the trends in IMMR between 2016 and 2021, and the causes and characteristics of maternal deaths in Kampala, Uganda	-retrospective study utilized routine data from all facilities in Kampala that provided childbirth services from 2016 to 2021. -conducted descriptive analysis and assessed time trends in IMMR	IMMR in Kampala increased from 2019-2021. Health infrastructure changes and maternal health initiatives potentially accounted for the observed trend by affecting data quality. Referral and facility readiness were underlying reasons for maternal deaths
Agballa et al. (2023)	to determine the hospital-based maternal mortality ratio and factors associated with maternal deaths	conducted a case-control study over two years from 1st January 2020 to 31 December 2021 in four Cotonou hospitals. It included 264 maternal deaths (case) matched to 264 controls by delivery mode. The dependent variable was the status at discharge. Independent variables included socio-demographic characteristics, gynecologic-obstetric	The hospital-based maternal mortality ratio was 1403 deaths per 100,000 live births. Age superior than or equal to 30 years old (OR= 3.09; 95% CI= 1.52 to 6.41; p=0.002), admission by a referral from public health facility (OR=4.26; 95% CI= 2.60-7.10; or private health facility (OR= 4.52; 95% CI= 2.49-8.38 ; gestational age less than or equal to 31 weeks (OR=3.77;

		information, medical and gynecologic history as well as type of complications. Univariate and multivariate analysis were performed to identify the factors associated with maternal deaths	95% CI= 2.13 to 6.84 ; occurrence of non-infectious (OR= 1.94; 95% CI= 1.27 to 2.97; p= 0.002) and fetal complications (OR= 1.98; 95% CI= 1.13 to 3.54; p=0.018) were the factors associated to maternal deaths.
Touolak et al. (2023)	To analyze the factors associated with maternal mortality that occurred at the Gyneco-Obstetric and Pediatric Hospital of Yaounde (YGOPH) from the 1st January 2018 to the 31st December 2021.	conducted an analytical case control study with a retrospective data collection, using medical files of 210 participants (for 1 case, 2 survivors, totally 70 cases and 140 survivors). Data were collected using a questionnaire and analyzed with SPSS 25.0. A multivariate analysis was done to determine the independent factors associated with maternal mortality at YGOPH	Maternal mortality at YGOPH was explained by the following among other factors: Hypertensive disorders (AHR=3.304; P-value=0.019; 95%; CI=[1.401; 5.020]), Co-morbidities (AHR=3.01; P-value = 0.003; 95%; CI= [2.059; 3.900]), mode of delivery (AHR=2.900; P-value=0.002; 95%; CI=[4.652; 8.549]), Postpartum hemorrhage (AHR=3.700; P-value = 0.011; 95%; CI= [1.730; 4.002]), Infections (AHR=9.489; P-value=0.004; 95%; CI=[3.552; 12.519])
Musarandega et al. (2021)	to identify the leading causes of maternal deaths using the international classification of disease – 10th revision, for maternal mortality (ICD-MM)	Systematic literature review	Obstetric hemorrhage, hypertensive disorders in pregnancy, non-obstetric complications, and pregnancy-related infections are the leading causes of maternal deaths in SSA
Meh et al. (2020)	To explore ratios and determinants of	-used the Cameroon Demographic and	Maternal mortality ratios and

	maternal mortality in women of childbearing age (15–49 years) and assessed differences between the North and South Cameroon	Health Surveys (2004 and 2011) to extract a sample of 18,665 living or deceased women who had given birth -applied logistic regression	determinants varied between women of childbearing age in the North and South of Cameroon
Wirsiy et al. (2019)	to assess the critical determinants of maternal mortality in Cameroon so as to facilitate inform decision making in regards to interventions on maternal health	Systematic review	Maternal age, parity, post-partum hemorrhage, unsafe abortion, domestic violence, hypertensive disorders of pregnancy, severe malaria, HIV/AIDS, inadequate antenatal care, pre-existing co-morbidities, place of delivery, education level, healthcare provider qualification, delays in arrival at health facilities, ectopic pregnancy, placenta previa, anemia, pneumonia, heart disease, number of prenatal visits

Methodology

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

G_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 Gabon 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	G
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.800
Forecast performance measures	
Mean Absolute Error (MAE)	17.566656
Sum Square Error (SSE)	24198.008823
Mean Square Error (MSE)	620.461765
Mean Percentage Error (MPE)	0.766777
Mean Absolute Percentage Error (MAPE)	8.444271

Residual Analysis for the Applied Model

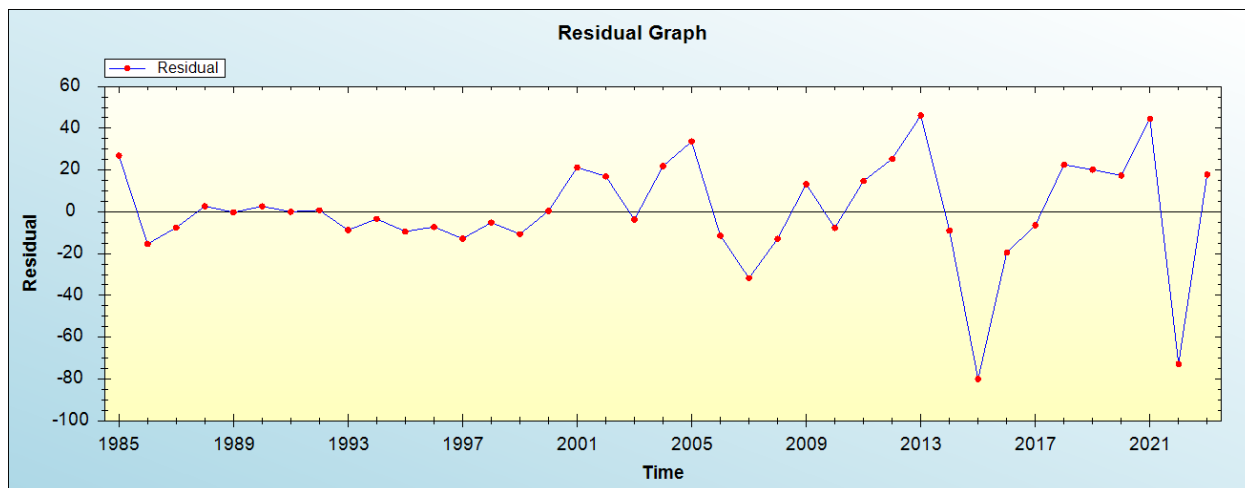


Figure 1: Residual analysis

In-sample Forecast for G

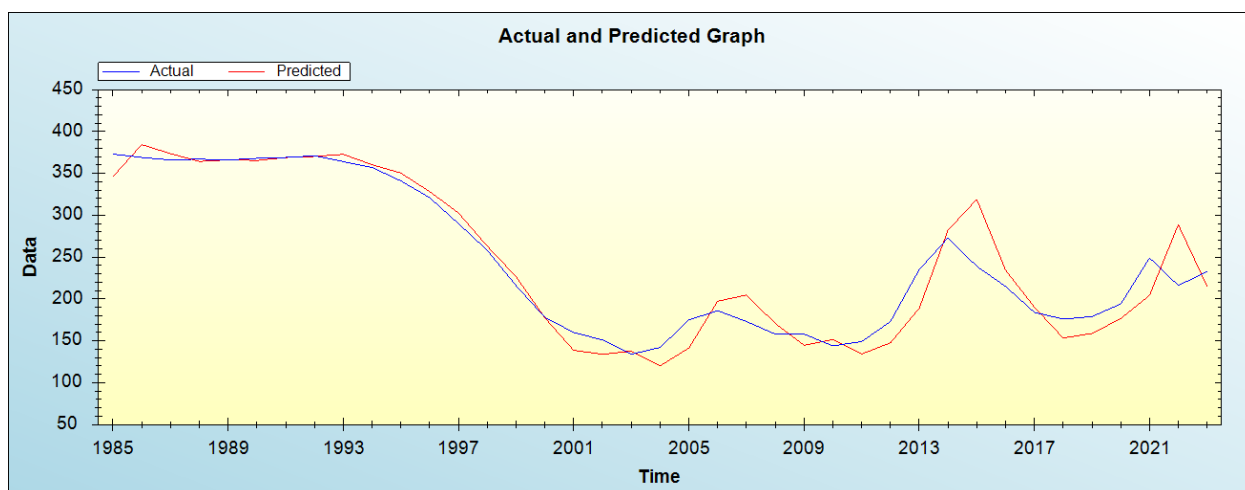


Figure 2: In-sample forecast for the G series

Actual and Smoothed graph for G series

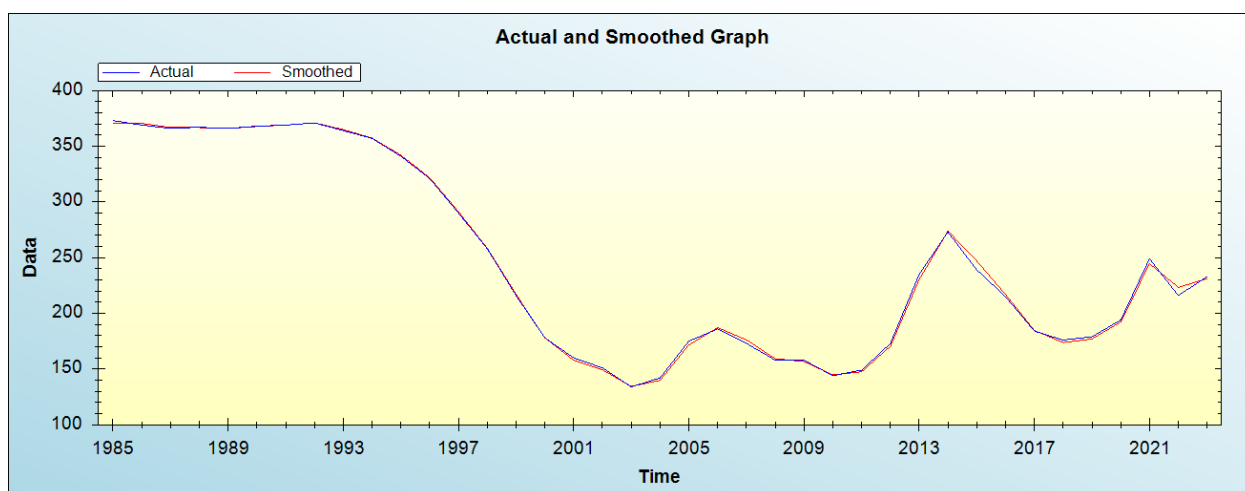


Figure 3: Actual and smoothed graph for G series

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

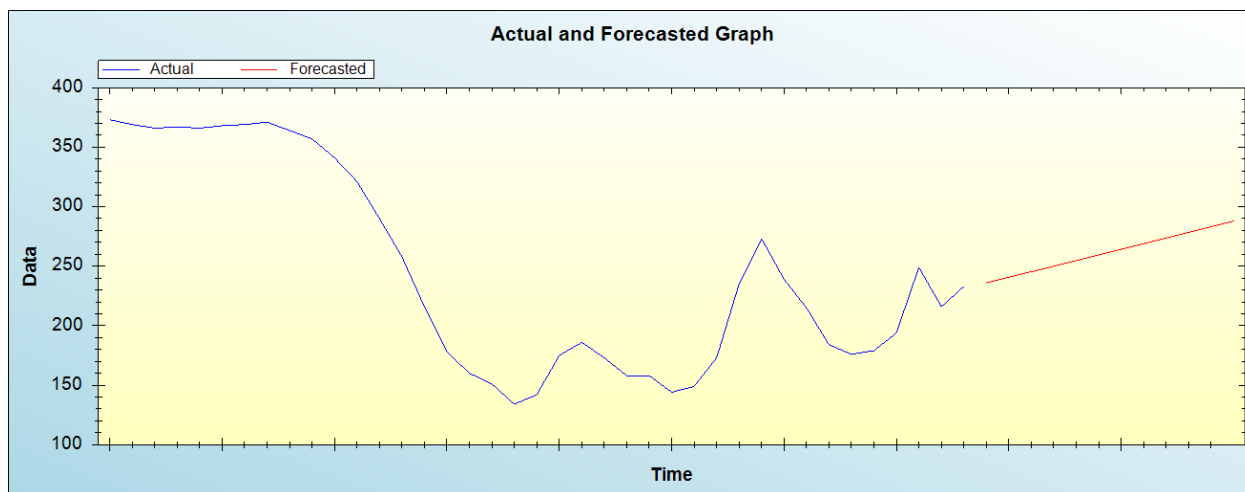


Figure 4: Out-of-sample forecast for G: actual and forecasted graph

Out-of-Sample Forecast for G: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	235.9269
2025	240.6416
2026	245.3563
2027	250.0710
2028	254.7857
2029	259.5005
2030	264.2152
2031	268.9299
2032	273.6446
2033	278.3593
2034	283.0740
2035	287.7887

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 is expected to increase and remain very high throughout the out of sample period.

Recommendations & Conclusion

Maternal mortality remains a public health issue of concern in the Republic of Gabon. This study applied the double exponential smoothing model to forecast MMR and the findings indicated that MMR will rise and remain very high in the forecast period. Hence, we implore health authorities to adopt the following policy direction: (1) end 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 country (3) improve quality of maternity services (4) ensure availability of adequate medical supplies and medical staff in all medical facilities and (5) establishing posts for obstetricians at government general or district hospitals particularly at high volume sites so that specialist services are accessed at the first referral level. Alternatively, Registrars undergoing Obstetrics & Gynecology training can be attached at high volume district hospitals under the supervision of provincial consultants.

References

- [1] Graham W., Woodd S., Byass P., Filippi V., Gon G., Virgo S (2016). Diversity and divergence: the dynamic burden of poor maternal health. *Lancet*. 2016; 388:2164–75. Medline:27642022 doi:10.1016/S0140-6736(16)31533-1
- [2] Urban Birth Collective (2025). Improving complex health systems and lived environments for maternal and perinatal well-being in urban sub-Saharan Africa: The Urban Birth Collective. *J Glob Health*. 2025; 15:03009.
- [3] World Health Organization (2009). *Monitoring emergency obstetric care: a handbook*. Geneva, Switzerland. Available: <https://www.who.int/publications/i/item/9789241547734>.
- [4] World Health Organization (2021). *Ending preventable maternal mortality (EPMM): a renewed focus for improving maternal and newborn health and well-being*. Geneva, Switzerland. Available: <https://www.who.int/publications/i/item/9789240040519>.
- [5] World Health Organization (2023). *Trends in maternal mortality 2000 to 2020: estimates by WHO, UNICEF, UNFPA, World Bank Group and UNDESA/Population Division*. Geneva, Switzerland. Available: <https://www.who.int/publications/i/item/9789240068759>.