Predicting Infant Mortality Rate in Botswana Using Artificial Neural Networks

[1]Dr. Smartson. P. NYONI, [2]Thabani NYONI

[1]ZICHIRe Project, University of Zimbabwe, Harare, Zimbabwe
[2]SAGIT Innovation Centre, Harare, Zimbabwe

Abstract - **In this research article, the ANN approach was applied to analyze infant mortality rate in Botswana. The employed data covers the period 1960-2020 and the out-of-sample period ranges over the period 2021-2030. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model indicate that the model is stable in forecasting infant mortality rate in Botswana. The ANN (12, 12, 1) model predicts that infant mortality rate will continue to decline in the country over the next 10 years. Therefore the government is encouraged consider the 7-fold policy directions suggested in this endeavor.**

Keywords: ANN, Forecasting, infant mortality rate.

I. INTRODUCTION

Public health surveillance is the ongoing systematic collection, analysis and interpretation of health related data essential for planning, implementation and evaluation of public health practice, closely integrated with timely dissemination of data to those responsible for prevention and control (Teutsch & Churchill, 2000). The main objective of surveillance includes assessment of the health status of the population, program effectiveness and stimulate research. Public health surveillance systems are key in the public health delivery system of a country. They help in the estimation of the magnitude of a health problem, determine geographic distribution of the disease, detect epidemics, and identify changes in infectious agents and changes in public health practices and behaviors. Time series modeling and forecasting has emerged as one of the key components of public health surveillance. Accurate predictions help detect disease outbreaks, changes in epidemic trends and facilitate mobilization of resources to prevent and control epidemic incidences (Camellia et al, 2018; Zhang et al, 2014; Weng et al, 2017; Nobre et al, 2001). Autoregressive integrated moving average (ARIMA) models are widely used time series forecasting techniques. The model was proposed by Box and Jenkins in the 1970s. ARIMA (p, d, q) is the basic representation of the ARIMA model where p and q are the non-seasonal autoregressive (AR) and moving average (MA) parts and d is the non-seasonal differencing order (Nyoni & Nyoni 2019 a & b). ARIMA models can be considered as stationarized models that use lags of the dependent variables and / lags of the forecast errors as regressors. ARIMA model building involves a 3 step iterative procedure: model identification, parameter estimation and diagnostic checking. The best model is chosen based on the Akaike information criterion (AIC). Artificial intelligence (AI) methods have become more popular in the field of time series forecasting. Machine learning techniques such as artificial neural networks (ANNs), SVM, Bayesian networks, ensembles and K nearest neighbors continue to gain prominence as tools for public health surveillance (Zhao et al, 2020; Nyoni et al, 2020; Weng et al, 2017; Kaushik & Sahi, 2018; Fojnica et al, 2016; Zhang et al, 2014; Zhang, 2003; Kishan, 1997; Patterson, 1995). In this paper we apply the ANN (12, 12, 1) model to predict infant mortality rate in Botswana. The results of the study will provide an insight of the future trends of infant mortality rate in the country. This will facilitate assessment of maternal and child health intervention programs which are aimed at reducing infant and child mortality.

II. METHODOLOGY

The Artificial Neural Network (ANN), which we intend to apply in this study; is a data processing system consisting of a huge number of simple and highly interconnected processing elements resembling a biological neural system. It has the capability of learning from any data-set to describe the nonlinear and interaction effects with great accuracy. No strict rules exist for the determination of the ANN structure hence 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 infant mortality rates in Botswana.

Data Issues

This study is based on annual infant mortality rates in Botswana for the period 1960 – 2020. The out-of-sample forecast covers the period 2021 to 2030. Infact mortality rate, which is simply a proxy for infant deaths; for the purposes of this study, is defined as the number of infants dying before reaching one year of age, per 1000 live births in a given year. All the data employed in this paper was gathered from the World Bank.

<div align="center">

III. FINDINGS OF THE STUDY

</div>

ANN Model Summary

<div align="center">

Table 1: ANN model summary

</div>

Variable	X
Observations	49 (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	0.020010
MSE	1.091966
MAE	0.830507

Residual Analysis for the Applied Model
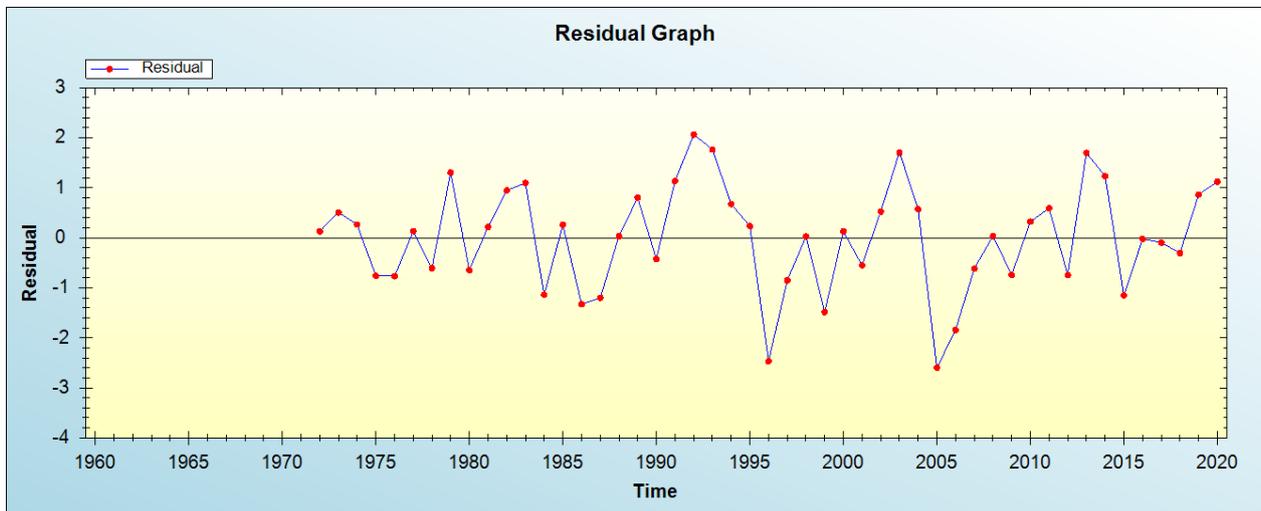

<div align="center">

Figure 1: Residual analysis
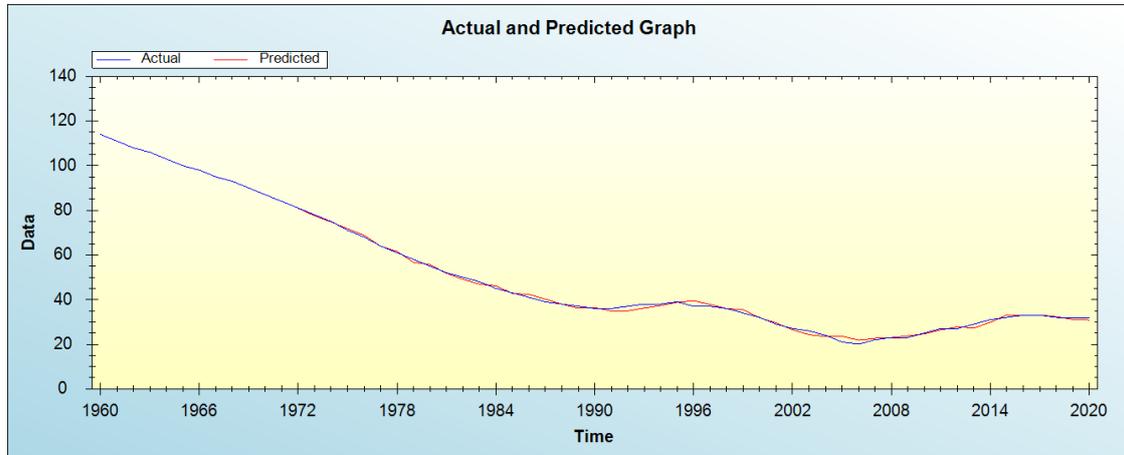
</div>

In-sample Forecast for X

Figure 2: In-sample forecast for the X series

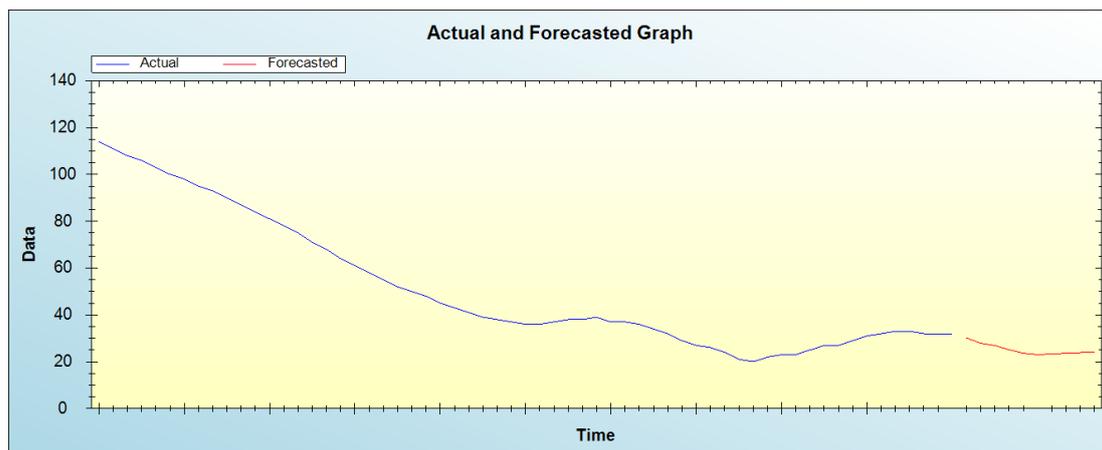*Out-of-Sample Forecast for X: Actual and Forecasted Graph*

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

Out-of-Sample Forecast for X: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Forecasts
2021	30.1762
2022	27.9401
2023	26.9012
2024	25.1114
2025	23.6580
2026	23.0372
2027	23.3397
2028	23.6370
2029	23.8880
2030	24.0899

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 infant mortality in Botswana is likely to decline from the current estimated 30 to approximately 24/live births per year by 2030.

IV. CONCLUSION AND POLICY RECOMMENDATIONS

Preventing infant mortality remains one of the main objectives of the health ministry in Botswana. The government of Botswana remains committed to ending preventable deaths infants in the country. The study used annual data to analyze the trends of infant mortality in Botswana. The applied model is the ANN model. In order to make sure that infant mortality in the country significantly declines, the government of Botswana ought to consider the following policy suggestions:

i. The government should continue to encourage mothers to breast-feed their babies adequately.
ii. There is need for all child-bearing women to be vaccinated against common illnesses.
iii. There is need to prevent birth defects in Botswana.
iv. The government of Botswana should address preterm birth, low birth-weight and their outcomes.
v. The government of Botswana should also ensure adequate access to pre-pregnancy and prenatal care.
vi. There is need to educate, especially, mothers on the importance of creating a safe infant sleep environment in Botswana.
vii. Healthcare providers in Botswana need to use newborn screening activities in order to detect hidden conditions.

REFERENCES

[1] Camillia R., Comeaux., MSPH., Florida A&M University (2018). Predictive Modeling for Healthcare Professionals: The use of time-series analysis for health-related data and the application of ARIMA modeling techniques in SAS for Public Health Practice SESUG Paper 245-2018.

[2] Dan W. Patterson (1995) Artificial Neural networks Theory and Applications. Singapore; New York: Prentice Hall.

[3] Fojnica, A., Osmanoviae & Badnjeviae A (2016). Dynamic model of tuberculosis-multiple strain prediction based on artificial neural network. In proceedings of the 2016 5th Mediterranean conference on embedded computing pp290-293.

[4] Kaushik AC & Sahi. S (2018). Artificial neural network-based model for orphan GPCRs.Neural.Comput.Appl. 29,985-992.

[5] Kishan Mehrotra., Chilukuri K., Mohan, & Sanjay Ranka (1997) Elements of artificial neural networks. Cambridge, Mass.: MIT Press.

[6] Naizhuo Zhao., Katia Charland., Mabel Carabali., Elaine O., Nsoesie., Mathieu MaheuGiroux., Erin Rees., Mengru Yuan., Cesar Garcia Balaguera., Gloria Jaramillo Ramirez., & Kate Zinszer (2020). Machine learning and dengue forecasting: Comparing random forests and artificial neural networks for predicting dengue burden at national and sub-national scales in Colombia. PLOS Neglected Tropical Diseases | https://doi.org/10.1371/journal.pntd.0008056

[7] Smartson. P. Nyoni, Thabani Nyoni, Tatenda. A. Chihoho (2020) PREDICTION OF DAILY NEW COVID-19 CASES IN GHANA USING ARTIFICIAL NEURAL NETWORKS IJARIIE Vol-6 Issue-6, 2395-4396.

[8] Smartson. P. Nyoni., Thabani Nyoni., Tatenda. A. Chihoho (2020) PREDICTION OF DAILY NEW COVID-19 CASES IN EGYPT USING ARTIFICIAL NEURAL NETWORKS IJARIIE- Vol-6 Issue-6, 2395-4396.

[9] Teutsch SM & Churchill RE (2000). Principles and Practice of Public Health Surveillance, 2nded. Oxford University.

[10] Weng SF., Reps J., Kai J., Garibaldi JM &Qureshi N (2017).Can machine learning improve cardiovascular risk prediction using routine clinical data? Plos One.

[11] Xingyu Zhang., Tao Zhang., Alistair A., Young., & Xiaosong Li (2014). Applications and Comparisons of Four Time Series Models in Epidemiological Surveillance Data PLOS ONE | www.plosone.org | Volume 9 | Issue 2 | e88075.

[12] Yan C Q., Wang R B., Liu C H., Jiang Y (2019). Application of ARIMA model in predicting the incidence of tuberculosis in China from 2018-2019.Zhonghua 40(6):633-637.

[13] Zhang GP (2003) Time series forecasting using a hybrid ARIMA and neural network model. Neurocomputing 50: 159–175.

****