



ANALYSING ANNUAL MATERNAL MORTALITY RATE FOR SENEGAL USING THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

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Abstract

This study uses annual time series data on MMR for Senegal 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 decline from around 221 in 2024 to about 67 deaths per 100 000 live births by 2035. Therefore, we encourage authorities to direct more resources towards the implementation of quality improvement initiatives.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

The global attention on maternal mortality will continue as long as pregnant mothers are still dying from preventable causes. Roughly 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). The burden of maternal mortality is higher in low-middle countries than the developed countries. Maternal mortality in the developing world is mainly due to direct causes whereas indirect causes are the major drivers of



maternal deaths in the developed world. According to the WHO, at the global level, the maternal mortality ratio in 2020 stood 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 reduction of 2.9% per year (WHO, 2023; WBG, 2023; WHO, 2020). This paper focuses on modelling and forecasting MMR for Senegal using the double exponential smoothing technique. The study results will inform policy making, planning and resource allocation to the health sector.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
Compaoré et al. (2025)	to determine the frequencies and causes of severe maternal outcomes (SMO: MNM + MD) in regional and district hospitals in Benin, Burkina Faso and Niger	Between 1st February 2008 and 31st October 2010, we conducted an SMO incidence study in 36 hospitals in the three countries	-At the time of our study the burden of severe maternal outcomes was high in Benin, Burkina Faso and Niger. -most women had a near miss complication on admission to a participating hospital, indicating the need to facilitate access to obstetric care for women with high-risk pregnancies and complications
Kawuki et al. (2025)	examines the relationship between maternal mass media exposure and two critical child health indicators: morbidity and mortality	This secondary analysis of the 2017/2018 Benin Demographic and Health Survey (BDHS) included 13,851 women. Childhood morbidity (fever, cough, and diarrhea) and mortality were analyzed as outcomes. Bivariable and multivariable logistic regression and Cox regression models were applied, and results were expressed as odds ratios (OR), hazard ratios (HR), and their adjusted counterparts	Maternal exposure to mass media, particularly radio and television, was associated with increased childhood morbidity. This association could reflect heightened maternal health awareness, leading to increased reporting of symptoms or exposure to misleading health information through media content
Thiam et al. (2025)	to evaluate the emergency obstetric care in a maternity	This was a retrospective longitudinal descriptive study from 1 January	The maternal mortality rate was 503 for 100,000 Live Births. 78% of cases were



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	peripheral and analyze trends evolving in order to offer solutions to improve the quality of care	2011 to 31 December 2024, a period of 15 years	direct causes and 22% were indirect
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	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;



		characteristics, gynecobstetric 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])
Diop et al. (2023)	to determine the epidemiological, clinical, and paraclinical profile of maternal deaths recorded in the Tambacounda region, Senegal, during the year 2023	retrospective and descriptive study	This study revealed a high maternal mortality rate (284 deaths per 100,000 live births) in the Tambacounda region, especially among women aged 20 to 24 years (31.1%) and primigravida (30.1%), with deficiencies in prenatal care and examinations
Diouf et al. (2021)	to suggest strategic plans that would help decrease maternal and perinatal mortality in the suburbs. It is a descriptive study that shows the different causes of maternal deaths during	retrospective descriptive study done between January 1st 2016 and the 31st of December 2018 in Dakar, Senegal	preeclampsia and its complications are the leading cause of maternal deaths in suburban settings



	pregnancy and puerperium period.		
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
Anya & Enaruna (2020)	to identify current and emerging causes of MM and to examine the recent trend in the etiology of MM University of Benin Teaching Hospital	-The case records of patients who suffered MM in the University of Benin Teaching Hospital, Benin City, Nigeria from 1st January, 2011 to 31st December, 2018 were retrospectively studied -Data on sociodemographic characteristics, clinical diagnosis, and primary cause of maternal death were extracted and analyzed	-A progressive decline in MMR was observed in the initial 5 years, with 58% reduction between 2012 (1.48%) and 2015 (0.61%). A further rise in MMR occurred in the last 3 years, climbing 53% from 2016 (0.81%) to 2018 (1.72%) -Maternal mortality occurred in 235 women during the study period, giving a MMR of 1.1% (1,114/100,000 live births). MMR among booked women of 161/100,000 live births was 6 times lower than MMR for referred women of 953/100,000 live births. Almost half (48%) of the MM occurred within 24 hours of admission to hospital, and 74.5% were postpartum. A teenager had 3-fold risk of mortality, age older than 35 years increased risk of dying 2-fold, and grand-multiparity conferred a 3-fold risk of mortality. Those in the lower socioeconomic class were 7 times more likely to suffer mortality
Meh et al. (2020)	To explore ratios and determinants of maternal mortality in women of childbearing age (15–49 years) and	-used the Cameroon Demographic and Health Surveys (2004 and 2011) to extract a sample of 18,665 living or	Maternal mortality ratios and determinants varied between women of childbearing age in the North and South of Cameroon



	assessed differences between the North and South Cameroon	deceased women who had given birth -applied logistic regression	
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
Yaya et al. (2018)	To comparatively explore the utilization level of maternal health care, and examine disparities in the determinants of major maternal health outcomes.	used data from two rounds of Benin Demographic and Health Survey (BDHS) to examine the utilization and disparities in factors of maternal health care indicators using logistic regression models	The results of multivariable logistic regression models showed disparities in maternal health care service utilization, including antenatal care, facility-based delivery, postnatal care and contraceptive use across selected maternal factors. The current BHDS showed age, region, religion was significantly associated with maternal health care services
Girum and Wasie (2017)	to identify correlates of maternal mortality in developing countries	Systematic review	Maternal mortality is correlated with multiples of socio-economic factors, health care system associated factors, disease burden and their complex interactions

Methodology

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

Z_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 Senegal 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	Z
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	18.146718
Sum Square Error (SSE)	35961.457545
Mean Square Error (MSE)	922.088655
Mean Percentage Error (MPE)	-0.080467
Mean Absolute Percentage Error (MAPE)	3.419012

Residual Analysis for the Applied Model

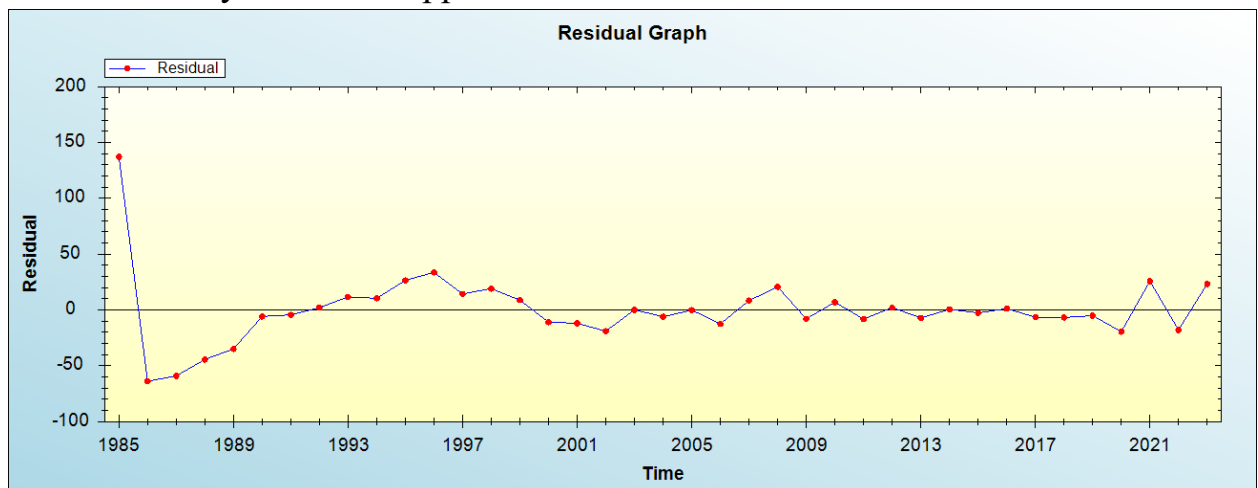


Figure 1: Residual analysis



In-sample Forecast for Z

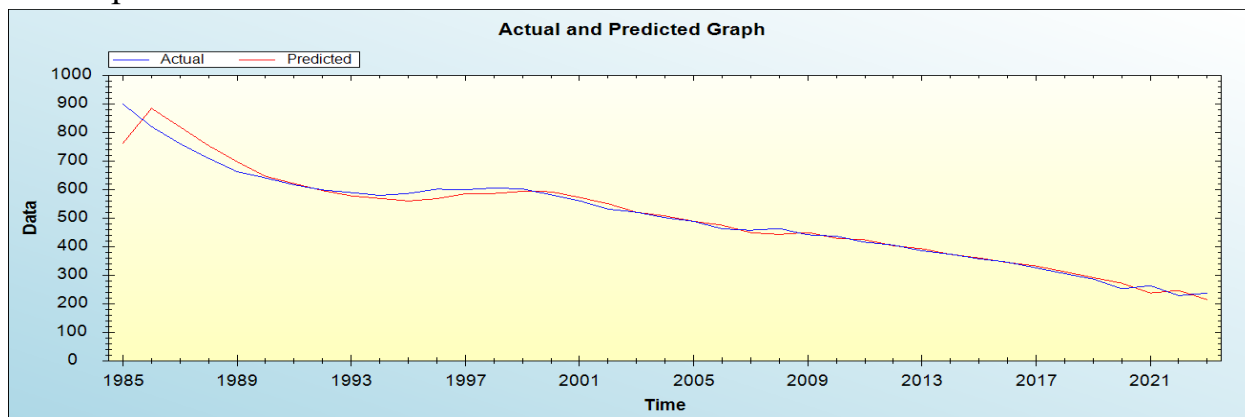


Figure 2: In-sample forecast for the Z series

Actual and Smoothed graph for Z series

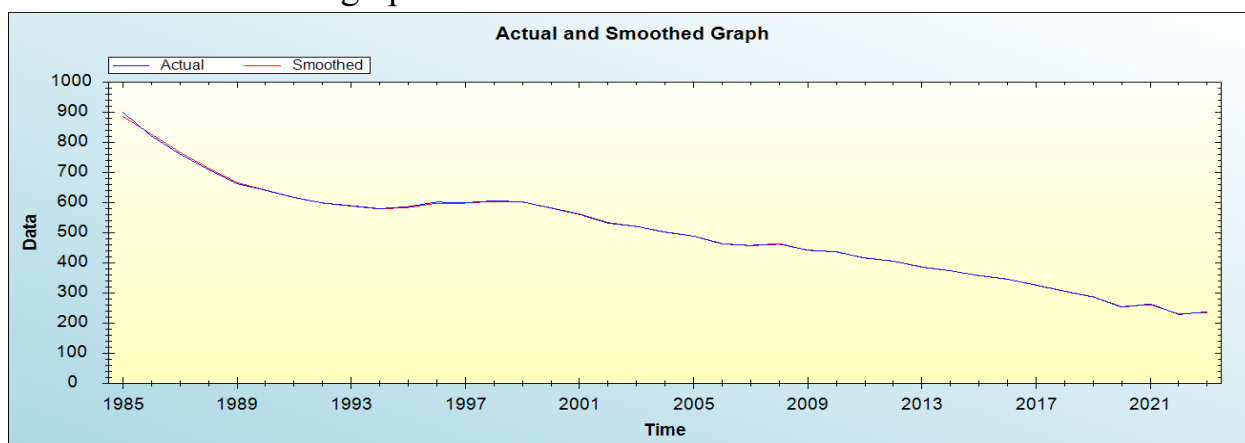


Figure 3: Actual and smoothed graph for Z series

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

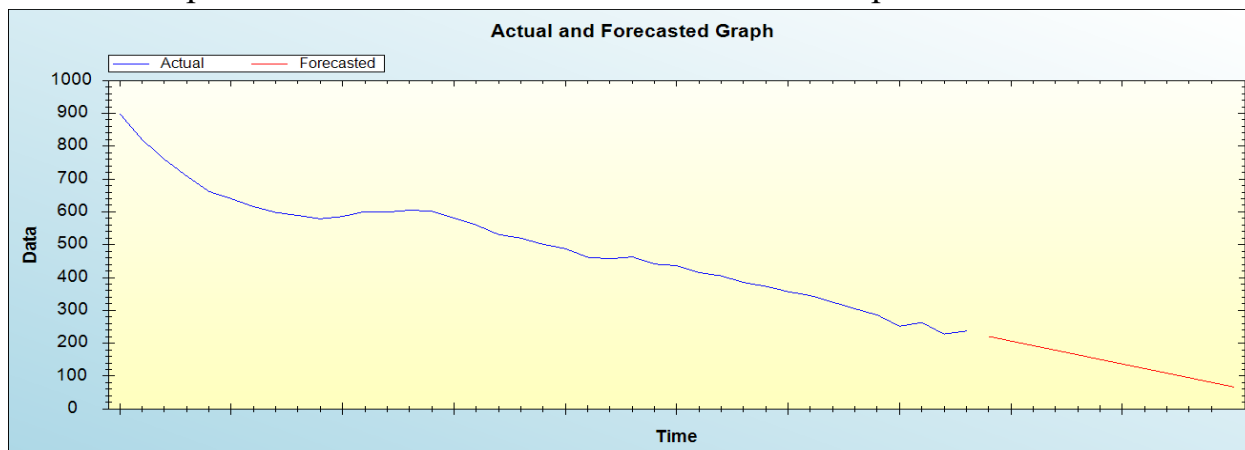


Figure 4: Out-of-sample forecast for Z: actual and forecasted graph



Out-of-Sample Forecast for Z: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	220.6981
2025	206.7235
2026	192.7490
2027	178.7744
2028	164.7998
2029	150.8252
2030	136.8506
2031	122.8760
2032	108.9014
2033	94.9268
2034	80.9522
2035	66.9776

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 decline from around 221 in 2024 to about 67 deaths per 100 000 live births by 2035.

Conclusion

In this study we used the double exponential smoothing technique to model and forecast MMR for Senegal and results indicated that MMR will decline from around 221 in 2024 to about 67 deaths per 100 000 live births by 2035. Hence, health authorities should direct resources towards routine implementation of quality improvement initiatives.

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