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USING ARTIFICIAL NEURAL NETWORKS FOR PREDICTING MATERNAL DEATHS AT CHITUNGWIZA CENTRAL HOSPITAL IN ZIMBABWE

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ABSTRACT
In this research paper, the Artificial Neural Network model has been used to model maternal deaths at Chitungwiza Central Hospital (CCH) in Zimbabwe. The study covers the period January 2012 to December 2019. The out-of-sample forecasts range over the period January 2020 to December 2021. The residual analysis of the model also further indicates that the model applied in this paper is stable and suitable for forecasting maternal deaths at CCH. The forecasts show a generally upwards trajectory of maternal death cases at CCH over the period January 2020 – December 2021. The paper offers a six-fold policy recommendation for use by the CCH health executive.

INTRODUCTION
Maternal death remains a serious public health issue especially in developing countries (WHO, 2007). Maternal death can be defined as the death of a woman while she is pregnant or within 42 days after delivery from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes (Laurenti & Buchalla, 1997; Shah & Say, 2007; Hoyert, 2007; WHO, 2005 & 2010; Hogan et al., 2010; Fabayo, 2010). Obstructed labour, maternal hemorrhage, postpartum sepsis, eclampsia, unsafe abortion, and anemia are among the most common causes of maternal deaths (WHO & UNICEF, 2014). The number of maternal deaths in a population is the product of two factors: the risk of mortality associated with a single pregnancy, and the number of pregnancies or births that are experienced by women of reproductive age (Alkema et al., 2015). The causes of maternal deaths in Zimbabwe are multifaceted and vary from medical and obstetric causes which may be facility-related and the demographic and socio-cultural factors which may be client-related (Chitura & Manyanhaire, 2013). In Zimbabwe, the top five causes of maternal deaths are HIV/AIDS, Malaria, pregnancy induced hypertension/eclampsia, postpartum haemorrhage and puerperal sepsis (Munjanja, 2007) Maternal deaths are an important proxy for maternal health in both developed and developing countries (Hoj et al., 2003). In Zimbabwe, 6 women die each day of pregnancy related complications. The most common causes of maternal deaths in Zimbabwe are postpartum hemorrhage, infection, pregnancy related hypertension and malaria (USAID, 2014).

1.1 OBJECTIVES OF THE STUDY
i. To examine maternal deaths at CCH over the period January 2012 to December 2019.
ii. To predict maternal deaths for CCH over the period January 2020 to December 2021.
iii. To determine whether maternal deaths are increasing or decreasing for CCH over the out of sample period.

1.2 RELEVANCE OF THE STUDY
Health, especially maternal health, occupies a special position in sustainable economic development because it is a precondition for and an outcome of economic development (Nyoni, 2019). However, maternal deaths remain unacceptably high in many parts of the world, despite the commitment set out in the MDGs (Klobodu et al., 2018). Maternal deaths are not only high, but have risen in Zimbabwe as the country becomes of the examples of fast deteriorating health care systems (Chitura & Manyanhaire, 2013). In fact, in Zimbabwe, maternal deaths are still acceptably high (Mlambo et al., 2013; Nyoni, 2019). At least 3000 women die every year in Zimbabwe during child birth and at least 1.23% of GDP is lost annually due to maternal complications (UN, 2013). Is it a curse to be a woman in Zimbabwe? (Nyoni, 2019). We attempt to

answer this question, based on a data set collected from one of Zimbabwe's quaternary level referral hospitals, that is, CCH.

LITERATURE REVIEW

In Ghana, Sarpong (2013) predicted maternal mortality at the Okomfo Anokye Teaching Hospital using time series data covering the period January 2010 – December 2012 and employed the ARIMA technique and found out that the ARIMA (1, 0, 2) model was the optimal model. In another Ghananian study, Quarcco (2015) analyzed maternal mortality at Korle-bu Teaching Hospital over the period 2001 – 2013 using the ARMA framework and revealed that ARMA models were the best because Maternal Mortality Ratio (MMR) data had a platykurtic distribution. In the case of South Sudan, Lado (2015) predicted MMR in Juba Teaching Hospital using time series data covering the period January 2008 – December 2014 and employed ARMA models and found out that the ARMA (3, 0, 1) was the optimal model. In yet another Ghananian paper, Adedia et al. (2018), predicted MMR data from a public health facility using time series data covering the period January 2000 – December 2013 and employed the ARIMA framework and revealed that the ARIMA (1, 1, 1) model was the optimal model. Nyoni (2019) used annual time series data on maternal deaths and MMR in Zimbabwe from 1990-2015, to model and forecast both maternal deaths and MMR using ARIMA models and found out that the ARIMA (0, 2, 2) model and the ARIMA (2, 2, 0) model are the parsimonious models for predicting maternal deaths and MMR respectively. Even though this study is closely related to Nyoni (2019), it is still new in the sense that it is hospital-specific rather than country-specific. Hospital specific study results tend to be more informative as compared to country-specific results which are generalized over the whole country.

METHODOLOGY

Most studies, for example, Sarpong (2013), Quarcco (2015), Lado (2015), Adedia et al. (2018) and Nyoni (2019); rely on ARIMA models in analyzing maternal deaths. This study employs the multi-layer perceptron neural network type of the Artificial Neural Network technique primarily because it performs better than ARIMA models especially when examining complex epidemiological data.

3.1 Data Issues

This study is based on monthly maternal death cases (reffered to as M series in this study; age group: 16 – 49) at CCH. The data covers the period January 2012 to December 2019 while the out-of-sample forecast covers the period January 2020 to December 2021. All the data employed in this paper was gathered from the DHIS information system for Chitungwiza city.

FINDINGS OF THE STUDY

4.1 DESCRIPTIVE STATISTICS

Table 1: Descriptive statistics

Mean	Median	Minimum	Maximum
2.8125	2.0000	0.0000	16.000
Std. Dev.	C.V.	Skewness	Ex. kurtosis
2.4422	0.86835	1.9362	7.5206

The average number of maternal deaths over the study period is approximately 3 deaths per month. The minimum number of maternal deaths is 0 while the maximum is 16 deaths.

4.2 ANN MODEL SUMMARY FOR MATERNAL DEATHS AT CCH

Table 2: ANN model summary

Variable	M
Observations	84 (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	0.132116
MSE	0.379141
MAE	0.899156

Residual Analysis for M the ANN Model Presented in Table 1 Above

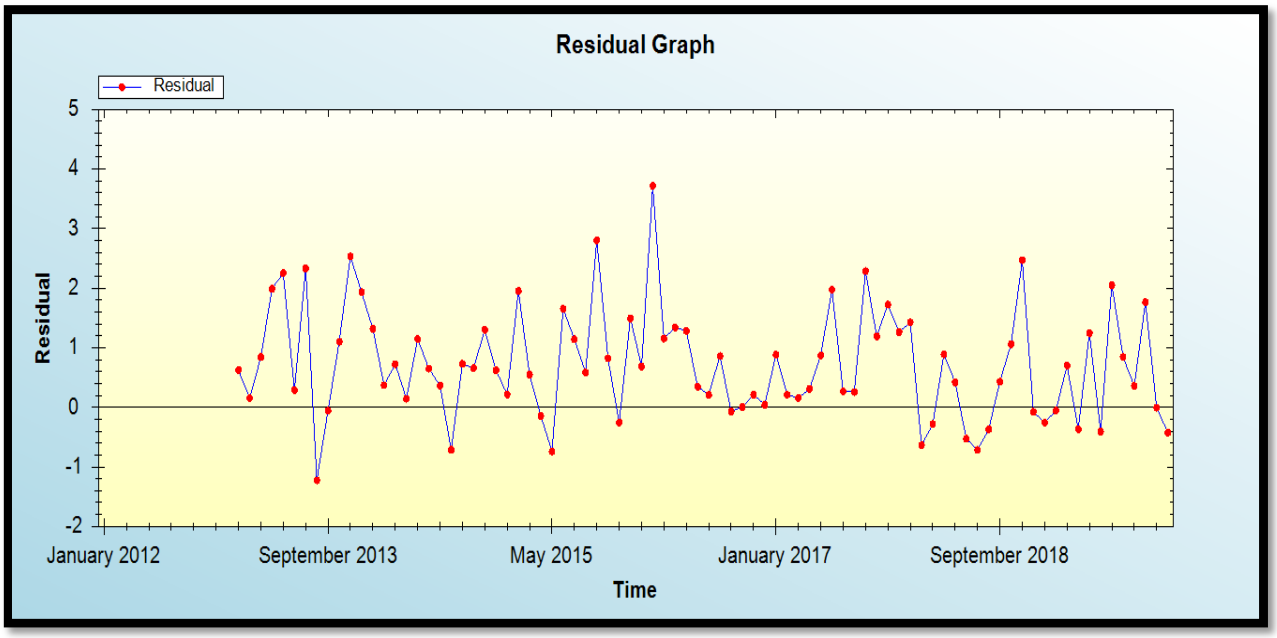

Figure 1: Residual analysis

In-sample Forecast for M

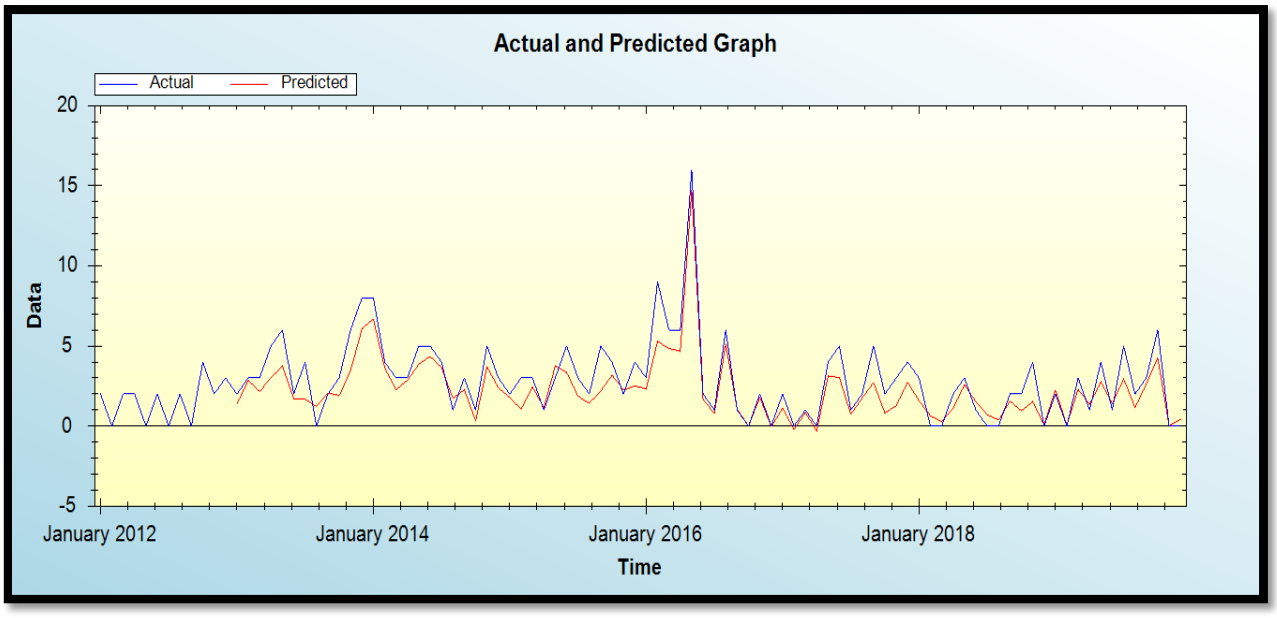

Figure 2: In-sample forecast for the M series

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

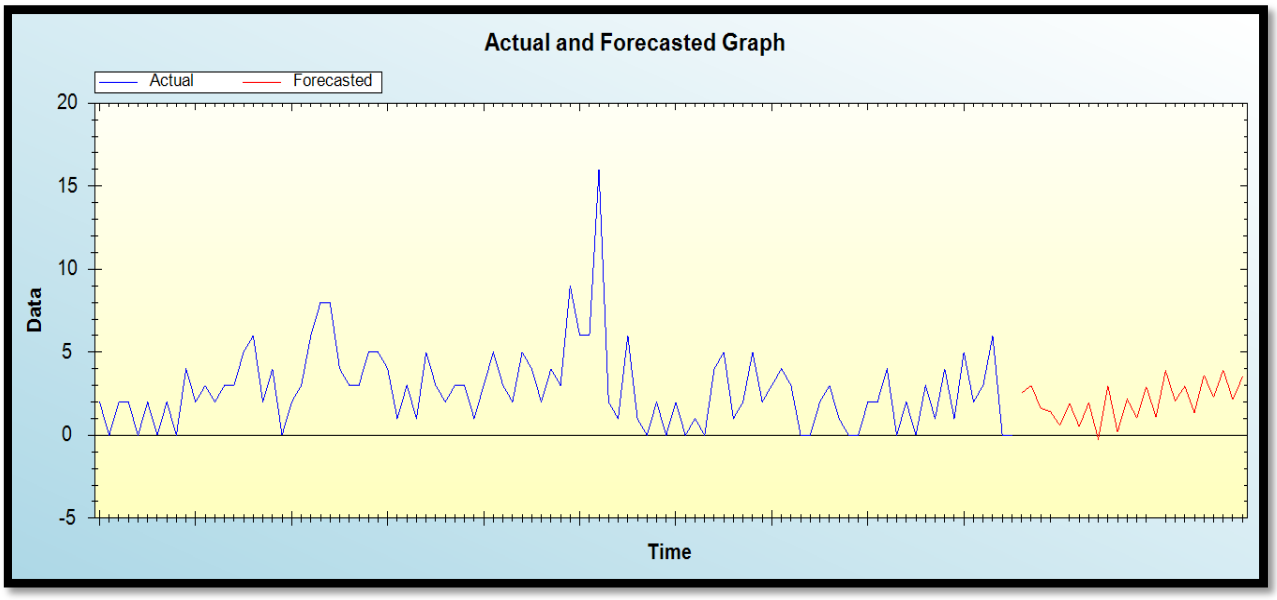

Figure 3: Out-of-sample forecast for M: actual and forecasted graph

Out-of-Sample Forecast for M: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Month/Year	Predicted M
January 2020	2.5268
February 2020	2.9955
March 2020	1.6416
April 2020	1.4272
May 2020	0.5834
June 2020	1.9275
July 2020	0.5143
August 2020	1.9597
September 2020	-0.2478
October 2020	2.9869
November 2020	0.1889
December 2020	2.1855
January 2021	1.0477
February 2021	2.9183
March 2021	1.0935
April 2021	3.8891
May 2021	2.0686
June 2021	2.9479
July 2021	1.3593
August 2021	3.6121
September 2021	2.2908
October 2021	3.9286
November 2021	2.1367
December 2021	3.5027

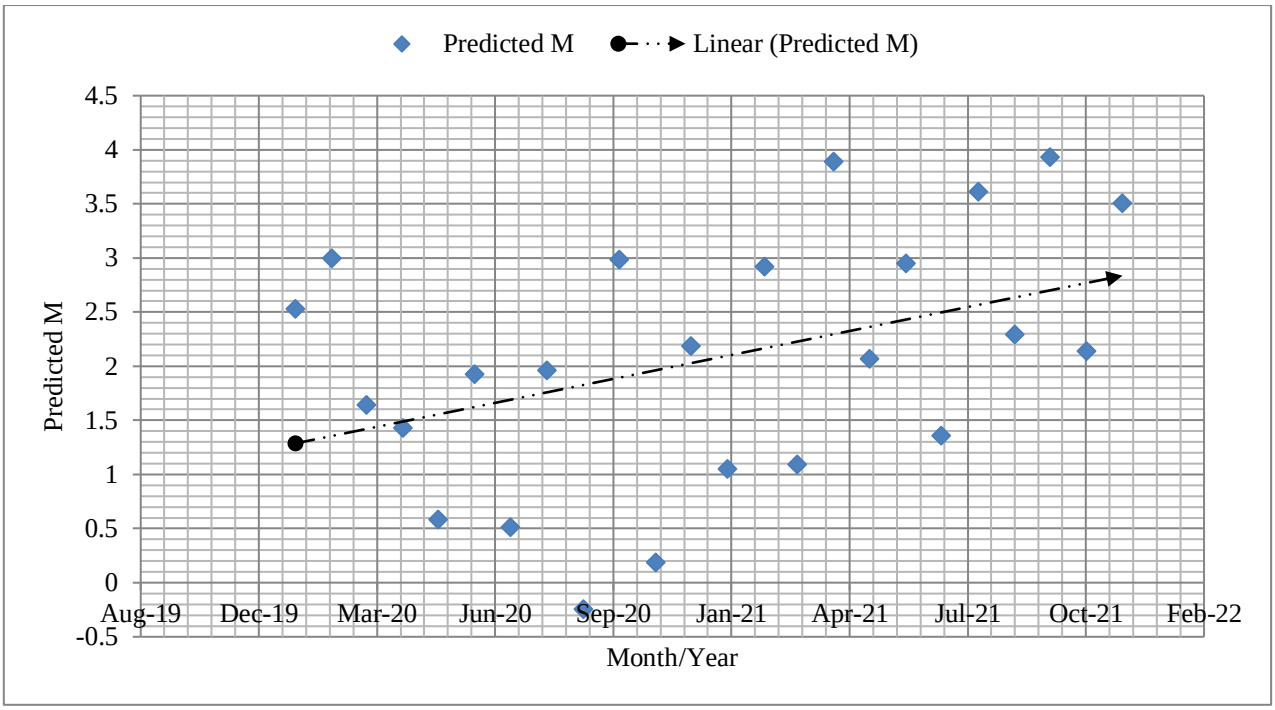

Figure 4: Graphical presentation of out-of-sample forecasts

Main results of the estimated model are shown in table 2. Figure 1 is the residual analysis of the presented model in table 2 and shows that the model is relatively stable. Figure 2 is the in-sample forecast of the series M while figure 3 is the out-of-sample forecast of the series M. Table 3 and figure 4 show out-of-sample forecasts only in tabular form and in graphical from respectively. From figure 4, it is quite clear that maternal deaths at CCH are projected to rise over the period January 2020 – December 2021. The results of this study concur with the argument made by Chitura & Manyanhaire (2013) that maternal deaths remains a major challenge to the healthcare systems in Zimbabwe. Hence, it appears as if it is a crime to be a woman in Zimbabwe! However, there is still hope for improvement at hospital-level: in this paper we suggest four main policy directions that need to be taken by CCH heath executive in order to reduce maternal deaths.

4.3 RECOMMENDATIONS

i. The CCH health executive should address indirect causes of maternal deaths such as HIV/AIDS, Malaria, TB, hypertension, diabetes and so on. In this regard, there is need to strengthen linkages amongst different health specialties at CCH.
ii. The CCH health executive should also improve the quality of obstetric care at the hospital. In the same vain, there is need for the CCH health executive to address staffing challenges faced in the maternity wards by seconding senior nurses to the maternity wards as well as capacitating junior nurses. Furthermore, regular quality improvement meetings are encouraged especially in light of addressing system challenges with the aim of improving maternal and child health.
iii. The government of Zimbabwe should capacitate city clinics with requisite staff (mainly 2 medical doctors) to minimize unnecessary referrals which increase the workload of CCH maternity staff.
iv. There is also the need to increase access to family planning services at CCH, to both women and man.
v. The CCH health executive should also increase the availability of and quality of medical care during pregnancy.
vi. The government of Zimbabwe should avail funds to acquire drugs and equipment for use in the maternity and theatre departments at CCH.

CONCLUSION

The problem of maternal mortality remains a national concern because of large numbers of women who die from avoidable causes, especially in rural parts of the country. Women in Zimbabwe suffer a high risk of dying during pregnancy, childbirth and the puerperium (Chitura & Manyanhaire, 2013). This study focused

on maternal deaths confirmed at CCH in Chitungwiza, Zimbabwe. The study employed Artificial Neural Networks in order to analyze the trends of maternal deaths at CCH over the study period. The results of the study are disturbing as they indicate that maternal deaths at CCH are generally on the rise: the opposite is a desirable health outcome.

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