



MATERNAL MORTALITY FORECASTING FOR THE CENTRAL AFRICAN REPUBLIC USING THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

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Abstract:

This study uses annual time series data on MMR for Central African Republic 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 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will continue to fall but still remain very high throughout the out of sample period. Therefore, we encourage health authorities to adopt the suggested 5-fold policy prescription

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio

INTRODUCTION

The Central African Republic (CAR) has been negatively affected by decades of political unrest, and the perpetuation of violence had negative effects on socio-economic spheres of the populace (OHCHR, 2020; Lombard, 2016). Despite the signing of the Khartoum peace deal of February 2019 (ICG, 2020; UNSC, 2019), armed conflict continues resulting in loss of life and human rights abuses. In 2018, CAR was ranked 188th out of 189 countries according to the human development index (UNDP, 2019). It is currently ranked as the 6th most fragile state in the world (Fund for Peace, 2019). It is known for lagging behind in achieving UN targets (OCHA, 2019). The estimated national maternal mortality ratio (MMR) is the 5th

highest in the world standing at 829 deaths/100,000 live births in 2018. The estimated birth rate is 35.3 births per 1000 population per year (World Bank, 2019) infant and neonatal mortality rates are 84 and 41 per 1000 live births respectively, all amongst the highest in the world (IGME, 2019). The purpose of this paper is to model and forecast MMR for CAR using the double exponential smoothing technique. The study findings are anticipated to stimulate an appropriate national response to the problem of maternal mortality in order to further reduce maternal deaths to levels less than 70 deaths per 100 000 live births.

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	This secondary analysis of the 2017/2018 Benin Demographic and	Maternal exposure to mass media, particularly radio and television,



	exposure and two critical child health indicators: morbidity and mortality	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	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
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 information, medical and gynecologic history as well as type of complications. Univariate and multivariate analysis were performed to	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; 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



		identify the factors associated with maternal deaths	3.54; $p=0.018$) were the factors associated to maternal deaths.
Gang et al. (2023)	To determine mortality in the Central African Republic	Two stage cluster surveys were conducted in two different strata: one in the roughly half of the country within the Government's control, and one in the areas mostly outside of the Government's control	The birth rate was lower and the death rate markedly higher in the strata outside of Government control. Families described malaria or fever, and diarrhea as the primary reported causes of death with violence accounting for 6% of all deaths
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
Robinson et al. (2021)	To carry out a retrospective mortality study in the Ouaka prefecture to obtain reliable mortality data.	conducted a population-based two-stage cluster survey from 9 March to 9 April, 2020 in Ouaka prefecture	The most common specified causes of death were malaria/fever (16.0%; 95%-CI: 11.0–22.7), violence (13.2%; 95%-CI: 6.3–25.5), diarrhea/vomiting (10.6%; 95%-CI: 6.2–17.5), and respiratory infections (8.4%; 95%-CI: 4.6–14.8). The maternal mortality ratio (MMR) was 2525/100,000 live births (95%-CI: 825– 5794)
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	-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,



		were extracted and analyzed	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
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



Alvarez et al. (2009)	to describe and determine different factors associated with the maternal mortality ratio in Sub Saharan countries	An ecological multi-group study compared variables between many countries in Sub Saharan Africa using data collected between 1997 and 2006. The dependent variable was the maternal mortality ratio, and Health care system-related, educational and economic indicators were the independent variables. Information sources included the WHO, World Bank, UNICEF and UNDP	Education and an effective and efficient health system, especially during pregnancy and delivery, are strongly related to maternal death
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METHODOLOGY

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

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

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**

$\mathbf{t}$ 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 Central African Republic 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

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	C
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.800
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	101.647024
Sum Square Error (SSE)	1055517.510517



Mean Square Error (MSE)	27064.551552
Mean Percentage Error (MPE)	-2.418501
Mean Absolute Percentage Error (MAPE)	9.221108

Residual Analysis for the Applied Model

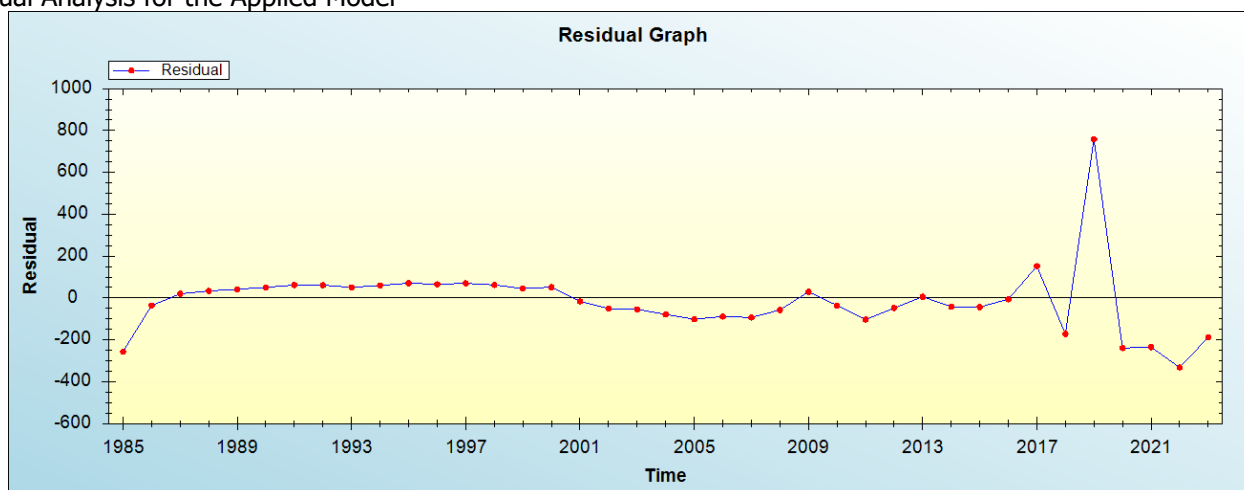


Figure 1: Residual analysis

In-sample Forecast for C

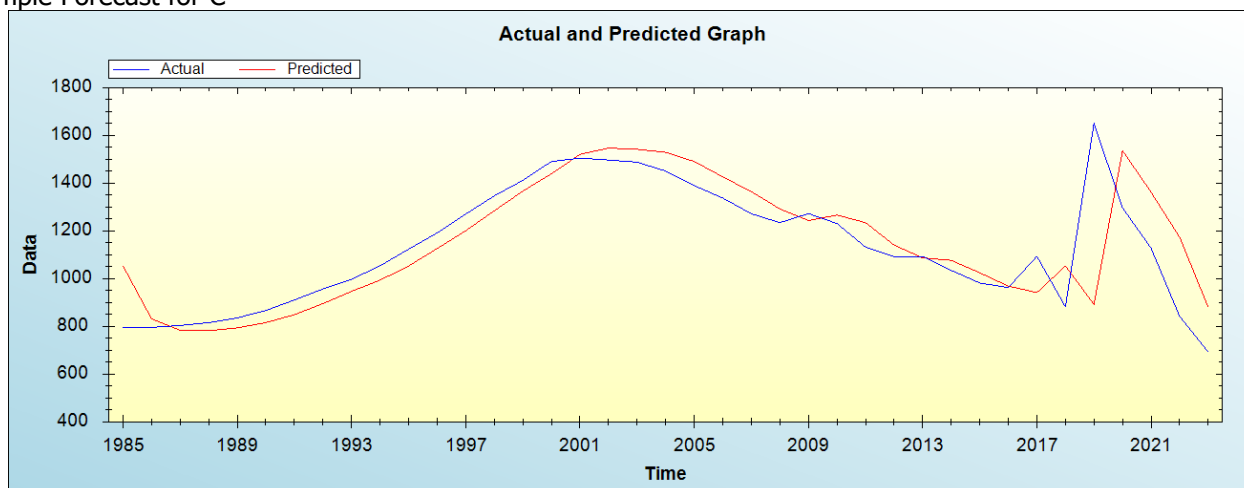


Figure 2: In-sample forecast for the C series

Actual and Smoothed graph for C series

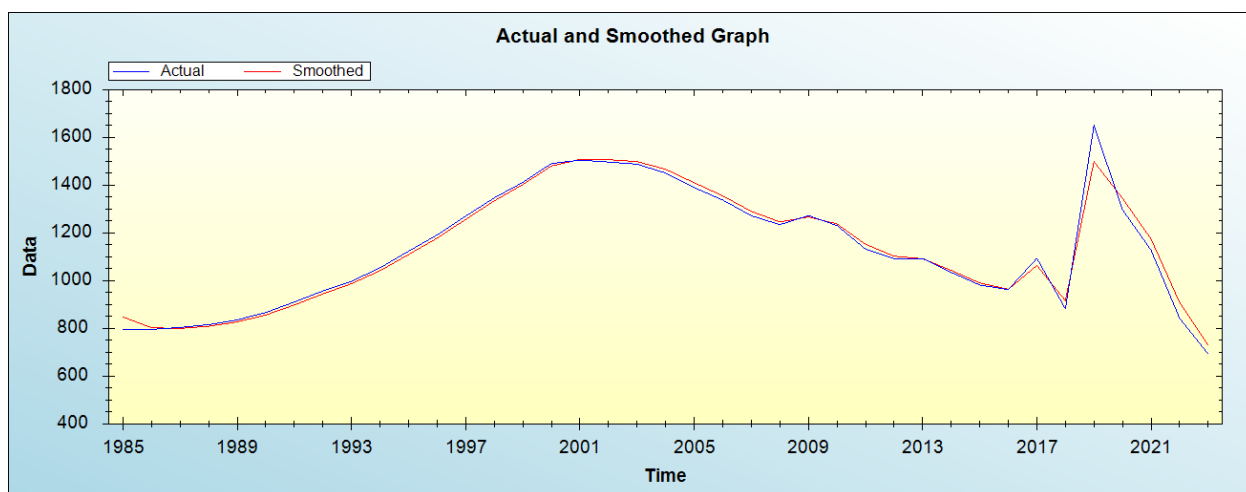


Figure 3: Actual and smoothed graph for C series

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

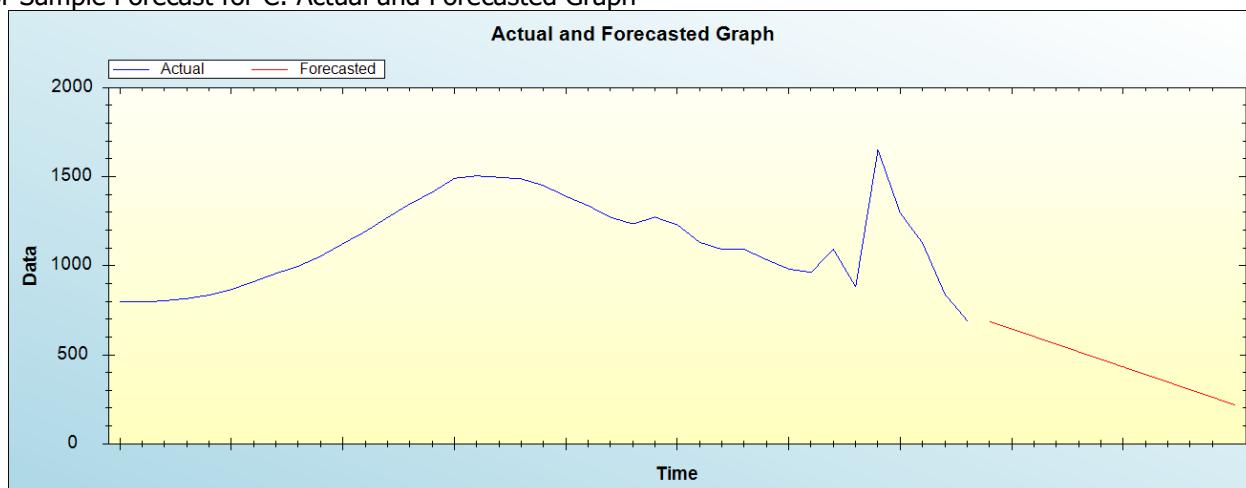


Figure 4: Out-of-sample forecast for C: actual and forecasted graph

Out-of-Sample Forecast for C: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	687.0066
2025	644.4424
2026	601.8783
2027	559.3141
2028	516.7499
2029	474.1858
2030	431.6216
2031	389.0574
2032	346.4933
2033	303.9291
2034	261.3650
2035	218.8008



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 fall but still remain very high throughout the out of sample period.

RECOMMENDATIONS & CONCLUSION

CAR is known for its very high maternal mortality rate which is among the highest in the world and this shows that more needs to be done to improve quality and access to maternity services around the country. In this paper we model and project MMR for CAR using and the results indicate that MMR is expected to continue to fall but still remain very throughout the out of sample period. Therefore, we encourage health authorities to adopt the following policy prescription: (1) curb 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 for maternal and child health services across the country (3) conduct routine quality improvement activities (4) ensure availability of enough medical supplies and medical staff in all medical facilities and (5) creating 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.

REFERENCES

- [1] Fund for peace (2020). Fragile states index. Available from: <https://fragilestatesindex.org/data/>. Accessed 30 Oct 2020.
- [2] International Crisis Group (2020). Report 277/Africa; Making the Central African Republic's Latest Peace Agreement Stick. Available from: <https://www.crisisgroup.org/africa/central-africa/central-african-republic/277-making-central-african-republics-latest-peace-agreement-stick>. Accessed 30 Oct 2020.
- [3] Lombard L (2016). State of rebellion: violence and intervention in the Central African Republic. London: Zed Books; 2016. <https://doi.org/10.5040/9781350222786>.
- [4] OCHA (2019). Financial tracking service, Central African Republic 2019 (Humanitarian response plan). Available from: <https://fts.unocha.org/appeals/674/summary>. Accessed 2 Aug 2020.
- [5] UN Inter-agency Group for Child Mortality Estimation (IGME). Levels & Trends in Child Mortality: Report 2019, Estimates developed by

the United Nations inter-agency Group for Child Mortality Estimation. New York: United Nations Children's Fund; 2019.

- [6] United Nations Development Programme (UNDP) (2020). Human Development Data (1990–2018). Available from: <http://hdr.undp.org/en/data>. Accessed 30 Oct 2020.
- [7] United Nations Human Rights Office of the High Commissioner (OHCHR) (2020). Rights Committee: entrenched impunity and "infernal cycle of violence" at the heart of the dialogue with the Central African Republic. Available from: <https://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=25665&LangID=E>. Accessed 30 Oct 2020.
- [8] United Nations Security Council (2019). Letter dated 14 February 2019 from the secretary-general addressed to the president of the security council; political agreement for peace and reconciliation in the Central African Republic; S/ 2019/145. United Nations security council; 2019.