

Projection Of Maternal Mortality For Cote D'Ivoire Using The Multilayer Perceptron

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Abstract

This research article employs annual time series data on MMR for Cote d'Ivoire from 1985 to 2023 to predict future trends of MMR over the period 2024 to 2035. The forecast evaluation criteria of the applied model indicate that the ANN (12, 12, 1) model is stable. The neural network model projections revealed that MMR will remain very high throughout the out of sample period. Therefore, we encourage the government to adopt the suggested 5-fold policy prescription.

Keyword(s): - ANN, Forecasting, Maternal Mortality Ratio

Introduction

Maternal mortality ratio is defined by the World Health Organization (WHO) as the number of female deaths per 100,000 live births taking place during pregnancy or within 6 weeks of termination, regardless of the cause (Alipour et al; 2023; WHO, 2012). Low-middle income countries bear the largest burden of maternal mortality in the world (Rodríguez-Robles et al. 2023; Ruas et al. 2020). Data from WHO indicated that, in 2017, around 295,000 maternal deaths were reported worldwide, with an overall maternal mortality ratio (MMR) of 211 per 100,000 live births (WHO, 2019). Moreover, above 300,000 women die yearly due to complications linked to pregnancy and childbirth (Huang et al. 2025). During the period 1990-2015, maternal deaths declined by 43%, from 532,000 to 303,000, with the MMR decreasing from 385 to 216 per 100,000 live births (Kurjak et al. 2023; Alkema et al. 2016). Maternal mortality continues to be a huge burden in Latin America and the Caribbean (LAC) as significant health disparities persist due to unequal access to medical resource (Nigenda & Serván-Mori, 2024; Sáenz et al. 2024). It is important to highlight that that maternal mortality is largely preventable through strategic interventions, including high-quality preconception, prenatal, intrapartum, and postpartum care (Souza et al. 2024; Lawrence et al. 2022; Kinney et al. 2021). In Côte d'Ivoire, indicators of maternal health service utilization are low despite the existence of a national policy of "free care" for pregnant women. The coverage rate in CPN4 was 38.23% in 2015, the modern contraceptive prevalence rate was 17%, and the assisted childbirth rate was 55.10% (Cote de d'Ivoire, 2015). The maternal mortality ratio stood at 645 per 100,000 live births (WHO, 2015). The western part of the country, which was particularly affected by the military-political crisis between 2002 and 2011, is reporting high mortality rates. There is marked underutilization of maternal health services with a 25% ANC 4 rate compared to 35% for the national average, with high ANC drop-out rates of up to 67% (Cote d'Ivoire, 2015). To improve access to care, the Government has introduced a policy of free care for pregnant women, taking into account prenatal consultations (ANC), childbirth and caesarean section throughout the country.

The purpose of this paper is to model and project MMR for Cote d'Ivoire using the multilayer perceptron. The study findings will inform policy and allocation of resources to the healthcare sector in order to bring down maternal mortality across the country.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
Estelle et al. (2026)	To describe trends, causes, and factors	retrospective descriptive study	Maternal mortality was increasing at the Yamoussoukro

	associated with maternal mortality		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
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

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
Anya & Enaruna (2020)	to identify current and emerging causes of	-The case records of patients who suffered	-A progressive decline in MMR was

	MM and to examine the recent trend in the etiology of MM University of Benin Teaching Hospital	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	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 assessed differences between the North and South Cameroon	-used the Cameroon Demographic and Health Surveys (2004 and 2011) to extract a sample of 18,665 living or deceased women who had given birth	Maternal mortality ratios and determinants varied between women of childbearing age in the North and South of Cameroon

		-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
Mamadou et al. (2019)	to identify the determinants associated with the use of maternal health services in the department of Bloléquin, in western Côte d'Ivoire	Analytical cross-sectional study	The results showed that women made less use of family planning services (OR=0.4), prenatal consultation (OR=0.2) and assisted childbirth (OR=0.2) when they provided the funding for care themselves. Women with incomes above \$26.8 used family planning services 4 times more than those with lower incomes. Married women used prenatal consultations 3 times more often than unmarried women (CI95% = 1.4 - 7.3)
Yaya et al. (2018)	To comparatively explore the utilization level of maternal health care, and examine disparities in	used data from two rounds of Benin Demographic and Health Survey (BDHS) to examine	The results of multivariable logistic regression models showed disparities in maternal health care

	the determinants of major maternal health outcomes.	the utilization and disparities in factors of maternal health care indicators using logistic regression models	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

The Artificial Neural Network (ANN) approach, which is flexible and capable of nonlinear modelling; will be applied in this study. The ANN is a data processing system consisting of a large number of highly interconnected processing elements in architecture inspired by the way biological nervous systems of the brain appear like. Since no explicit guidelines exist for the determination of the ANN structure, the study applies the popular ANN (12, 12, 1) model based on the hyperbolic tangent activation function. This paper applies the Artificial Neural Network (ANN) approach in predicting annual maternal mortality ratio (MMR) for Cote d’Ivoire.

Data Issues

This study is based on annual MMR in Cote d’Ivoire 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

ANN Model Summary

Table 1: ANN model summary

Variable	C
Observations	27 (after adjusting endpoints)
Neural Network Architecture:	
Input Layer Neurons	12

Hidden Layer Neurons	12
Output Layer Neurons	1
Activation Function	Hyperbolic Tangent Function
Back Propagation Learning	
Learning Rate	0.005
Momentum	0.05
Criteria:	
Error	0.005647
MSE	17.230260
MAE	2.699750

Residual Analysis for the Applied Model

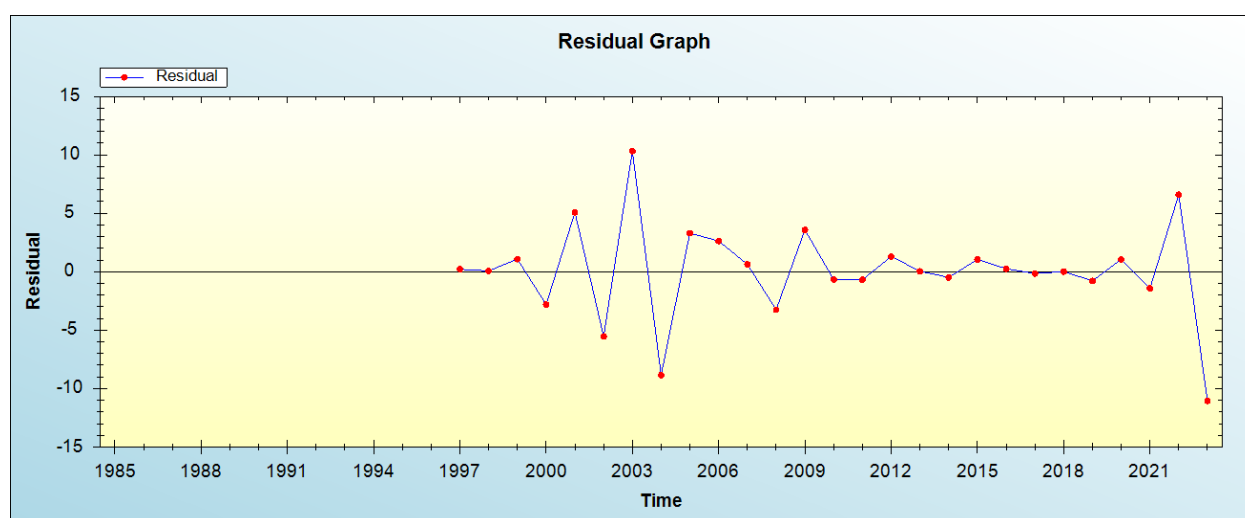


Figure 1: Residual analysis

In-sample Forecast for C

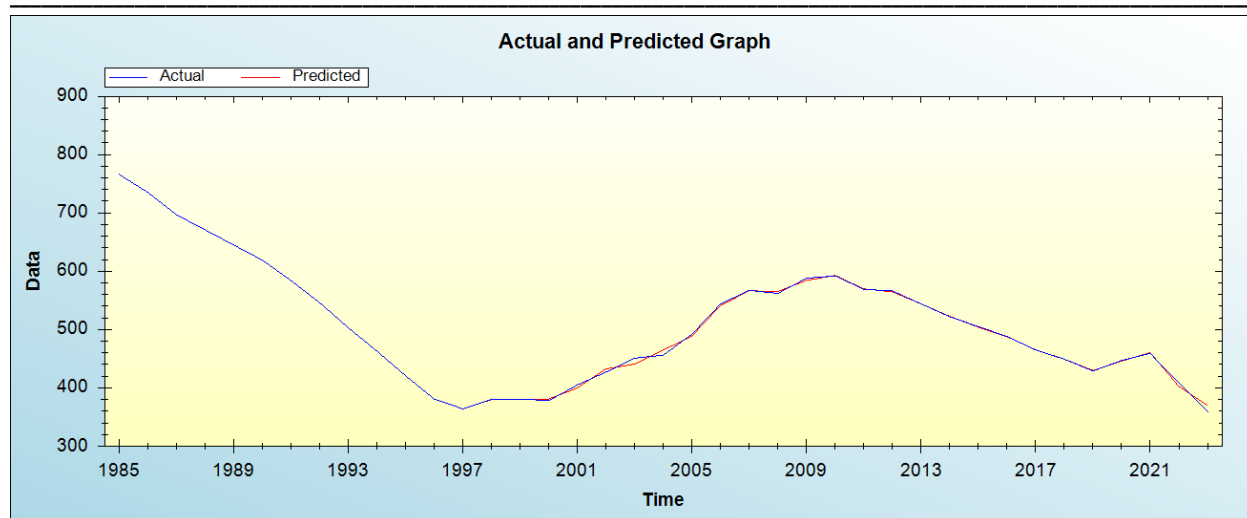


Figure 2: In-sample forecast for the C series

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

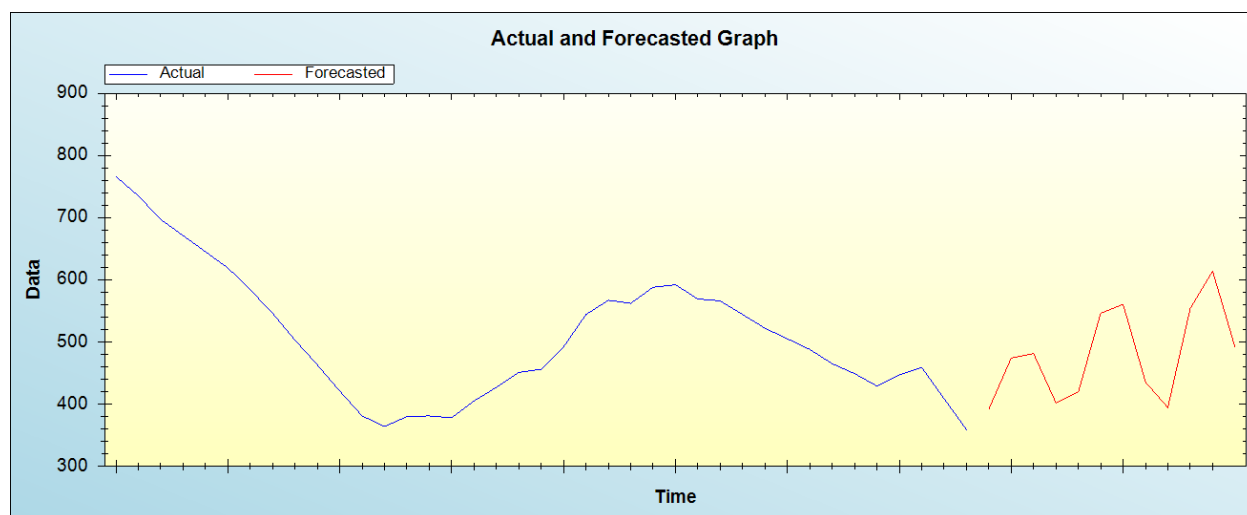


Figure 3: Out-of-sample forecast for C: actual and forecasted graph

Out-of-Sample Forecast for C: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	391.7920
2025	473.9896
2026	481.2077
2027	402.0587

2028	419.4743
2029	546.2287
2030	560.3507
2031	435.6835
2032	394.3659
2033	553.8024
2034	613.7935
2035	491.8726

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 remain very high over the out of sample period.

Recommendations & conclusion

The high burden of maternal mortality in Cote d'Ivoire is an indication of low health service utilization and low quality of maternity services. This paper applies the multilayer perceptron to forecast MMR and the results show that MMR will remain very high over the out of sample period. Therefore, we implore health authorities to adopt the following policy prescription: (1) reduce adolescent pregnancy by enforcing laws that prohibit early child marriage, promote female education and comprehensive sexual and reproductive health education in schools (2) increase coverage of maternal and child health services across the country (3) carryout routine quality improvement activities (4) ensure availability sufficient commodities 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.

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