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MATERNAL MORTALITY PROJECTION FOR BOSTWANA USING THE MULTILAYER PERCEPTRON

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Abstract
This research article employs annual time series data on MMR for Botswana 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 4-fold policy prescription.

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

Introduction

Maternal deaths continue to be a huge problem especially in low- and middle-income countries. In 2020, the number of maternal deaths was estimated at 287,000 worldwide with around 70% in sub–Saharan Africa. The global maternal mortality ratio was estimated at 223 maternal deaths per 100,000 live births worldwide. According to WHO, Sub-Saharan Africa reported 545 maternal deaths per 100,000 live births (World Health Organization, 2023). Nearly 7.08% of deaths among women aged 15-49 were due to maternal death in 2019, while in Africa this same proportion was 12.66% (Institute for Health Metrics and Evaluation, 2023). According to the government of Botswana, 89 maternal deaths were reported in 2022 from 50,704 live births resulting in a Maternal Mortality Ratio (MMR) of 175.5 maternal deaths per 100,000 live births. Over the years there has been a fluctuating trend in the Maternal Mortality Ratio (MMR) ranging from 127 deaths per 100,000 live births in 2015 to 240 deaths per 100,000 live births in 2021. This shows that the country is still far away from reaching the 70 deaths per 100,000 live births target set by the World Health Organization (WHO). In addition, 99.8 percent of all births happened in health facilities supervised by a skilled health professional. Approximately three fifths of maternal deaths (57.3%) occurred in Gaborone and Francistown DHMT's with Gaborone leading at 31.5 percent followed by 25.8 percent of births occurring in Francistown. The highest maternal deaths in 2022 were reported among age groups 30-34 years (27.0%), followed by ages 35-39 years (21.4%) and 25-29 years (20.2%). The highest reported leading cause was genital tract and pelvic infection following abortion and ectopic and molar pregnancies (14.6%). The second leading causes were the Rapture of the uterus during labor and cardiovascular diseases complicating pregnancy childbirth and the puerperium (7.9% each). The purpose of this study is to model and forecast MMR for Botswana using the multilayer perceptron. The study findings are expected to trigger a national response to the problem of maternal mortality so as to further reduce MMR to levels recommended by WHO.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)

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Ara et al. (2025)	to summarize the frequencies of sociodemographic characteristics, parity distribution, antenatal care patterns, and causes of death among maternal mortality	Conducted a retrospective study which analyzed maternal mortality at Rangpur Medical College Hospital, Bangladesh, in 2024, reviewing 4,741 birth records with 83 maternal deaths	-Among 83 maternal deaths, majority of deaths occurred among women aged 16–25 (41%) and those from low socioeconomic backgrounds (72.2%). -Parity distribution showed 49.39% had 1–2 children, while 73.4% received no antenatal care (ANC), highlighting gaps in healthcare access. - Eclampsia (37.35%) and obstetric hemorrhage (26.50%) were the predominant cause of maternal deaths.
Singh & Swain (2025	to explore the factors influencing CDMR and its effect on maternal and fetal outcomes	Prospective cohort study	The prevalence of CDMR was 21.35%, which was relatively higher than the World Health Organization's recommended guidelines
Manamo et al. (2023)	to examine the socio-economic differentials of under-five mortality in Botswana within	The was based on the data from 2001 and 2011 Botswana Population and Housing Censuses and the 2017 Botswana Demographic Survey. One census method was used to	socio-economic disparities in under-five mortality disfavoring the worse-off exist

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	the framework of equality and equity	indirectly estimate under five mortalities for different socio-economic groups using Princeton west model life tables.	in all the selected socio-economic variables
Chacha et al. (2022)	review the current cardiac obstetrics practice, gaps, and potential areas of improvement.	Systematic review	With an increasing number of women with pre-existing cardiac conditions becoming pregnant, the contribution of CVD to maternal mortality is also growing. Consequently, there is a need for accurate diagnosis and appropriate care of pregnant women with CVD to minimize adverse outcomes
Isaacson et al. (2021)	to evaluate the prevalence and outcome of twin pregnancies in Botswana	Quantitative analysis	Adverse birth outcomes are common among twins in Botswana, and are often severe
Akhter et al. (2018)	to present, analyze and interrelate recent data to find barriers to achieving set MDG 5 targets by 2015	literature review has been done as a main method of data collection from Elsevier, Lancet, WHO, UNICEF, BBMS, NIPORT published from 2001 to May 2018	approximately 80% of maternal deaths could be averted if women had access to essential maternity and basic health care services

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Madzimbamuto et al. (2014)	To determine the underlying causes of maternal deaths reported in 2010, to categorize contributory factors and to prioritize appropriate interventions based on the identified causes, to prevent further deaths.	Case-notes for maternal deaths were reviewed by a panel of five clinicians, initially independently then discussed together to achieve consensus on assigning contributory factors, cause of death and whether each death was avoidable or not at presentation to hospital. Factors contributing to maternal deaths were categorized into organizational/management, personnel, technology/equipment/supplies, environment and barriers to accessing healthcare	The high number of contributory factors demonstrates poor quality of care even where deaths were not avoidable: 14/23 (61%) of direct deaths were considered avoidable compared to 12/32 (38%) indirect deaths. Highest ranking categories were: failure to recognize seriousness of patients' condition (71% of cases); lack of knowledge (67%); failure to follow recommended practice (53%); lack of or failure to implement policies, protocols and guidelines (44%); and poor organizational arrangements (35%). Half the deaths had some barrier to accessing health services
Alvarez et al. (2009)	to describe and determine different factors associated with	An ecological multi-group study compared variables between many countries in Sub Saharan Africa using data collected	Education and an effective and efficient health system,

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	the maternal mortality ratio in Sub Saharan countries	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	especially during pregnancy and delivery, are strongly related to maternal death

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 Botswana.

Data Issues

This study is based on annual MMR in Botswana 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	B
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	0.000396
MSE	0.525649
MAE	0.441425

Residual Analysis for the Applied Model

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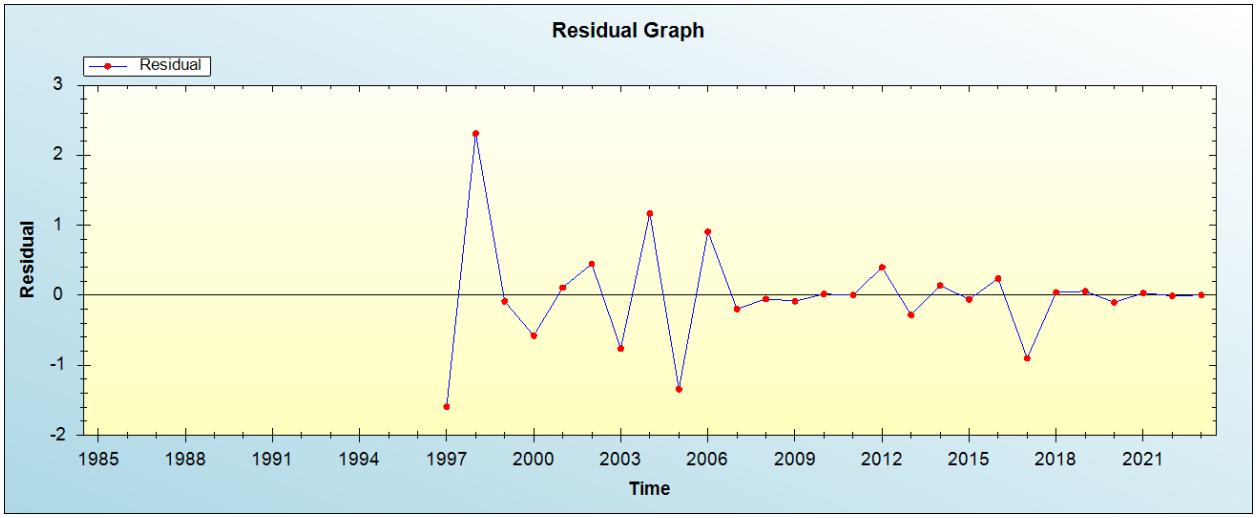


Figure 1: Residual analysis

In-sample Forecast for B

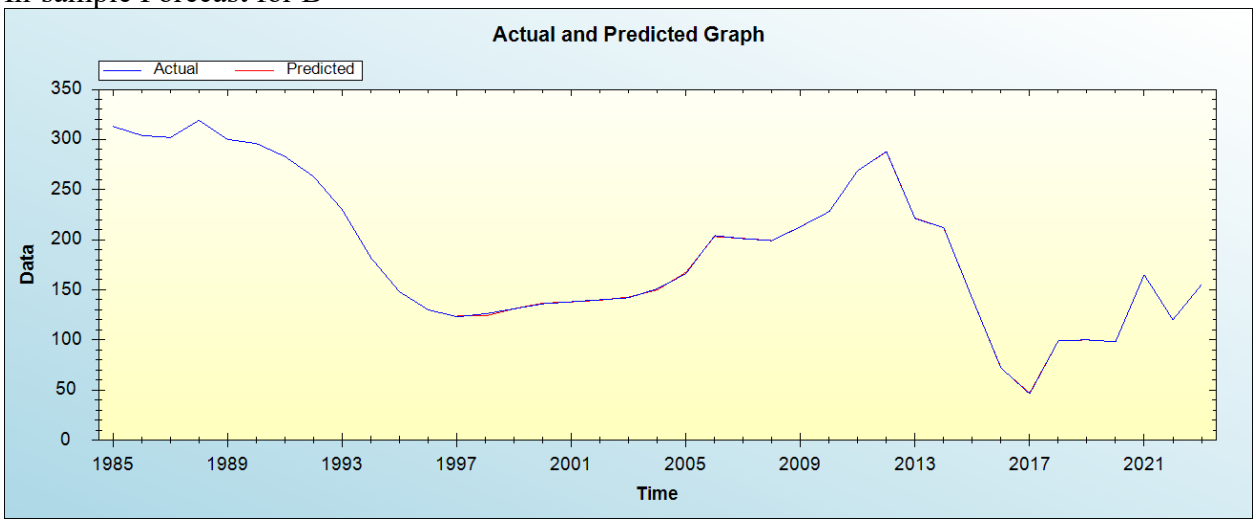


Figure 2: In-sample forecast for the B series

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

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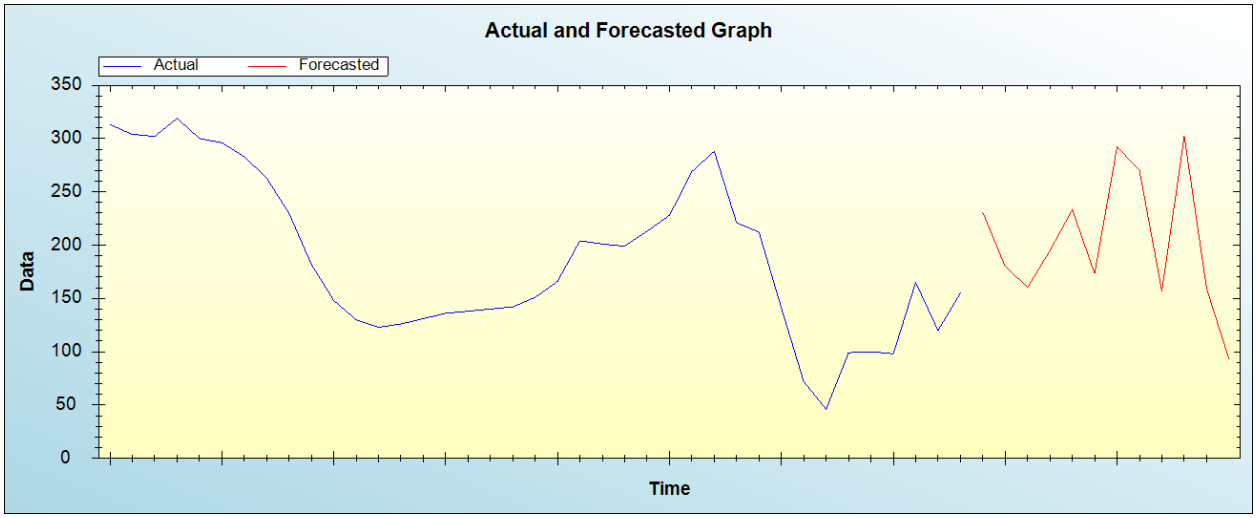


Figure 3: Out-of-sample forecast for B: actual and forecasted graph

Out-of-Sample Forecast for B: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	230.7567
2025	179.9366
2026	160.3632
2027	194.8192
2028	233.2303
2029	173.2665
2030	292.3217
2031	269.8626
2032	156.7784
2033	302.1470
2034	159.1010
2035	93.3581

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.

Conclusion

Maternal mortality is still a huge problem in Botswana. The highest reported leading cause is genital tract and pelvic infection following abortion and ectopic and molar pregnancies. The second leading causes were the rupture of the uterus during labor and cardiovascular diseases complicating pregnancy childbirth and the puerperium. This paper uses the multilayer perceptron to forecast MMR for Botswana and the results indicate that MMR will remain very high in the forecast period. Therefore, we encourage the government to adopt the following policy prescription: (1) continuous implementation of quality improvement initiatives (2) to ensure availability of adequate supplies of commodities and healthcare staff at all levels of care (3) secondment of obstetricians at high volume district hospitals if resources permit and (4) continuously enforce laws that prohibit early child marriages to curb adolescent pregnancy.

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